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Collaborative Interactions: The Process of Joint Production and Individual Reuse of Novel Ideas

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Abstract

Collaborative problem solving involves the active exchange and interaction of ideas between two or more people and such interactive exchanges can result in the joint production of co-constructed ideas, some of which may be novel. We analyzed verbal data of pairs of students collaboratively solving problems posed by a computer workplace simulation (a banking business), and then individually solving two transfer problems, in order to examine the frequency of occurrence of co-constructed novel ideas, and the subsequent individual reuse of these co-constructed ideas. The results show that in collaborative interactions, about 20% of the task-relevant ideas were produced jointly, whereas about 80% of the utterances were produced individually (i.e., they were self-explanations). However, about half of these jointly produced ideas (or 10%) were novel. Moreover, individual collaborators were able to reuse these jointly constructed ideas to solve transfer problems. Finally, more interactive collaborative pairs produced a higher proportion of jointly constructed ideas than less interactive pairs, and individual members of more interactive pairs reused jointly constructed ideas more than low interactive pairs.

Introduction

In classrooms and workplaces, individuals frequently learn by collaborating with others, in tasks such as solving physics problem (Kneser & Plotzner, 2001), planning (Barron, 2000), and learning electricity (van Boxtel, van der Linden, & Kanselaar, 2000). Although operational definitions of collaboration vary widely both within and across various fields (e.g., Psychology, Education, Artificial Intelligence, CSCL), for the purposes of this paper, we define collaboration as the active exchange and interaction of ideas between two or more individuals attempting to discover solutions or create knowledge together (Damon, 1984). While some of the results of previous collaboration research are inconsistent, the majority support the conclusion that compared to solving a problem alone, collaborative problem solving is often more efficient, and in some conditions, more efficacious than individual learning (SCANS, 1991; Webb & Palinscar, 1996).

Most of the initial research on collaborative learning focused on the environmental conditions under which collaborative learning was more effective than individual learning. Some examples of such environmental factors are group composition, task features, context, and communicative medium (Dillenbourg et al., 1996). However, these mediating factors also interact in a highly complex manner, and this complexity has made the resulting examination of this complexity has made the resulting examination of how these multiple interactions produce collaborative learning effects a very difficult pursuit.

In part due to this difficulty, an alternative approach to the study of collaboration focuses on the interactive processes that are thought to underlie successful collaborative learning. Examples of such processes are observing peers' strategies, engaging in productive argumentation, explaining one's own thinking, sharing knowledge, and providing critique (Azmitia, 1988; Bos, 1937; Coleman, 1998; Hatano & Iganaki, 1991; King, 1990; Phelps & Damon, 1989; Webb, Troper, & Fall, 1995). Many of these processes are captured more-or-less in Webb & Palinscar's (1996) 'Input-Process-Output' model of group (collaborative) processes.

The process component of the model contains four common collaborative learning processes: (a) resolving conflict and controversy, (b) giving and receiving explanations, (c) providing emotional and motivational support, and (d) co-constructing new ideas. The first two processes result in the generation of explanations, either to resolve a conflict, or to explain a problem or solution, and such explanation generation is known to produce learning gains (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Palinscar & Brown, 1984). The third process is generally comprised of personality factors (e.g., emotion regulation, motivation, social skills, and attitudes), each of which effects how collaborators interact with one another. The fourth process, co-construction, can potentially result in novel ideas, or ideas that no collaborator previously possessed explicitly.

While Webb & Palinscar's (1996) four collaborative processes do drive collaborative learning effects, the first three processes are not unique to collaboration -- that is, each can also be observed and implemented in individual learning environments. For example, conflict and controversy can arise within oneself when one thinks more deeply about, or attempts to integrate new information with, one's prior beliefs. The resolution of such conflict (or self-repairs) produces learning gains (Chi, 2000). Similarly, giving help or explanation is akin to self-explaining one's own thinking without interacting with another individual, and such self-explanations foster learning (Chi et al., 1989). Similarly, receiving explanations has always been shown to be helpful as well, but less so than giving explanations. Providing emotional and motivational support is also not unique to collaboration – individuals are capable of supporting their own emotional and motivational needs. In the end, while all four of Webb & Palinscar's (1996) proposed collaborative processes do drive collaborative learning effects, co-construction is the only one that is unique to collaborative learning

Co-construction has been defined as the process of the joint production of ideas (by members of a group) that no individual group member is likely to produce on their own (Barron, 2000; Rafal, 1996). Thus, co-construction is a process that may differentiate collaborative and individual learning environments. That is, collaborators may co-create novel ideas that were not coherently present before they collaborated, or were unlikely to have been elaborated individually. For example, Kneser and Ploetzner (2001) administered qualitative and quantitative pre-test, intermediate-test, and post-test questions to individuals learning mechanics. One group of students was instructed on how to solve mechanics problems qualitatively, while another group was instructed quantitatively. After administering the intermediate-test, individuals from the two contrasting groups were placed in dyads and asked to collaboratively solve new mechanics problems. The authors found that individuals were able to answer questions (post-test) that they were unable to answer prior to collaborating (intermediate-test). However, the results of this study must be interpreted cautiously since the pairs differed in expertise, which suggests that one member of the dyad may have learned from the other member, and not that the dyads co-constructed the answers together.

Hence, the goals of this paper are to document the extent to which collaboration facilitates the joint production of novel ideas, and the extent to which individual members of collaborating pairs take ownership of jointly produced novel ideas such that they are able to assimilate and reuse those ideas later in individual (transfer) situations. To address these questions, we report a detailed verbal analysis of collaborative protocols collected in the context of dyads interacting with a computer simulation.

Methods

The verbal data that we analyzed were collected and described in Jeong, Taylor, and Chi (2000). Here we briefly summarize how the verbal data were collected and the measures that are relevant to our analysis.

Participants

Twenty-six high school students (juniors and seniors from local urban high schools) participated in this study, comprising 13 collaborative pairs (4 male and 9 female same-sex collaborative pairs). Data from one pair was excluded from analysis due to a collection error, resulting in 12 collaborative pairs. Individual participants brought a friend of the same gender to participate in the study with them, resulting in pairs where each collaborator had known the other for a mean of 4 years. All participants were compensated for participation in the study and all reported familiarity with computers. A majority of the students reported that they had used other computer simulations or games in the past.

Materials

Court Square Community Bank (CSCB). CSCB is a computerized workplace simulation (SIM) in which the user assumes the role of a new vice-president at a small local bank. The VP is required to solve problems arising at the bank that cover a variety of general business issues such as facilities upgrades or customer relations. The problems encourage the VP to employ a number of business management activities (see Ferrari, Taylor, and VanLehn, 1999; and McQuaide, Leinhardt, & Stainton, 1999; for more details on the simulation program). We will use the more general term SIM to refer to CSCB.

SIM Problems. The SIM is sub-divided into 14 different episodes, 8 of which were selected for this study so that diverse topics would be covered with a minimum amount of overlap. Sample episode topics were reinvesting profits into bank facilities, closing/relocating branches, approving mortgages, and selecting the best candidate for a position.

Measures. Several measures, such as definitions and general business knowledge questions, were designed to assess participants' overall pre-test and post-test performance. The one relevant here is the transfer task that assessed general and context-specific knowledge at a deeper level than the definitions and questions measures.

The transfer task consisted of two problems (Fresh Foods and Giant Gallery), each modeled after two problems discussed in two SIM episodes (episode 9 and 10). The transfer problems were designed to appear different on the surface, but shared the same deep structure as the associated SIM problems. During the transfer problems, participants acted as vice-president (VP) of a grocery store company that experiences some of the same problems that the bank experienced in the SIM. In the Fresh Foods problem, students decided how to allot available funds to various facilities improvement options for the grocery store – as they did for the bank in SIM episode 9. In the Giant Gallery problem, students decided whether to close a less profitable store and/or open a new store – as they did for bank branches in SIM episode 10.

Talk-aloud protocols were elicited from participants to obtain more detailed performance data. Participants were instructed to talk-aloud (Ericsson & Simon, 1984) during their collaborative (simulation) and individual (transfer) problem-solving sessions, both of which were audiotape. All collaborative SIM sessions were also video-taped

Procedure

Participants took part in four laboratory sessions, each separated by approximately four days, in the following order: (1) pre-test, (2) simulation session I, (3) simulation session II, and (4) post-test.

The pre-test and post-test were administered to participants individually, and both tests asked participants to respond to the definitions, transfer, and questions tasks – and in that order. Each simulation session consisted of four episodes. The first three episodes in each session were performed collaboratively in dyads, and the last problem in each session was performed individually. On the collaborative problems, the pairs were instructed to work as a team in discussing how to handle the problems and to reach a consensus before making any decisions.

Analyses and Results

We report the results of verbal analyses (Chi, 1997) of individuals' performance on the two transfer problems and their associated SIM episodes 9 and 10. This section describes each step of verbal analysis employed, followed by its result.

The Number of Task-relevant Ideas

Did collaborators produce task-relevant ideas? To assess the number of task-relevant ideas the pairs articulated, each pairs' verbal protocols were coded for any combination of utterances representing a meaningful concept. Hence, ideas could be produced either by one individual in one turn, by one individual over several conversational turns, or by both individuals over several turns on one topic. Ideas were also required to be task-relevant – that is, related either to business in general, the theme of the episode (i.e., facilities improvement), or a solution the pair considered. Task irrelevant ideas consisted of comments of several types, such as "I guess you just gotta ask", "We need to find out some more information", or "Read the memo", and they were not coded.

Example 1 shows an articulated task-relevant idea. Note that examples are verbatim excerpts from protocols with prior utterances (in brackets) added for additional context.

Example 1: Articulated Idea

A: [If we renovate the floors] we will not be able- [to maintain our leadership because…]
B: [subjects speaking simultaneously] new technology.
A: Exactly…because we will not have the new technology.

The basic idea expressed in example 1 is that renovating the floors will consume the majority of the funds available for facilities improvements, resulting in a lack of funds available to purchase new technology (ATMs) that would help the bank maintain its leadership position in the marketplace.

In general, the protocols were sparse in terms of the amount of substantive ideas produced. For example, the total number of lines available to code from two randomly chosen pairs were 2,131 and 1,320 (pairs 8 and 11, respectively, episode 9). Of those lines, only 3% and 1%, respectively, were substantive enough to warrant coding. This is consistent with evidence in the literature showing that in collaborative tasks in which concrete actions have to be taken (such as working with a simulation), the dialogues are action-oriented and less abstract and rich (Bennet & Duane, 1991; Pilkington & Parker Jones, 1996; van Boxtel et al., 2000) Nonetheless, in playing the two episodes of the simulation, collaborative pairs produced a total of 365 task relevant ideas ($\underline{M}$=30.42, SD=9.23, per pair). The remaining analyses will be reported in the context of the total number of task relevant ideas.

The Number of Novel and Restated Ideas

Were the task-relevant ideas produced while playing the two simulation episodes novel or restated? To assess whether collaborators generated novel constructions, as opposed to merely restating information presented by the SIM, we compared the ideas produced by collaborators to the ideas explicitly presented by the SIM (SIM-ideas). SIM-ideas were identified through content analysis of the two relevant SIM episodes (9 and 10). This content analysis produced a transcript of the virtual conversations, interactions, and materials explicitly presented by the SIM. SIM-ideas were then identified in the SIM-transcripts following the same procedure employed to identify collaborative ideas. We then compared the collaborative ideas produced by a pair to the SIM-ideas that they were exposed to in order to determine whether the collaboration idea was a novel construction (no match), or a restatement of information embedded within the simulation (match). When comparing ideas we focused on their conceptual meaning rather than the literal vocabulary used.

Ideas coded as novel constructions were new reasons generated by students (most likely from prior knowledge or experience), inferences following from what was stated in the SIM episode, substantial paraphrases (paraphrases of more than one idea), and integration statements in which students combined ideas expressed in the SIM episode in ways that the SIM did not explicitly suggest. Restated ideas were unsubstantial paraphrases (one idea), or verbatim restatements of information presented by the SIM. Examples of a novel construction and a restated idea are given below:

Example 2: A Novel Construction (also jointly produced)

B: This proposal [New ATMs] helps the bank's profitability
A: help
B: helping the bank to run
A: more smoothly

Example 2 was coded as a novel construction because the SIM never explicitly relates the bank's profitability with new ATMs or with the bank running smoothly. (Note that example 2 is also a jointly produced idea, which will be described in the next section).

Example 3: A Restated Idea

B: [New ATM] cards will be easier to use
SIM: New ATMs are easier for the customer to use.

Example 3 was coded as a restated idea because what B articulates is an unsubstantial paraphrase of the SIM explicated idea that new ATMs are easier to use. The results of this analysis show that collaborators produced just as many novel ideas (197) as restated ideas (168).

Individually and Jointly Constructed Ideas

Given that many novel ideas were produced, the question of interest is whether they were jointly produced (i.e., co-constructed), or individually produced, as compared to restated ideas. Thus, for each of the 197 novel and 168 restated ideas we determined whether they were individually constructed or jointly co-constructed. Co-constructed ideas were defined as those ideas that when taken together, across speakers, form a complete idea, but when taken individually, do not represent the same complete idea (Rafal, 1996; Barron, 2000). Thus, we decomposed each idea unit into 3 component parts: initiation, elaboration, and completion. Initiation was defined as the point at which the first utterance (word) of the idea occurred; completion was defined as the point at which a meaningful statement could be identified; and elaboration was defined as the collection of utterances between initiation and completion, where the content of the idea was articulated. We then examined how each idea was produced in terms of who articulated each component.

For each idea, if the same collaborator produced all three components, then the idea was coded as individually produced. Alternatively, if different collaborators produced any of the components of one idea, then that idea was coded as jointly produced. Hence, jointly produced ideas required the collaborators to display conversational moves such that they completed each other's ideas. The following examples illustrate this.

Example 4: An Individually Produced Idea

A: revenues and expenses at the downtown branch changed
B: Uhh….
A: revenues have just start like increase and decrease and then leveled off so…
B: Umm…yeah… [typing] how do you spell fluctuate
A: fluctuating, but now it's leveled off and…
B: How do you spell…
A: well, they generally decreased

Example 4 shows a complete idea (revenues and expenses fluctuated but decreased in general) initiated, elaborated, and completed by one collaborator (A), while the other (B) interjects task-irrelevant utterances. The initiation component in this case is the beginning of the statement: "revenues…" the completion component is the point at which a complete idea is identifiable: "…generally decreased"; while the elaboration component is the content between the initiation and the completion of the idea.

Example 5: A Jointly Produced Idea:

B: Okay, the new system would give the- give the employees…
A: more time to deal with the customers.

Example 5 shows an idea (of a new system) initiated by one collaborator (B), then elaborated and completed by the other collaborator (A). Example 2 also illustrates a jointly-produced idea.

Table 1 shows the number of novel and restated ideas that were either individually or jointly produced. Not surprisingly, roughly four times (81%) as many ideas were individually (297) rather than jointly (19% or 68) produced. Proportionately, jointly produced ideas were just as likely to be novel (59%, 40/68) as restated (41%, 28/68).

Table 1: Total Number of Jointly and Individually Produced, Novel and Restated Ideas for All Collaborative Pairs

	Novel	Restated	
Individually Produced	157	140	297
Jointly Produced	40	28	68
	197	168	365

In sum, collaborative pairs produced ideas jointly about 20% (or 68) of the time; individually about 80% (or 297) of the time. Given that jointly produced ideas were equally likely to be novel as restated, about 10% (or 40/365) of the ideas were jointly produced novel ones.

Reuse of Ideas During Transfer

Did individuals reuse the jointly produced novel ideas on transfer problems? In other words, were the individual collaborators able to reuse the jointly produced novel ideas, to indicate that they have, to some extent, taken ownership of or assimilated the ideas? Each individual idea stated while solving a transfer problem was compared to each idea originally produced by the pair when they solved the associated SIM episodes. If an idea articulated while solving the transfer problem matched one that was produced while playing the SIM, then the idea was coded as a reused idea.

In order to make more sensitive comparisons between collaborative pairs during the SIM and individuals at transfer, each individual's transfer performance was averaged with the individual transfer performance of the other member of their original collaborative pair. This averaging procedure resulted in equal *n* in each condition (collaboration vs. transfer).

In general, the transfer transcripts were sparser than the collaborative transcripts in terms of the total number of ideas produced (114; M=9.5, SD=3.75). Of these, 32% (36/114) were ideas that were originally produced during their collaborative session. Overall, individual collaborators reused more ideas that were originally produced individually (25) than ideas that were produced jointly (11). However, recall that a significantly greater number of ideas were originally produced individually (297, see Table 1), rather than jointly (68). Thus, proportionately, a larger percentage of jointly produced ideas were reused (16% or 11/68) than individually produced (8%, or 25/276), although this difference is not significant. Basically, jointly and individually produced ideas were equally likely to be reused.

Not surprisingly, of the individually produced ideas, participants tended to reuse those that they generated on their own (64% of the times, 16/25) more than those that were generated by their partner (36% of the time, 9/25; $t(11) = 2.86$, $p < .05$). In contrast, in the reuse of jointly produced ideas, there was no preference for self-initiated or partner-initiated (59% or 6.5/11 versus 41%, 4.5/11). Taken together, these results suggest that jointly produced novel ideas were equally shared by each partner, regardless of who initiated them, whereas individually produced ideas were not as well assimilated by the partner.

In sum, these results show that about one-third (32%) of the ideas individuals stated while solving the transfer problems were originally produced during collaboration, and these reused ideas were equally likely to have been individually produced as they were to have been jointly produced. However, collaborators had a definite preference to reuse self-initiated, individually produced ideas, but had no such preference when reusing jointly produced ideas. This gives the jointly produced ideas a special status, as if the ideas were truly shared and owned by both partners.

High and Low Collaborative Pairs

We hypothesized that pairs who were more interactive would produce more co-constructed ideas. To test this hypothesis, we determined whether specific pairs were more or less collaborative based on the number of conversational turns taken by each pair while they solved SIM episodes 9 and 10. High and low collaborative groups were then formed based on a median split (Mdn = 933 turns), and excluded two pairs extremely close to the median. The mean number of turns for high and low groups was significantly different (1186.4 vs. 763.8 turns, respectively; $t(8) = 5.171$, $p < .01$,), and there was no significant difference in the total number of ideas produced overall. (Note that from this point forward high and low collaborative pairs will be referred to as such, while individual members of high and low collaborative pairs will be referred to as high and low collaborators).

Once the groups were established, we compared the proportion of ideas produced jointly versus individually by high and low collaborative pairs. For the high collaborative pairs, the proportion of ideas that were jointly produced was greater (27% vs. 9%; $t(8) = 3.77$, $p < .01$); while the proportion of individually produced ideas was lower (73% vs. 91%, $t(8) = 3.82$, $p < .01$). Additionally, the proportion of jointly produced and novel ideas was also greater for high collaborative pairs (17% vs. 6%); ($t(8) = 3.10$, $p < .05$).

In sum, being a member of a high collaborative pair resulted in a redistribution of the types of ideas produced during collaboration. That is, high and low collaborative pairs produced equal numbers of ideas overall, but high collaborative pairs produced more ideas jointly and fewer ideas individually than low collaborative pairs; and high collaborative pairs produced a greater proportion of novel co-constructed ideas than low collaborative pairs

High and Low Individuals' Reuse of Ideas

While solving the transfer problems alone, individual members of high and low collaborative pairs produced roughly equivalent total numbers of ideas (52 vs. 46.5, respectively), as well as roughly equivalent numbers of reused ideas (19 vs. 13; see Table 2). However, the types of reused ideas were again differentially distributed - high collaborators reused more jointly produced ideas than low collaborators (18% vs. 8%, 8.5/47 vs. 1/12**;** $t(8) = 2.434$, $p < .05$), and high collaborators were more likely to reuse jointly produced novel ideas than low collaborators (20% vs. 11%, 5.5/28 vs. 1/9), although this difference was not significant ($p = 0.10$).

In sum, individual members of high collaborative pairs reused more jointly produced ideas, and had a greater tendency to reuse jointly produced novel ideas. Taken together, this pattern of results suggests that if collaborators engage in more interaction then they are more likely to produce co-constructed ideas, these co-constructed ideas are likely to be novel, and both the co-constructed and novel co-constructed ideas are likely to be reused. Hence, collaboration has the advantage of producing co-constructed ideas and co-constructed novel ideas that are reusable.

Table 2: Number of Ideas Reused by Individuals Who Participated in High and Low Collaborative Pairs

	High	Low
Ideas at Transfer	52	46.5
Ideas Reused	19 (36%) [1]	13 (28%) [1]
Individually Produced	10.5 (8%) [2]	12 (9%) [2]
Jointly Produced	8.5 (18%) [2]	1 (8%) [2]
Novel Ideas	13.5 (13.5%) [2]	7.5 (10%) [2]

[1] % of ideas produced at transfer that were reused (e.g., 19/52 = 36%).
[2] % of ideas reused at transfer given the number produced during collaboration (see Table 1); (e.g., Reused Individually Produced = 10.5; Individually Produced during collaboration = 128; 10.5/128 = 8%).

Discussion

These results suggest that one advantage of collaboration may arise from the co-construction of novel ideas. Overall, we found that collaborators tended to produce more ideas individually than jointly, confirming the overall benefit of self-explaining (Chi, et al, 2000). However, joint production did occur close to 20 percent of the time, and jointly produced ideas were just as likely to be novel as restated. Overall, more novel ideas were produced individually than jointly (again, confirming the benefit of self-explaining). However, individuals reused fewer novel ideas that were individually produced by their partner than were jointly produced with their partner, suggesting that listening to novel ideas produced by another was not as effective as co-constructing novel ideas together. These results suggest that one does not assimilate knowledge produced by a partner as well as knowledge co-constructed by both partners. Finally, the more interactive collaborators reused a greater percentage of jointly produced ideas, as well as a greater percentage of jointly produced novel ideas, thus being more interactive provided more opportunities to co-construct and reuse novel ideas. Thus, we may conclude, (cautiously since the numbers are small), that collaboration is an effective form of learning in part because about 10% of collaborative efforts result in the production of co-constructed novel ideas, a portion of which individuals take ownership of and reuse subsequently.

References

Azmitia, M. (1988). Peer interaction and problem solving: When are two heads better than one? *Child Development, 59,* 87-96.

Barron, B. (2000). Achieving coordination in collaborative problem-solving groups. *Journal of Learning Sciences, 9 (4),* 403-436.

Bennett, N. & Dunne, E. (1991). the nature and quality of talk in co-operative classroom groups. Learning and Instruction, 1, 103-118.

Bos, M.C. (1937). Experimental study of productive collaboration. *Acta Psychologica, 3,* 315-426.

Chi, M.T.H., Bassok, M., Lewis, M., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science, 13*, 145-182.

Chi, M.T.H. (2000). Self-explaining expository texts: The dual processes of generating inferences and repairing mental models. In Glaser, R. (Ed.). *Advances in Instructional Psychology*. (pp. 161-238). Mahwah, NJ: Lawrence Erlbaum Associates.

Coleman, E. (1998). Using explanatory knowledge during collaborative problem solving in science. *Journal of Learning Sciences, 7,* 387-427.

Damon, W. (1984). Peer education: the untapped potential. *Journal of Applied Developmental Psychology, 5,* 331-343.

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In P.Reimann & H. Spada, *Learning in Human and Machines: Towards an Interdisciplinary Learning Science.* (pp. 189-211). Oxford: Elsevier Science.

Ferrari, M., Taylor, R. & VanLehn, K. (1999). Adapting work simulations for schools. *Journal of Educational Computing Research, 21 (1),* 25-53.

Hatano, G. & Inagaki, K. (1991). Sharing cognition through a collective comprehension activity. In R.L. Resnick, J. Levine, & S. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 331-348). Washington, DC: American Psychological Association.

Jeong, H., Taylor, R., & Chi, M. (2000). Learning from a Computer Workplace Simulation. *Proceedings of the 22nd annual meeting of the Cognitive Science Society*, (pp 705-710). Mahwah, NJ: Lawrence Erlbaum Associates

King, A. (1990). Facilitating elaborative learning in the classroom through reciprocal questioning. *American Educational Research Journal, 27*, 664-687.

Kneser, C. & Ploetzner, R. (2001). Collaboration on the basis of complementary domain knowledge: Observed dialogue structures and their relation to learning success. *Learning and Instruction, 11,* 53-83.

McKendree, J., Stenning, K., Mayes, T., Lee, J., & Cox, R. (1998). Why observing a dialogue may benefit learning: The vicarious learner. *Journal of Computer Assisted Learning*, *14 (2)*.

McQuaide, J., Leinhardt, G., & Stainton, C. (1999). Ethical reasoning: Real and simulated. *Journal of Educational Computing Research, 21 (4),* 425-466.

Phelps, E., & Damon, W. (1989). Problem solving with equals: Peer collaboration as a context for learning mathematics and spatial concepts. *Journal of Educational Psychology, 81, 639*-646.

Pilkington, R.M. & Parker-Jones, C.H. (1996). Interacting with computer-based simulation: The role of dialogue. Computers and Education, 27, 1-14.

Rafal, C. (1996). From co-construction to takeovers: Science talk in a group of four girls. *Journal of Learning Sciences, 5,* 279-293.

Secretary's Commission on Achieving Necessary Skills. (1991). What *work requires of schools: A SCANS report for America 2000.* Washington, DC: U.S. Department of Labor.

van Boxtel, C., van der Linden, J., & Kanselaar, G. (2000). collaborative learning tasks and the elaboration of conceptual knowledge. Learning and Instruction, 10, 311-330.

Webb, N.M., & Palinscar, A.S. (1996). Group processes in the classroom. In D. Berliner & R. Calfee (Eds.), *Handbook of educational psychology (pp. 841-873).* New York: Macmillan.

Webb, N.M., Troper, J.D., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. *Journal of Educational Psychology, 87,* 406-423.