Collaborative Processing of Incompatible Information

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Abstract

This study examined the effects of peer collaboration and investigated discourse activity employed by successful and unsuccessful learners in the domain of biological evolution. Participants included 108 students from grades 9 and 12 assigned to four conditions: individual-assimilation, peer-assimilation, individual-conflict, and peer-conflict. Depending on the condition, students were asked to think aloud or discuss with their peers eight scientific statements presented in the order which either maximized or minimized conflict. Several measures of prior knowledge and posttest conceptual change measures were obtained. There were no significant peer effects on conceptual change; a number of interaction effects indicated that peer collaboration was beneficial for older students and when conflict was maximized. Indepth analyses of discourse activity were conducted for four successful and four unsuccessful learners based on posttest gain scores. Unsuccessful learners tended to assimilate information from their peers as if it were something already known. Conversely, successful learners were engaged in problem-centred discourse moves treating new information from their peers as something problematic which requires explanation. Contrasts between groups indicated significant differences in problem-centred discourse moves.

A common approach to fostering scientific understanding is to encourage students to make their ideas explicit and to compare their ideas to those of their peers. It is believed that engaging students in scientific discourse will help them examine their own perspectives, evaluate alternative conceptions, and identify conflict which could then lead to conceptual change (Lonning, 1993; Mandl, De Corte, Bennett, & Frederich, 1990; Palincsar, Anderson & David, 1993).

Despite much enthusiasm with collaborative science learning, empirical findings on the efficacy of peer interaction in conceptual change have been equivocal: ideational confrontation is effective with the older students, but not the younger ones (Champagne, Gunstone, Klopfer, 1985); conflict is often undetected (Dreyfus, Jungwirth, & Eliovitch, 1990); and social norms tend to outweigh theory-evidence coordination in peer learning (Pintrich, Marx, & Boyle, 1993). A theme of emerging interest in collaborative science learning is how students talk about science (Lemke, 1990). Research on discourse processes has shown considerable differences in how students approach collaborative learning situations: Many students engage in some kind of colloquial discourse using debilitating strategies (Eichinger & Anderson, 1992); conversely, others construct collaborative explanations in negotiating their convergent understanding (Roschelle, 1993). There is a need to examine how students construct knowledge in collaborative science learning.

Increased attention has now been given to constructive activity in science learning (Chi, de Leeuw, Chiu, & LaVancher, in press). Research on knowledge building has identified two contrasting approaches to learning--problem-minimization versus problem-centred learning (Bereiter & Scardamalia, 1993). Whereas some students simply assimilate or reject new information to minimize belief revision, others employ a problem-centred approach, treating new information as something problematic which needs to be explained. Students' problem-centred approach to integrating text information has been shown to be an important predictor of posttest learning (Chan & Bereiter, 1992; Chan, Burtis, Scardamalia, & Bereiter, 1992)

Since information from peers needs to be processed and interpreted, it follows that discourse moves can be conceptualized as a kind of collaborative constructive activity and analyzed based on the framework of problem-centred learning. Instead of merely assimilating or refuting the peer responses, students using problem-centred discourse moves jointly identify difficulties in what their peers say, formulate problems into questions of enquiry, and engage in collaborative explanation. If conceptual change involves learning of ontologically incompatible concepts (Chi, Slotta, & de Leeuw, 1994), problem-centred discourse moves may be important because they enable students to avoid equating new concepts with prior conceptions, to recognize difficulties with the status of the new concepts, and to collaboratively construct what they need to understand.

This study examined collaborative science learning in the context of how student dyads jointly process text information which contradicts what they believe. The domain of investigation is biological evolution. The first goal was to examine whether peer collaboration fosters deeper processing activity and conceptual change, by comparing an individual and a peer condition. In addition, comparisons were also made between two different age groups, and two groupings in which conflict was either maximized or minimized. The second goal was to characterize how successful and unsuccessful learners differed in their constructive discourse activity in collaborative learning. Specifically, we sought to examine whether successful students engaged in more problem-centred discourse moves in collaborative knowledge construction.

Method

Subjects

Participants included 108 students, 54 in grade 9 and 54 in grade 12 from a suburban high school. They had no previous formal instruction in evolution, and students holding a creationist view were not included in the study.

Test Material

This paper was based on a larger study designed to examine the effects of conflictual information on conceptual change. A computer-based connectionist methodology was developed to provide a systematic way to present students with scientific information at different degrees of discrepancy from their beliefs (for details, see Chan & Bereiter, 1992). Three groups of units were included: (a) four "factor-statement" units, (b) eight "specific-statement" units, and (c) eight "probe-statement" units. In the experiment, students were asked to rate on an 11-point scale the importance of four factor statements about evolution: (1) Purpose--Evolution is directed by needs and purposes of animal species; (2)Battle--Evolution is a battle of stronger species killing off weaker ones; (3) Environmental Determinism--Evolution depends on changes which occur in the environment; (4) Chance--Evolution depends on changes which first occur by chance. Students' ratings, which indicated their conceptions, were entered as inputs to a competitive activation network where outputs were the activation levels of a set of eight "probe" statements--scientific information which contradicts students' naive conceptions (e.g., *New characteristics arise first by chance, not by needs. Random changes in genetic material through mutation or genetic recombination produce new variations whether animals need them or not*). Activation of the network allows each student's patterns of agreement and disagreement to the four factors to be used to identify whether he or she will agree with the probe statements. Accordingly, the experimenter could systematically provide the student with probe statements which were, in varying degrees, congruent or contradictory to his or her beliefs.

Conditions

Students were randomly assigned to one of the four conditions: (a) individual-assimilation, (b) peer-assimilation, (c) individual-conflict, and (d) peer-conflict. Student dyads from the same grade level read the statements together to negotiate their understanding of evolution; no elaborate instruction was given on collaboration strategies. Since most students held similar intuitive conceptions, they were not grouped according to differences in conceptions. Students in the individual condition were asked to read and think aloud about the statements. In the conflict conditions, students were presented with eight scientific (probe) statements in the order which was maximally conflictual to their beliefs; in the assimilation conditions, the ordering of statements was maximally congruent.

Procedure

Pretest. Students were asked to (a) tell what they know about evolution; (b) rate eight specific statements; (c) rate four factor statements. Student dyads were assessed individually on the first two tasks, and they worked together on the third one.

Experiment. Students were presented with eight scientific statements, one at a time, and asked to think aloud or discuss the new information. They were then given the opportunity to revise their ratings of the four factor statements. This procedure was followed until all eight probe statements had been presented. Student verbalizations were tape recorded and transcribed verbatim for analyses.

Posttest. Students' posttest learning was assessed by asking them to (a) finalize the ratings of the four factor statements, (b) summarize their understanding of evolution, (c) tell what else they did not understand, (c) answer two application questions, and (d) re-rate the eight specific-statements. All except the first task were administered individually.

Measures

Knowledge-Processing Activity. Students' verbal responses to each probe statement were blind rated for knowledge-processing activity on a 5-point scale: (1)Sub-Assimilation - react to new information at an associative level; (2) Assimilation - reject, ignore, or conflate new information with existing beliefs; (3) Comprehension - paraphrase and ask surface questions; (4) Implicit Knowledge Building consider new information as something problematic which needs to be explained; and (5) Explicit Knowledge Building - accumulate new information to construct domain understanding. Verbal responses from student dyads were coded separately; coding was based on the utterance which showed the highest level of knowledge-processing activity. Inter-rater reliability is 0.85 for the individual condition and 0.81 for the peer condition.

Knowledge Quality (Qualitative Measure). Posttest learning on summary, wonderments, near-application and far-application was rated on a 5-point scale ranging from intuitive, mixed to scientific understanding. The inter-rater reliability for these four measures ranged from 0.86 to 0.95.

Specific Statement and Factor Statement Ratings (Quantitative Measures). Student ratings on the eight specific statements (11-point scale) were obtained at pre and posttests. Ratings on the four factor-statements (11-point scale) were also obtained at pre-posttests, and on each occasion when students were presented with a new probe statement.

Results

Peer Collaboration and Knowledge-Processing Activity

A three way ANOVA (Grade x Peer x Conflict) on mean knowledge-processing ratings showed no significant peer effects; significant grade and conflict effects were obtained. Further analyses of the proportions of different levels of knowledge-processing responses indicated significant effects for decreased assimilative ($F(1,100) = 4.76$, $p<.05$) and increased comprehension ($F\ (1,100) = 8.58$, $p<.01$) activity favoring peer group; no differences in high-level knowledge-building activity were obtained. There were no interaction effects.

Peer Collaboration and Conceptual Change

Peer Collaboration and Knowledge Quality. The four posttest qualitative measures were combined to produce a single composite score, called Knowledge Quality, using principal component analysis. A three-way ANOVA (Grade x Peer x Conflict) on knowledge quality showed no peer effects although there was a trend favoring grade 12 in peer conditions. Corresponding analyses of individual scores showed a significant peer-by-grade interaction effect for summary ($F\ (1,100) = 5.34$, $p<.05$) and a marginally significant peer-by-grade interaction effect for near-application ($F\ (1,100)= 2.89$, $p =.08$).The results suggest that grade 12 students performed better in the peer condition but the effects were absent in grade 9.

Peer Collaboration and Belief-Change Ratings. A three-way ANCOVA (Peer x Grade x Conflict) on posttest factor statement ratings controlling for pretest ratings showed no significant main effects. However, a significant peer-by-conflict interaction effect was obtained ($F\ (1,100) = 4.25$, $p<.05$) on this negotiated score. The result indicates that peers performed better than individuals in the conflict condition. No significant peer effects were obtained for the specific-statement ratings.

Taken together, these findings show that peer collaboration in itself did not promote higher-level processing activity or posttest conceptual change. It was, however, more advantageous for older students and in situations when conflict was maximized.

Discourse Patterns of Successful and Unsuccessful Learners

Qualitative Analysis. The preceding results suggest that only some students benefited from peer collaboration. It would therefore be important to examine what successful and unsuccessful students do differently in collaborative learning. In the initial analysis, an overall score was given to students' knowledge-processing activity in integrating text information. To examine how students co-construct knowledge, indepth analyses were conducted to analyze their discourse moves based on the framework of problem-centred learning. Problem-centred discourse moves are operationalized as any utterances which treat information from peers and texts as problematic, in need of explanation. These responses do not include unelaborated questions, simple requests for help, or refutation without identifying source of difficulties. Excerpts from two dyads, each followed by an interpretation, provide examples of problem-centred discourse moves. As well, they show how successful and unsuccessful learners approach the collaborative learning situation.

Dyad #1

Probe Statement: An animal cannot evolve by adapting to its environment. It is the environment which selects the well-adapted animals. A deer cannot choose to evolve long legs although long legs are important for survival. Some deer, however, may be born with longer legs which allow them to run faster. These individuals have a better chance of survival and leave more offspring.

S1A: *Maybe there is something to do with genes with the long legs, so a deer cannot choose to have long legs. However, they may be born with longer legs. So, that may be chance. So, [name of student], does it have something to do with chance? Is it possible that this card has a double meaning?* (#1)

S1B: *Probably. The deer that are born with longer legs have a better chance of survival. It does have something to do with chance.* (#2)

S1A: *But chance (card 4) is pretty high up already, would you want to change it?* (#3)

S1B: *I think it is good.* (#4)

S1A: *I think it is fine. Is there a right or wrong*

answer to it? (#5)
S1B: *Did we get any right?* (#6)

In this example, S1A initiated a problem-centred move and requested information from his peer (#1). Interestingly, even though his statement consisted of new information which was different from what S1B believed, the difference was not recognized. Instead of treating this new piece of information as problematic and attempting to explain what was said, S1B responded by giving a simple text paraphrase (#2). Similar to direct assimilation of new text information, S1B equated what S1A said about 'chance' with his everyday understanding (*Some deer have a better chance of survival*). Interestingly, S1B's utterance, which should have caused some problem or conflict for S1A, was simply ignored. S1A responded with a superficial move, treating S1B's response as satisfactory (#3). Enquiry was terminated and the problem was apparently settled. The last few moves (#4-#6) suggest that the two students were merely concerned with a task-completion activity--getting the correct ratings.

Dyad #2

Two excerpts were taken from another dyad who demonstrated considerable success in advancing their knowledge in their discourse.

S2A: *I'm not sure if it's a moth, but they noticed something that became pitch black.* (#1)
S2B: *It became pitch black because of what?* (#2)
S2A: *It developed a darker color because the pollution affected the moth. I guess the cells go through a color change. So this should be higher* [Card 3 - environment card]. (#3)
S2B: *But this* [text] *is saying, basically, it is not dependent on the environment.* (#4)
S2A: *No yeah. Wait* (reread text). *See, if this is true, I find that difficult to agree with this* [text] *because if there is some environmental change, it will kill the species. I don't know.* (#5)

In response to the probe statement, S2A recalled her prior knowledge (#1). S2B initiated a problem-centred move by asking S2A to explain the data (#2 -- *because of what?*). S2A explained and constructed her argument in favor of environmental change (#3). S2B disagreed by pointing out the discrepancy between S2A's explanation and the new information (#4). A problem-centred move was coded because Dyad #2, unlike Dyad #1 who ignored new information from peers, demonstrated a careful uptake of information as S2A identified the source of difficulty (text) which posed a problem to be explained. Instead of assimilating the new information or providing a justification to defend her claim, S2A responded with another problem-centred move by trying to deal with the conflictual information posed by her peer (#5). She re-read the information (*no, wait*) and identified the knowledge conflict (*I find it difficult to agree with this because*) even though she did not have enough information to resolve the problem then. In treating their peer's responses as problems that needed to be dealt with, the dyad continued to make progress in their discourse.

S2A: *So, first, what they are saying is that it cannot evolve by adapting...Oh, I see.* (#6)
S2B: *I don't.* (#7).
S2A: *You don't. OK. What they are saying, first, they are saying the environment does not affect the adaptation of the animal. If the animal somehow changes, then due to its environment, it might survive. I think that's what they are saying. There is always this conflict of whether it is environment or needs which cause change, and I see that scientists say it's by chance and that ... what do you think?* (#8) . . . .
S2B: *Well, it's just the fact that I still think the environment has an effect on evolution, and it (text) is saying that it's not.* (#9)
S2A: *In a way, I am starting to get convinced with this. Just think about it this way. If the environment happens to be a rocky terrain, and you have an animal like a goat which climbs up the rocky terrain. Well, let's say, it's some sort of goat born in a sandy terrain, it probably would not survive. So, in other words, the best environment the animal would survive is the best suited environment, right? But the environment does not have to necessarily change for the animals to change along with it. Is this what they are saying?* (#10)

The second excerpt was based on the dyad's responses to a later probe statement. As S2A started to process the text information (#6), S2B responded by acknowledging her lack of understanding (#7). These two utterances were not coded as problem-centred moves based on our scheme because they were simply text paraphrases and requests for help. S2A then took the opportunity to elaborate and explain the new information to S2B. It is interesting to note that as S2A explained, she then detected a problem with her understanding--the conflict between different hypotheses--and thus generated another problem-centred move (#8).

As the discussion continued, this student dyad continued to deepen the discourse by posing problems to each other. At a later point in time, S2B stated that she still had this lingering doubt about the role of environment, which seemed to be different from what the scientists said (#9). S2B's problem-centred move then elicited S2A's elaborate explanation on environmental selection. Again, S2A did not seem to consider her explanation as definitive as she once again subject her understanding to joint enquiry

(#10). In employing problem-centred discourse moves, these two students recognized difficulties, sought out discrepancies, elicited and helped each other construct explanations.

Quantitative Analysis. Analyses were conducted to contrast the discourse patterns of successful and unsuccessful learners to examine whether problem-centred moves are related to learning. Based on students' gain scores on factor-statement ratings, two highest-achieving (4 HA) and two lowest-achieving dyads (4 LA) were selected for indepth analyses.

Student verbalizations across the eight probe statements were individually coded for problem-centred moves. The mean number of utterances were 46.8 and 61.5 for the high-achieving and low-achieving group respectively. The high-achieving students made fewer but more elaborate responses whereas the low-achieving ones produced many more short utterances. The mean number of problem-centred moves were 14.2 for the high-achieving group and 2.0 for the low-achieving group ($\underline{t}(6) = 2.9$, $\underline{p}<.05$). The difference is more pronounced when proportion rather than frequency is used in the analysis ($\underline{t}\ (6) = 3.6$, $\underline{p}<.02$). These results suggest that successful student-dyads generated more problem-centred discourse moves in collaborative knowledge construction.

Discussion

This study examined constructive learning activity in collaborative science learning. Simply putting students together is not necessarily beneficial. Although peers engaged in more text-comprehension activities than individuals, there were no differences in deep knowledge-processing activity or posttest learning. Surface-constructive activities such as paraphrases may not be effective in promoting science learning (Chi et al., in press).

Consistent with the positive effects for more advanced students (Champagne et al., 1985), the older students in this study benefited more from peer collaboration. There were no pretest prior-knowledge differences; the results, therefore, suggest that older students were engaged in different sorts of constructive discourse activities, which facilitated their learning. The peer-by-conflict effect on the negotiated score provides some support for the cognitive conflict hypothesis; caution needs to be taken since the effects were not carried over to the individual tasks. Detailed analyses are required to examine constructive discourse activity in response to contradictory information.

Analysis of the discourse activity of successful and unsuccessful learners showed the different ways in which they approached the learning task. The successful student dyads were found to engage in more problem-centred discourse moves--recognizing difficulties, identifying problems, and constructing explanations. Some features of problem-centred discourse moves have been abstracted to shed light on why they may be effective in collaborative science learning.

Problem Recognition. Student varied in the extent to which they attended to what their peers said. For example, Dyad #1 did not understand what each other were saying; they conflated information from their peers and equated it as something already known (e.g., chance). Conversely, successful students were on the look-out for discrepancy, inconsistency and lingering doubts. Not only did Dyad #2 attempt to understand what each other said, they also actively sought out problems in what was said in relation to the new information. Problem recognition may play a role in the learning of incompatible concepts (natural selection, in this case): It helps students to refrain from direct assimilation, to identify sources of difficulties, and to create meaningful internal conflict based on the contradictory information.

Problem Representation. It is now commonly accepted that experts represent problems at a deeper level, whereas novices attend only to the surface features (Chi, Glaser & Farr, 1988). Consistent with research on discourse processes (Roschelle, 1993), the present findings show that the expert and novice learners differed in the kinds of problems they chose to work on. Dyad #1 seemed concerned with the literal features of the text and the correctness of ratings. Dyad #2, however, were tackling a deeper problem of domain understanding as they pondered the relative importance of conflicting explanatory models (*There is always this conflict of whether it is environment, needs, or chance?*). Although the construction of deep problems does depend on prior knowledge, the expert learners were able to move towards deeper understanding by actively constructing connections among discordant pieces of text information.

Problem-Centred Explanation. As students engaged in problem recognition and problem formulation, it led to another positive effect - elicitation of explanations for self and peers. The present data are consistent with the findings on the effects of self-explanations (Chi et al., in press); problem-centred moves are one form of constructive activity which may help elicit self-explanations. Evidently, students may generate inaccurate explanations in science learning due to incompatible prior knowledge. Nevertheless, those who employ problem-centred moves may benefit more compared to those who provide one-shot explanation to justify their beliefs or to refute discrepant arguments from their peers. In viewing their knowledge as problematic and as requiring explanations, students are engaged in an ongoing process of problem recognition and conflict resolution. Even if they have constructed inaccurate explanations (e.g., S2A, moves #3 & #5), they are more likely to detect anomalies in upcoming information and revise their models continually.

It may be said that the above analysis has not taken account of the powerful roles of social norms and structures among high school students. Social-contextual variables may indeed be important in science learning; this study, however, has focused on examining what discourse activity facilitates co-construction of knowledge. Although it is useful to have students talk about science, the benefits probably stem from the kinds of constructive activity undertaken in collaborative learning--what kind of talk promotes learning.

This study employs a cognitive constructivist perspective to examine collaborative science learning. Extending earlier findings on problem-centred learning (Bereiter & Scardamalia, 1993; Chan et al., 1992), there is evidence suggesting the positive effects of problem-centred discourse activity on subsequent learning. In order to help students move from colloquial to productive discourse, there is a need to encourage students to seek out knowledge conflict, formulate productive questions, and construct explanations in collaborative problem-centred enquiry.

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