

The Role of Activities and Verbal Interactions on Engineering Students' Learning Outcomes across Dyadic and Individual Conditions

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Collaborative learning is an instructional method in which two or more people work in small groups to construct knowledge jointly and/or to achieve a common goal (Dillenbourg, 1999; Roschelle, 1992; Webb, Troper, & Fall 1995). Many studies illustrated the cognitive benefits of collaborative learning as comprehension of ideas, retention of knowledge, integration of new and old knowledge, and transfer of knowledge (e.g., Chi & Menekse, 2015; Fischer & Mandl, 2005; Slavin, 1996; Stahl & Hesse, 2009).

Even though the value of collaborative learning has been well documented across domains, there is no single definite description in order to explain the learning processes in collaborative learning (e.g., Hausmann, Chi & Roy, 2004; O'Donnell, 2006). In addition, some studies showed, under some conditions, collaboration do not facilitate learning (e.g., Barron, 2003; Dillenbourg et al., 1996; Phelps & Damon, 1989). For example, Lou and colleague's (1996) meta-analysis showed almost 25% of the published studies in collaborative learning showed null or even unpredicted effects when compared to individual learning conditions. Dillenbourg and Hong (2008) argued that the lack of the elaborated explanations, the mismatch in mutual regulations of cognitive processes between group members, low quality of arguments and the nonexistence of negotiation of meanings reduces the effectiveness of collaborative learning. Barron's (2003) work showed students' supportive communication and responsiveness toward proposed ideas significantly affected the learning outcomes of the collaborative group. She found less successful groups did not discuss the proposed ideas or directly rejected them compare to successful groups.

We conducted two studies (Study 1 and 2) to explore the learning processes in collaborative settings. Specifically, we investigated the effective dialogue patterns and verbal moves for productive interactions, and how these collaborative interactions are influenced by the instructional materials provided for students to engage. For both studies, we compared the dyads' performance in collaborative learning condition with individual students' learning outcomes in solo condition. While all the analysis for the Study 1 is finalized and reported in this paper, the verbal analysis for the Study 2 is still in progress, therefore we only report the overall learning results for the Study 2.

Study 1

The sample for study 1 included 72 undergraduate engineering students at a large state university located at southwest of the USA. There were 24 individual students in solo settings and 24 dyads (48 students) in collaborative settings. We videotaped while dyads working together. We created the '*connecting atomic bonding and physical properties*' activity which required engineering students to understand the relations between bonding energy, elastic modulus, melting points, and coefficient of thermal expansion concepts. There were graphs, figures and an activity sheet in this activity. These graphs and figures illustrated the properties of three metals in terms of elastic modulus, bond energy, thermal expansion and melting points. We also created an activity sheet with five short answer questions to scaffold and guide students to interpret specific aspects of the information provided in the graphs and figures. Students were

asked to write their responses on the worksheets. The accompanying activity sheet delivered an inquiry-oriented activity in which the data and relations embedded within the graphs and figures were followed by questions that directed students to generate analyses and conclusions.

All participants read an introductory text individually for 10-15 minutes. Sections of this text was taken from two introductory materials science and engineering textbooks that are commonly used in universities and colleges (Callister, 2006; Newell, 2009). The introductory text was two pages long and contained definitions of terms such as bond energy, bond strength, and tensile properties. The main goal of the introductory text was to review the definitions of terminology used in the tests and the learning activity. Then all participants were given 25 minutes to complete the pretest individually. The learning activity was provided for each dyad in the collaborative condition and they were instructed to study together. Dyads were told to reach a consensus for each question before writing their answers on the activity sheet, and their discussions were videotaped. No content-related feedback nor scaffolding were provided during the collaborative sessions. Students were given up to 30 minutes to complete the learning activity. Finally, all participants took the posttest individually and they were given 30 minutes to complete the posttest. Each session lasted approximately 90-100 minutes with data collection being completed in one session. The same sequence of procedure was administered to the solo condition. After reading the introductory text and completing the pretest, the same learning activity was provided for each individual participant. Similarly, no content-related feedback nor scaffolding were provided during the collaborative sessions. They were given up to 30 minutes to complete the learning activity. All participants took the posttest individually and they were given 30 minutes to complete the posttest.

Analysis for the Study 1

A pretest-posttest design was used to measure students' prior knowledge and learning from the intervention. The questions were closely aligned with the content covered in the learning materials, thus ensuring representative sampling of content in the assessment of student learning. We evaluated the randomness of participants' assignment into conditions by conducting a one-way ANOVA to assess whether there were differences between students' pretest scores across conditions.

In order to investigate how dyads collaborated, dyads' dialogue was coded based on the frequency and quality of the interaction in each segment. We coded the dialogue segment as highly interactive (score 3 in the coding scheme) when substantive statements and responses of each student build upon those of the other throughout the question segment. The spectrum of the interaction quality ranged from dyads that largely construct their ideas and write them down independently with only minor statements of approval from the other, to collaborative discussions in which both students reach a shared understanding indicated by the proportion and/or frequency of substantive statements and responses of clarifying statements and restatements. Therefore, interaction in each segment were coded based on an ordinal scale from score 1 (i.e., less interaction, mostly one-sided/one student dominant) to score 3 (i.e. more interaction, mostly co-constructive/both students contributing). Table 1 shows the coding scheme for this analysis.

Table 1
Coding Scheme to Investigate the Quality of Dyads' Interaction

Coding Scores	Description
Score 1	<ul style="list-style-type: none"> • There is little substantive discussion or only one student's statements are substantive. • Students do not clarify or complete their partners' statements, instead voicing generic responses of agreement. • One student decides what to write while the other agrees but contributes very little or nothing.
Score 2	<ul style="list-style-type: none"> • One student's statements are mostly substantive and the other varies between substantive and shallow statements and responses. • Statements and responses are discontinuous as each student makes assertions independent from those of the other. • One student contributes most to what will be written while the other takes a smaller, though substantive, role.
Score 3	<ul style="list-style-type: none"> • Substantive statements and responses of each student build upon those of the other, indicating a shared line of reasoning. • Students clarify or complete their partners' statements through expanding, elaborating, restatement or rebuttal. • Conclusions are co-constructed with both students involved fairly equally in determining what to write.

We also investigated students' discussion at a finer grain size by coding each utterance. Pairs' discussions were coded to investigate: (1) The characteristics and function of the individual students' contribution during discussion, and (2) the nature of discourse actions when individual students respond the proposed idea. We iteratively developed a coding scheme to document students' discourse moves. We initially started with the four broad categories of *claim*, *accept*, *oppose*, and *discuss*. Then, we revised them and added more categories as needed to identify more specific utterances. Table 2 provides descriptions and examples for each discourse move.

Table 2
The Discourse Moves Used to Investigate the Characteristics and Function of the Individual Students' Contribution during Dialogue

Moves	Description	Example
Claim	Proposing the initial idea; first response to questions on the activity sheet.	<p>"Metal C has the greatest coefficient"</p> <p>"So, elastic modulus of metal A is greater than metal B"</p>
Accept	(1) Expression of acceptance and/or agreement with peer's claim; or (2) Repetition of the peer's comment, claim, explanation without adding anything new.	<p>"I agree"</p> <p>"Yeah, that sounds right"</p>

Oppose	(1) Raises an alternative to peer's claim; or (2) Challenges peer's claim; or (3) Briefly rejecting or disagreeing with peer's claim.	<p>"No, I think it is the difference between both"</p> <p>"I do not think so"</p> <p>"It might be this"</p>
Elaborate	(1) Completing peer's claim and/ or explanation; or (2) Adding new ideas on a peer's claim and/or explanation.	<p>"Like this, it expands a little bit that's all I can tell. And then this one and this one seems equal"</p> <p>"Yeah, so the max highest is iron and then the one is the second lower actually this one is max highest."</p>
Expand	(1) Reflecting on or clarifying <u>own</u> claim; or (2) expanding/elaborating <u>own</u> claim by adding explanations and/or new information.	<p>"The melting point plus a greatest stretch expand"</p> <p>"We do not know the exact temperature but you can get a comparison"</p>
Change of Claim	Changing the original claim	<p>"Yeah, this has a greatest change, sorry"</p> <p>"Oh no, metal A was the greatest and for the melting point, it should be metal C"</p>
Question	Asking for explanation, clarification or approval.	<p>"That is the one, right?"</p> <p>"Does this make it more elastic?"</p> <p>"Which one?"</p>
Response	Providing any type of response(s) to peer's yes/no type or wh type questions.	<p>"No, relation is between bond strength and elastic modulus"</p> <p>"Yes"</p> <p>"It depends"</p>
Off-task	Comments that are not are not related to topic/content.	" I am late"
Ignore	Ignoring peer's claims and/or questions.	"You said you had chicken scratch"

Two raters coded ten of the 24 transcripts individually. The initial percent agreement was 85% for the discourse moves. Rest of the transcripts was coded by one of the raters. We conducted a multiple regression to evaluate how well the discourse moves predicted the adjusted gain scores.

Results for Study 1

First, the results for the learning outcomes indicated a significant effect of condition, $F(1, 70) = 7.12, p < .01, \eta^2 = .09$. Figure 1 shows students' scores on pre and post-tests in two conditions.

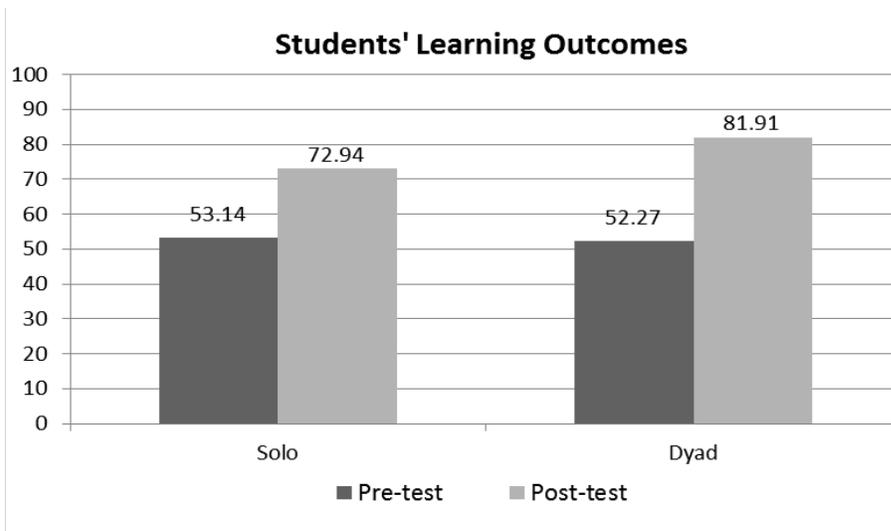


Figure 1. Percentages of students' pretest and posttest score for two conditions in Study 1.

Second, in terms of the quality of dyads' interaction, correlation analyses were conducted by using Pearson product moment correlation coefficient. We investigated the relation between dyads' interaction quality scores and their adjusted gain scores. The correlation was significant; $r(22) = .47, p < .05$. Figure 2 shows the scatterplot for the relation between the interaction quality scores and adjusted gain scores.

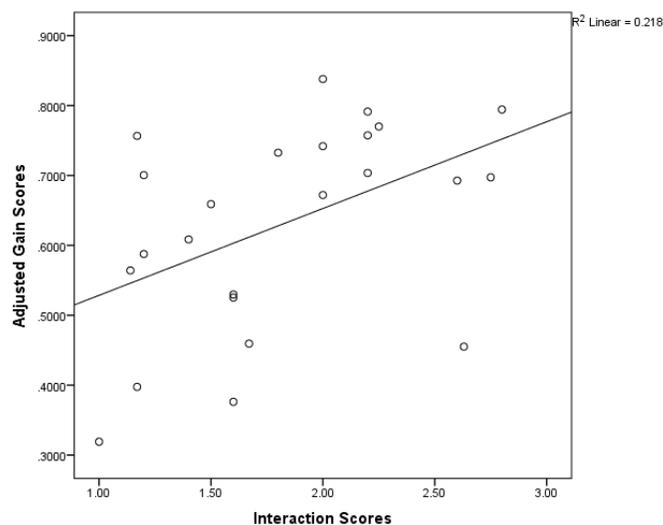


Figure 2. Scatterplot showing the interaction quality scores and pairs' average adjusted gain scores.

Third, we explored the discourse moves. Most of the discourse moves were observed in *accept* (22.5%), *elaborate* (17.4%), and *expand* (21.8%) categories. On the other hand, *oppose* (3.04%), *change of claim* (.62%) and *ignore* (.09%) and *off-task* (2.40%) type moves were rarely observed in students' dialogue. Since the main goal was to investigate the effects of discourse

moves on students' learning outcomes and there were very few of *oppose*, *change of claim* *ignore* and *off-task* categories, we excluded these categories for this multiple regression analysis.

The linear combination of discourse moves was significantly related to the adjusted gain scores, $F(6, 17) = 4.74, p < .01$. The sample multiple correlation coefficient was .79, indicating 63% of the variance of the adjusted learning gains can be accounted for by the linear combination of discourse moves. The prediction equation for the standardized variables is as follows:

$$Z_{Adjusted\ Gain} = .16 Z_{Claim} - .69 Z_{Accept} + .55 Z_{Elaborate} + .48 Z_{Expand} - 1.08 Z_{Question} + .72 Z_{Response}$$

Among the standardized coefficients of discourse moves, two were significant as *accept* and *elaborate* (both smaller than alpha value of .05).

Based on these results, we created two scatterplots (Figures 3 and 4) to illustrate the relation between adjusted gain scores and the frequency of *accept* type moves; and the relation between adjusted gain scores and the frequency of *elaborate* type moves. As expected, the first scatterplot indicated a negative correlation between pairs' average learning outcomes and the frequency of *accept* type moves in a dialogue. On the contrary, figure 12 indicated a positive relation between pairs' average learning outcomes and the frequency of *elaborate* type moves in a dialogue.

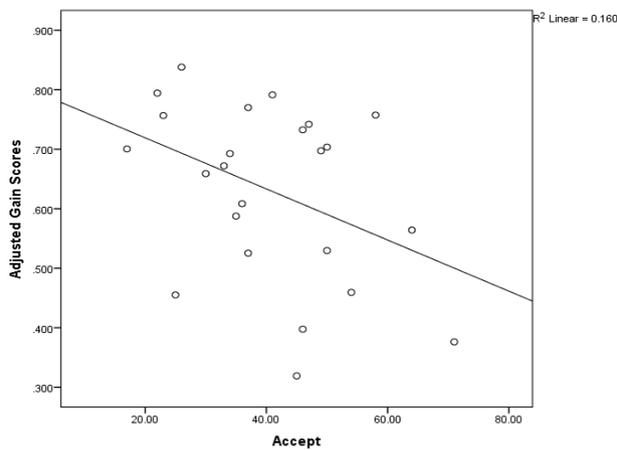


Figure 3. Scatterplot showing the correlation between the frequency of *accept* type moves in pairs' dialogue and adjusted learning gain scores.

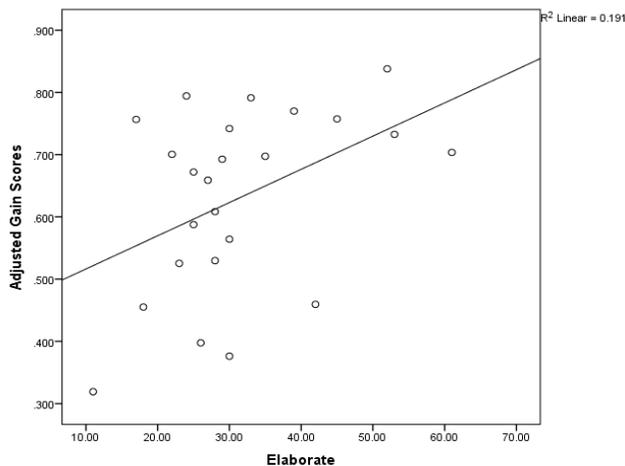


Figure 4. Scatterplot showing the correlation between the frequency of *elaborate* type moves in pairs' dialogue and adjusted learning gain scores.

Study 2 (*work in progress*)

The sample for study 2 included 62 undergraduate engineering students. There were 22 students in solo condition and 20 dyads (40 students) in collaborative condition. All participants were given eight pages long text described bonding energy, elastic modulus, melting points, and coefficient of thermal expansion and included examples of each concept. The text's content was based on materials science and engineering textbooks that are commonly used in US universities and colleges written by William D. Callister (2006) and James Newell (2009). We selected the relevant passages that provided fundamental definitions and descriptions for each concept, and we created related examples for each concept. This text's content was conceptual; we avoided using complex mathematical representations or statements, and there were no questions embedded in the reading. Students in both conditions were asked to read the text and generate graphs and/or figures based on this text. While dyads generated these graphs/figures collaboratively, students in the solo condition worked alone.

Same pre and posttests from study 1 were used to measure students' prior knowledge and learning from the intervention. A one-way ANOVA was conducted in which the within-subject factor was condition and the dependent variable was percentages of students' gain scores from pretest to posttest. The results for the ANOVA indicated no significant effect of condition at the alpha value of .05. Figure 5 shows students' scores on pre and post-tests in two conditions.

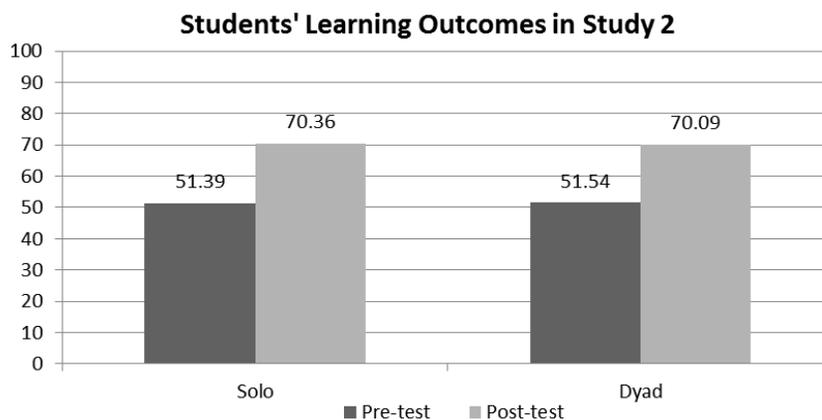


Figure 5. Percentages of students' pretest and posttest score for two conditions in Study 2.

In order to investigate why there was no difference between students in dyad and solo conditions, we will conduct verbal analysis. (Same analysis we did in the study 1.) Currently, videotapes for Study 2 were transcribed. Qualitative analysis will be conducted to investigate the deepness of students' interactions of ideas and knowledge. The transcripts of students' dialogues in collaborative condition will be coded and analyzed based on the same coding schemas we used for the study 1. Overall, qualitative analysis will show: (1) the type and frequency of discourse moves students use while collaboratively working on activities; (2) the effect of

discourse moves on students' interactions; (3) the relationship between the deepness or quality of explanations and learning outcomes. In addition, student generated graphs and figures will be coded based on the correctness and the sophistication of the representation.

Summary and Conclusion

In this study, our goal was to explore how different learning activities and verbal interactions affect engineering students' learning outcomes across dyadic and individual conditions. While the students in study 1 were provided with figures and graphs and asked to work on specific questions, the students in study 2 were provided with a long text and asked to generate figures and/or graphs. We used same pre and posttest in both studies and results showed dyads in the study 1 outperformed the individual students. However, there was no difference between dyads and individuals in the study 2. In order to understand, why dyads in the study 1 outperformed the individuals (but not in the study 2), we conducted verbal analysis in two different but related coding method (verbal analyses are complete for the study 1, but in progress for the study 2).

The first coding was for the interaction quality, which the dialogue units were coded as highly interactive (with a score of 3), medium, or low interactive (with scores of 2 and 1, respectively). A highly interactive score is given when substantive statements and responses of each student build upon those of the other throughout the question segment, whereas a score of 1 is given when the dialogue is mostly one-sided or dominated by one student. The spectrum of the interactional quality ranged from dyads who largely construct their ideas and write them down independently with only minor statements of approval from the other, to collaborative discussions in which both students reach a shared understanding indicated by the proportion and/or frequency of substantive statements and responses of clarifying statements and restatements. And the second coding focused on each statement. The motivation for coding discourse moves was to explore the students' reasoning and their contribution to dialogue in a more detailed manner. Each discourse move was used to highlight the participatory roles of students and to dissect the complexities of the dyadic exchanges.

The analysis of the interactional quality indicated that both students benefited from the collaboration when the statements and responses of each student built upon those of the other while working on cognitively challenging engineering tasks. In contrast, when there is little substantive discussion and only one of the students contributes very little or nothing, there was no meaningful gain for the non-contributing partner. However, the contributing partner was still benefiting which aligns with the findings of the "peer teaching" literature.

The analysis at a finer grain size, by classifying each utterance based on the discourse moves, revealed that frequency of the *elaborate* type moves in which students complete or add new ideas to peer's claims and explanations positively correlated with the learning outcomes; whereas frequency of the *accept* type moves in which students simply accept peer's claims and explanations without adding anything new negatively correlated with learning outcomes. Taken as a whole, the finer-grained analysis of verbal data in study 1 revealed that when there was a joint dialogue pattern in that each student made substantive contributions, both students benefited from collaboration beyond what one can accomplish individually. On the other hand,

when there was an individual dialogue pattern where one student dominated the discussion and constructed most of the ideas, only the “speaker” student benefited from the interaction.

Our next goal is to finalize the verbal analysis for the study 2 and understand the type and frequency of discourse moves students use while collaboratively working on activities, and the relationship between the deepness or quality of explanations and learning outcomes. Overall, these analyses will help us to investigate the differences between learning processes in Study 2 and Study 1, and understand how both instructional materials and dialogue patterns influence students’ engagement in the collaborative discussions.

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