DIALOGUE ACTS WITHIN TYPED-CHAT COLLABORATIVE PROBLEM-SOLVING FOR A UNIVERSITY PROGRAMMING CLASS

Duy Bui[1], Matthew Trotter[1] , Jung Hee Kim[1], Michael Glass[2], Soo-Hyung Kim[3]

[1]North Carolina A&T State University (UNITED STATES)
[2]Valparaiso University (UNITED STATES)
[3] Chonnam National University (KOREA)

Abstract

This project is attempting to observe and measure collaboration between students who are working together to solve problems in a computer programing class. In COMPS (Computer Mediated Problems Solving) exercises students work together via online typed-chat. Student dialogue turns are manually classified according to four categories of collaborative utterance: sharing ideas, negotiating ideas, regulating problem-solving, and maintaining communication. Patterns of collaborative dialogue acts are expected to reveal the conversational fingerprints which are characteristic of healthy and unhealthy student's collaborations. In COMPS problem-solving dialogues from a Java programming class, these patterns seem to distinguish between student collaboration in learning and dialogues where the teaching assistant has disrupted the collaborative patterns. They also reveal differences in dialogue behaviors between the students who came to the conversation most prepared, and least prepared. This research advances toward promoting better student collaborative problem-solving exercises, more fully using student group cognition and collaboration skills, and advances toward computer assessment of student collaboration skills. Problem-solving collaboration is among the 21st Century Skills recently mandated for K-12 education in the U.S. and measured by the PISA international comparison of educational achievement.

Keywords—Computer Mediated-Chat, Collaborative Learning Environment, Collaborative Utterance, Online Teaching tools, Conversation Analysis

1 INTRODUCTION

The students in this study were in a 2nd-semester undergraduate computer programming class, engaged in COMPS (Computer Mediated Problem Solving) group problem-solving exercises. Each group has typically three students, aided by a teaching assistant (TA) who oversees many conversations. COMPS exercises present the students with some programming questions, for example analyzing the behavior of some Java code. The exercise includes a script to guide the collaboration activity: it instructs the students to come to an agreement on successive segments of the problem. At the conclusion of each segment, the teaching assistant passes judgment and perhaps provides assistance, permitting the students to revise their answer then proceed to the next part. This script is constructed to promote mutual dependence (the students don't signal for the TA until they all agree) and accountability (students should exhibit understanding for each part of the problem).

A COMPS project research activity is to observe and measure collaboration by examining the dialogue stream of students engaging these collaborative problem solving sessions. In this paper, we report on patterns related to identifying when students are not engaged in collaborative activity. This research is in service of better administering computer-assisted collaborative learning exercises, and it furthers the goal of producing technology which can sense the quality of the collaboration by reading the dialogue streams.

COMPS records and stores the dialogues for further analysis. Using these student dialogue files, the main data preparation activity consists of manually classifying student dialogue acts according to four categories. From these annotated transcripts we count the different behaviors and look for patterns of interaction. This reveals the conversational fingerprints which could be characteristic of successful and unsuccessful student collaborations.

Analysis of dialogue acts showed that the collaboration script as executed in real exercises is not reliable. Dialogues do begin with collaborative problem-solving. However if the group's answer is incorrect then group cognition sometimes ceases. Students individually address questions to the TA, the conversation becomes like a class with TA responding to the individual questions.

Sometimes the TA will explicitly direct the students to resume working together. Ideally, the TA should give a hint, and then allow the group collaboration to continue. However, this ideal scenario is defeated by normal conversational discourse obligations: it is hard not to answer questions. The role of the TA thus too easily turns into tutoring, and sometimes this means tutoring individual students while the rest of the group lurks.

The second result is to advance toward fingerprinting collaborative activity. From pre-tests immediately prior to the exercise, it is possible to identify which of the three students in the conversation is the most prepared for the exercise at hand. Similarly the least-prepared and middle-prepared students are identified. Those students with the most sharing ideas and regulating problem-solving tend to be the most prepared students in the group. These students also tend to contribute more dialogue turns. In addition, groups with more TA involvement are shown to have fewer turns involving negotiating ideas.

The sections of this paper are: a description of the data and its annotation, the characterization of off-script behaviors and overall dialogue act percentages obtained from annotated transcripts, and discussion of how this might inform the goals of machine identification of well-performing and badly-performing collaborative discussions.

2 BACKGROUND

2.1 COMPS computer-mediated chat exercises

The dialogues in this study were administered during the computer lab sessions of a university 2nd semester computer programming sequence. The students were computer science and engineering majors. These exercises were administered 1 to 4 times during the course of the semester, as a counterpoint to the more usual exercises where the students write computer code. This curriculum intervention is intended to help students to engage with the ideas and concepts of the code, as a counterpoint to the instrumental skills of writing code [1, 2, 3].

Lab sessions start with a pre-test, then students are assigned to a chat group. They discuss and solve the problem together using the COMPS web-delivered typed-chat interface. Students in one group are seated in separated locations around the computer lab, so all communication is through the computer and recorded. Students then complete a survey and a post-test.

The COMPS web page, shown in Figure 1, is specialized for collaborative problem solving with instructor oversight. COMPS asks the students to compose an agreed-upon answer in a static text area apart from the scrolling dialogue window. The chat affordance has a very interactive feel. Students can all type at once and read and respond to each other’s dialogue in real time as they type, it isn’t necessary to wait for conversational turn-taking [5]. The page contains affordances for each student to signal agreement with the answer, and to signal the TA to come review.

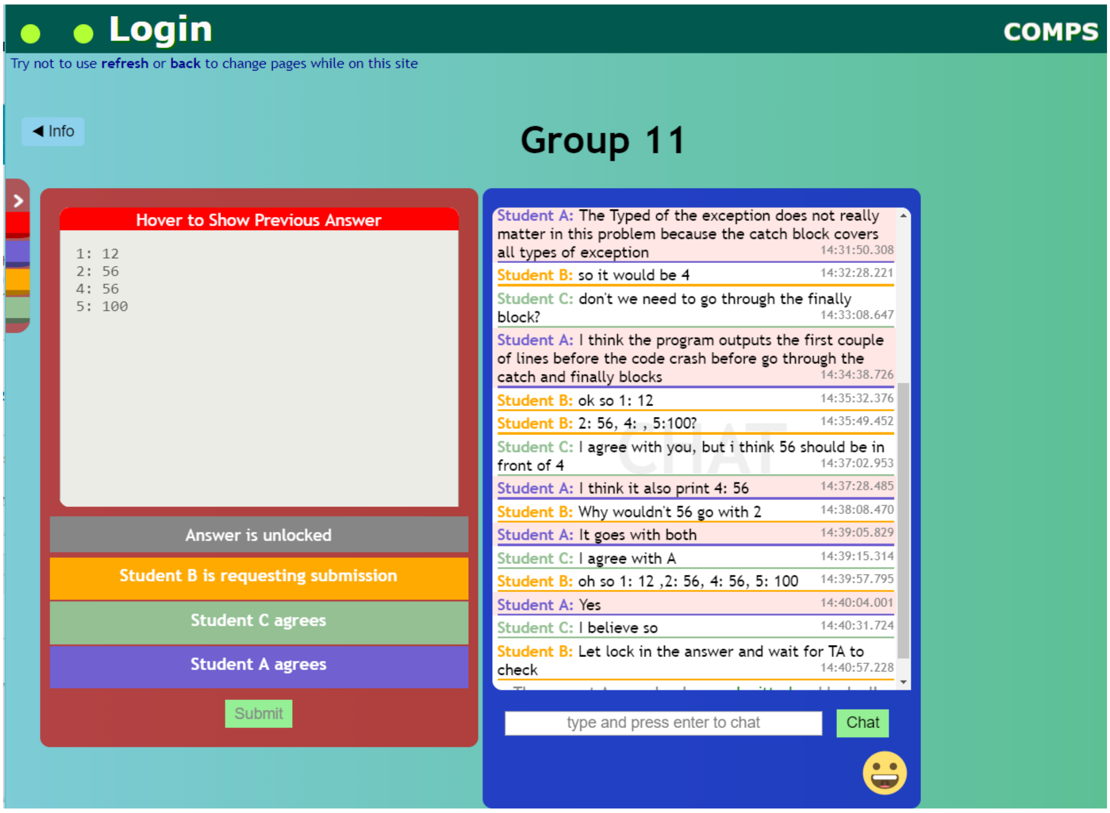

Figure 1. COMPS interface.

2.2 Dialogue act annotation

The results in this paper come from annotating seven dialogues, 1280 dialogue turns. Excluding teaching assistant dialogue turns, there were about 1000 student dialogue turns in the seven student groups. Dialogues averaged 70 minutes. Two annotators read and annotated each dialogue turn, where a turn most often contained one dialogue act but could contain several. They trained on several other dialogues until they achieved a satisfactory degree of interrater reliability. The differences in the seven multiply-annotated dialogues were then resolved by consensus.

Small amounts of dialogue before students started addressing the exercise (e.g. logging in and greeting each other) were excluded from the annotation and analysis. The segments of dialogue containing TA interaction were marked so the difference in dialogue style during TA participation could be studied.

The categories of dialogue acts were obtained from a collaborative skills assessment task under development by the Educational Testing Service [4], as follows:

A. Sharing Ideas: The participant shares their idea to the group. The idea has to be task-relevant or information that contributes to the problem-solving process.
B. Negotiating Ideas: The participant modifies or reacts to ideas already on the table, e.g. by agreeing/disagreeing, rephrasing, pointing out a gap, or asking for clarification.
C. Regulating of Problem Solving: Examples of these dialogue moves are suggesting the next step or goal, expressing frustration, checking understanding, and evaluating whether some part of the discussion has been useful.
D. Maintaining Communication: The participant engages with the group by attending to conversational or social norms or contributing to social interaction, but the turn is not part of the cognitive work of solving the problem. Some examples are apologizing, offering help, regulating turn-taking, conversational repair, and responding with emojis or displays of affect.

Table 1 shows illustrative dialogue turns for each of the four categories. A few of the common sub-categories of each category are shown.

Table 1: Four Dialogue Act Categories with Common Sub-categories

Category-subcat	**Description**	**Example Dialogue Turn**
A-1 (Sharing Ideas)	A student gives task-relevant information.	"I think for a and b they are both public and c is private"
A-3 (Sharing Ideas)	A student responds to a teammate's request for task-relevant information	" encapsulation allows validation"
B-1 (Negotiating)	A student expresses agreement with a teammates	"I'm wrong about 2 and ok"
B-4 (Negotiating)	A student asks the teammates to repeat or clarify a statement	"it would be the three formal parameters for number three right?"
C-1 (Regulating Problem Solving)	A Student suggests the next step or suggests the group role before continuing	"right so a is done let's get on b" "Are you okay with being the leader?"
C-2 (Regulating Problem Solving)	A student expresses confusion/frustration or lack of understanding	"Im a bit confused, I know it all, but only how z is 26!"
C-7 (Regulating Problem Solving)	A student explains their current action to contribute to problem-solving	"idk ima google it" "I am working on it"
D-1 (Maintain Communication)	A student greets teammates or engages in small talk	"hi" "whats up" "Isn't this a blast?"
D-3 (Maintain Communication)	A student attends to conversational norms.	"Good question"

2.3 Successful collaborative dialogue

The elements of successful vs. unsuccessful collaboration are based on two main factors:

- Learning [6]
- Collaborative Participation [7]

We measured learning gain over the course of the lab exercise from the pretest and posttest [3]. Learning gain is calculated by: (posttest score - pretest score) / (full point score - pretest score)

However learning gain is not by itself a marker of successful collaborative problem-solving activity. COMPS utilizes several measurements to gauge whether students are contributing. A turn participation parameter [11] measures the fraction of dialogue turns contributed by a participant on a scale of 0 (lurking) to 1 (dominating the discussion). This number is normalized so that if a student is contributing an equal fraction of the turns ($1/n$ of the turns in an n-person group), the parameter is 0.5, it is further scaled by a logistic function so that extreme values are compressed. The COMPS project has also experimentally trained classifiers to recognize the fraction of substantive turns. A substantive turn was shallowly defined as one containing both problem-related words plus other words [8].

There was also manual judgement of degree of collaborative dialogue by our annotators. The analysis of the two tutoring roles depended on categorizing dialogue segments manually.

3 RESULTS

3.1 Tutor or mentor behavior

Each transcript was segmented into sections which correspond to one complete discussion, answer, and approval from the TA. Recall that the script asks students to develop and agree an answer to one section of the problem. They signal the TA to judge the answer, possibly check their understanding, and possibly provide assistance. They proceed to the next section when the TA approves. Table 2 shows typical collaborative discussion from our dialogues.

Table 2: A Collaborative Conversation

Participant	Text	Dialogue Acts	Sub-category
St1	public String toStrong(){ String result = null; result = lendingInstitution +' '+ PAmount +' '+ iRate +' '+ etc.	A	Sharing Idea
St2	lol yall going in i think thats right tho	D, B	Joking, Agreement on the idea
St1	we just have to explain the getters and setters now	C	Suggest next step
St3	Student 1 can u explain them	C	Check on understanding
St1	besides excapsulation, accessors make it easier to change future things mybad on the spelling	A, D	Explain Idea, small talk
St4	So everything except the setters and getters are explained right?	C	Reflects on what the group did
St1	encapsultion allows validation	A	Continue to explain Idea
St3	I dont believe we've explained the properties	C	Suggest next step

When students start to address the teaching assistant, however, the dialogue often ceases to be between the students and becomes between students and TA. We say the TA adopts a tutoring role. Otherwise, where TA works to promote student collaborative problem-solving, we say the TA adopts a mentoring role. The TA-involved segments of several dialogues were thus manually categorized as Group A (tutoring role, 178 turns) and Group B (mentor role, 120 turns). Tables 3 and 4 illustrate these two styles of dialogue.

The TA-participation sections, especially in the tutor behavior, sometimes show the participation rate of the TA rise above 0.6. The dialogue segment in Table 3 shows 6 out of 13 turns uttered by the TA, whereas with 4 people approximately 3 turns would represent an even participation rate of 0.5. Group members who are not involved in these exchange reach a low of 0.3. In Table 3 student 3 is lurking.

Table 3: A Teaching Assistant in Tutor role, Group A

Participate	Text	Dialogue Acts	Reasoning
St1	TA could you re explain the question	C	Expresses confusion
TA	for # 3?	TA-C	Check on understanding
St1	yes	D	Agree on none task-relevant
TA	Basically, you have to tell me which variables you can access from your method	TA-A	Share idea
St2	it would be the three formal parameters for number three right?	B	Ask to clarify
TA	*which class variables	TA-C	Suggest next step
St1	the principalAmount, intreset rate, and the term? because thats the values the method uses to calculate	A, B	Sharing idea, collaborate on an idea
St2	3. the principalAmount, intreset rate, and the term.....because thats the values the method uses to calculate TA?	C	Express of understanding
TA	Actually, its a bit more complicated than that.	TA-C	Suggest next step
St1	totalCurrentMortages	A	Sharing idea
TA	You have a static method for your example. Therefore you can only access a particular class var Explain why that is	TA-A	Sharing idea
St1	static methods can only access other static variables	A	Sharing idea
TA	good, you got it	TA-C	Show satisfaction of the group did

Table 4: A Teaching Assistant in Mentor Role, Group B

Participate	Text	Label	Reasoning
St1	num 4	C	Suggest next step
St2	yes sir	D	Small talk
St3	cool	D	Small talk
St2	i suck at tracing code	D	Small talk
St3	I am working on it	C	Explain current action
St1	can we get some help	C	Express confusion
St2	TA since i cant talk, can u please help me us*	D, C	Express

			confusion
TA	Can you point out which part is giving you trouble in the code	TA_C	Check on understanding
St3	public string toString	C	Express confusion
TA	Do you understand the code from main()?	TA_C	Check on understanding
St2	no sir	C	Express confusion
St1	well im confused still	C	Express confusion
St2	any ideas guys? guys??TA?	C	Express confusion
TA	Ok try to discuss the 1st two lines of main and what they do	TA_C	Suggest the next step

Numerically, there are distinct differences in the dialogue acts performed by the teaching assistants between the group A and group B mixtures of dialogue acts. In both cases, categories B (negotiating) and D (maintaining communication) are negligible. The other two categories are quite different. Both contain frequent regulating turns. These are often checking understanding or probing the students as illustrated in the Tables 3 and 4 dialogues. However in the tutoring role segments the TAs contribute many more ideas into the conversation.

Table 5: Teaching Assistant Dialogue Acts

	Group A tutoring	Group B mentoring
Sharing ideas	32%	06%
Regulating	60%	88%

3.2 Fingerprinting participant behavior and preparedness

Are well-running collaborative problem-solving dialogues characterized by equal levels and styles of dialogue acts and participation? Toward fingerprinting well-running dialogues, we ranked students according to their relative level of preparedness for solving the problem. The hypothesis is that perhaps the student who enters the conversation with the most knowledge of the topic may have different contributions than the student who enters with the least knowledge. The relative preparedness was based on the pre-test scores of the three students. Rank 1 is the most prepared student in the conversation, rank 2 is the middle, and rank 3 is the least prepared [9, 10]. Table 6 shows average measures of learning and collaboration according to relative to student preparedness rank, taken from a set of 10 dialogues. With participation increases with increasing relative preparedness. The most knowledgeable student talks more. The variety of dialogue act varies also. With more preparedness: a) sharing dialogue acts increase, b) negotiating dialogue acts decrease, c) regulating increases. One other result is that the most prepared students show zero learning gains, on average, while the others show positive learning gains from the experience.

Table 6: Student Rank Statistics

Student Rank	Average Learn Gain	Average Participation	A Sharing	B Negotiating	C Regulating	D Maintaining
1	0	0.56	29%	26%	28%	15%
2	0.10	0.49	26%	34%	26%	14%
3	0.75	0.40	19%	37%	19%	23%

Rank 3 least prepared students show the largest dispersion in participation and dialogue act behavior analysis. Some rank 3 students seem to be disengaged or lurkers, resulting in a participation rate under 0.2. Others may constantly ask for clarification, which enriches participation and negotiation dialogue acts. Others devote large numbers of turns to conversation maintenance, frequently contributing “LOL” or other comments not related to solving the problem at hand. The requirement in the script that students come to agreement, and the TA can probe for understanding, encourages rank 3 students engaged.

4 CONCLUSIONS AND FUTURE WORK

The main goals of this study were a) diagnose whether the collaboration script was being followed and b) discover measurable differences between properly working collaboration dialogues and less successful ones. We found that a notable cause of departure from collaborative activity was the behavior of the teaching assistants. We found also measurable differences in the dialogue act and participation behaviors that might be useful for building text classifiers that a) recognize the teaching-assistant off-script activity, and b) possibly help detect conversation quality.

4.1 Collaboration script: tutoring vs. mentoring teaching assistants

It has proven to be a challenging to keep the teaching assistants on-script, promoting group collaborative discourse. Discourse obligations dictate that the TA should answer questions. For the TAs, answer students’ questions is normal behavior, what is expected of them when interacting with students in the course. Answering questions is a large fraction of their activity during the regular non-COMPS programming lab sessions. Clearly better training of TAs should be attempted.

With regard to fingerprinting errant conversations and providing machine recognition of this deviation from collaborative work, we observed that tutoring-mode TAs increase their participation and increase their type A sharing ideas dialogue acts. Being able to detect these behaviors via text machine classifiers seems promising.

As an early report and a stepping stone to the future developments, we will apply our finding and provide training to TA to better collaborative exercise through typed-chat. It is a promising result which can identify a characteristic and attribute of conversational interaction between student and lab instructor. We can help a machine tutor to understand what happened in the lab section and apply a response that is appropriate and helpful to every participant.

4.2 Characteristic patterns of dialogue acts

COMPS experiments to train machine classifiers to recognize dialogue exchange structure -- whether dialogue turns were responding to earlier turns -- have not been successful [1]. The results from this study contradict the naive expectation that a healthy collaborative dialogue could be recognized by roughly equal styles of participation from all the students. However they do suggest a possible way forward. The next step will be to endeavor to train machine classifiers to recognize and annotate the four categories of dialogue acts, in a manner similar to recognizing substantive contributions. Since the most prepared two students in the group are more predictable, it might then be possible to reduce the noise and variability by considering mainly the dialogue act contributions of the two most prepared students. Finally, we have begun analyzing sequences of dialogue acts, starting with pairs, because these often represent dialogue exchanges. We hypothesize that well-functioning collaborative problem-solving dialogue might contain characteristic patterns of dialogue exchanges.

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REFERENCES

[1] M. Glass, J.H. Kim, K. Bryant, and M. Desjarlais, “Indicators of Conversational Interactivity in COMPS Problem-Solving Dialogues,” in *Third Workshop on Intelligent Support for Learning in*

Groups (ISLG), Honolulu, 2014.

[2] M. Glass, J.H. Kim, K. Bryant, and M. Desjarlais, "Come let us chat together: simultaneous typed-chat in computer-supported collaborative Dialogue," in *Journal of Computing Sciences in Colleges*, vol. 31, no. 2, pp 96-105, 2015.

[3] J.H. Kim, T. Kim, and M. Glass, "Early experience with computer-supported collaborative exercises for a 2nd semester Java class," in *Journal of Computing Sciences in Colleges*, vol. 32, no 2, pp 68–76, 2016.

[4] J. Hao, L. Liu, A.von Davier, P.C. Kyllonen, "Initial Steps Towards a Standardized Assessment for Collaborative Problem Solving (CPS): Practical Challenges and Strategies". In *Innovative Assessment of Collaboration. Methodology of Educational Measurement and Assessment* (A. von Davier, M. Zhu, P. Kyllonen, eds.), pp. 135-156, Springer, 2017.

[5] M. Glass, A. Nelson, C. Emeka, and J.H. Kim, "Not Interfering: Simultaneous Typed Chat in COMPS Computer-Mediated Dialogues," in *Proceedings of Modern Artificial Intelligence and Cognitive Science (MAICS)*, pp. 107-113, 2017.

[6] R. Chiong and J. Jovanovic, "Collaborative learning in online study groups: An evolutionary game theory perspective," in *Journal of Information Technology Education: Research*, vol. 11, pp 81-101, 2012.

[7] M. Glass, J.H. Kim, K. Bryant, Y. Jagvaral, N. Bouman, E. Graham, S. Kalafatis, L. Arndt, and M. Desjarlais, "Problem-Independent Text Analytics for Real-Time Judgment of CSCL Typed-Chat Dialogues," in *Journal of Computing Sciences in Colleges (CCSC)*, vol. 34, no.1, pp 145-154, 2018.

[8] A. Willis, A. Evans, J.H. Kim, K. Bryant, Y. Jagvaral, and M. Glass, "Identifying Domain Reasoning to Support Computer Monitoring in Typed-Chat Problem Solving Dialogues," in *Journal of Computing Sciences in Colleges (CCSC)*, vol. 33 no.2, pp. 11-19, 2017

[9] M. Glass, J.H. Kim, M. Desjarlais, and K. Bryant, "COMPS Computer-Mediated Problem Solving Dialogues," in *International Conference on Computer Supported Collaborative Learning (CSCL 2013)*, Madison, 2013.

[10] J.H. Kim, M. Desjarlais, K. Bryant, and M. Glass, "Observations of Collaborative Behavior in COMPS Computer Mediated Problem Solving", in *Proceedings of the 24th Midwest Artificial Intelligence and Cognitive Science Conference (MAICS-13),* pp. 71-77, 2013.

[11] J.H. Kim, M. Glass, T. Kim, K. Bryant, A. Willis, E. McNeil, and Z. Thomas, "Student Understanding and Engagement in a Class Employing COMPS Computer Mediated Problem Solving: A First Look," in *Proceedings of the 27th Modern Artificial Intelligence and Cognitive Science Conference (MAICS-13),* pp. 69-74, 2016.