An analysis of Interaction of Cognitive and Social Aspects during Collaborative Problem Solving

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***Abstract*—Collaborative problem solving (CPS) is a key skill for the success in education and workforce. The CPS performance is determined by the interaction of problem solving process and collaboration. Thus, the interaction of cognitive and social aspects should be included in the CPS assessment. This study presented a method to analyze the interaction through extending the coding framework from the Assessment and Teaching of 21st Century Skills (ATC21S) project. The results showed that the high task performance group outperformed the low one in terms of the interactive chat-action pattern and participation pattern. Besides, a visual representation of the participation pattern exhibited more details about the interaction.**

Keywords—collaborative problem solving, interaction, interactive chat-action pattern, participation pattern

I. INTRODUCTION

Collaborative problem solving (CPS) is one of the necessary skills to gain achievement in education and workforce [1][2]. However, the nature of CPS Skill such as interactivity makes CPS assessment a challenging job. In this paper, we present a method to analysis the triad's interaction of the social and cognitive aspects during CPS. We focus on the group-level CPS performance assessment. The results would provide some worthy information for the CPS assessment.

II. RELATED WORK

A. The Interactivity of CPS Skill

Interaction shapes CPS[3][4]. The quality of collaboration depends on the interaction of the members within the group [5]. Based on the ATC21S project and PISA2015 project, CPS skill comprises a number of subskills, which draws on cognitive and social aspects[6][7]. Thus, the outcome of a CPS task should be the results of the interaction of both[8]. As each member's cognitive and social performance will influence others' because of the interaction, the interaction should be considered while assessing CPS performance.

Some studies have tried to explore the interaction of social and cognitive aspects of CPS skill, for example, ATC21S tried to explain the collaboration by counting the combinations of chat and action between the player and partner [9]. Chang indicated that collaboration and problem solving activities were closely related in the successful CPS groups [10]. These previous studies just focused on the frequency analysis at the cost of simplification of the meaningful behavioral data.

B. The H-H Approach for the CPS Skill Assessment

In the H-H approach, each participant communicates with human partners, which could produce the authentic H-H interactions [11]. With the development of the computer-based assessment technology, the interactions could be recorded in "log stream data" [9]. ATC21S project recorded all the actions and chat events in a time-sequenced log file, and came up with a method to quantify the interaction by counting the interactive chat-action blocks. However, it did not check whether the player's chats and actions were influenced by his/her partner's previous activities. The Collaborative Science Assessment Prototype (CSAP) developed by Educational Testing Service (ETS) treated each dyad as the unit of analysis and quantified the collaboration by two variables [8], which were based on the difference between the initial responses and revised responses [12]. This study just reported the outcome of the interaction without deeper analysis of the interaction in CPS.

Therefore, in order to provide more detailed information about the interaction of the CPS process and give some hints for CPS skill assessment, more researches are needed to explore the interaction of cognitive and social aspects during CPS process.

III. RESEARCH QUESTION

This study aim to investigate the interaction in triad via the log stream data of students' CPS performance. We want to investigate two main research questions:

RQ1: what are the interaction differences between high CPS task performance and low CPS task performance?

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RQ2: what aspects of the triad's interaction can be good evidences that can distinguish between high and low CPS performance groups?

IV. METHODS

A. Participants

The participants were thirty-six students in the first year of their secondary education (ages 13-14 years) from a public secondary school. There were eighteen girls and eighteen boys. They gave informed consent to participate in the study, which received the ethical approval from their school and supervisors. The students were divided into twelve triads randomly.

B. Data collection

We collected the log steam data through the Problem Solving Ability Assessment (PSAA) System. It is a computer-based assessment system developed by our technical team. Each triad needed to finish three tasks within eighty minutes.

Fig. 1. The CPS Task Interface

As Fig. 1 illustrates, the CPS task interface is comprised of three main parts: **Task area:** to show the task information, items and task time. **Chat area:** to support the group members to communicate with their partners synchronously. **Information Center:** to provide the student with some resources.

There are two types of the process stream data. **Action data:** it is generated from the students' online behaviors (e.g., clicking the button, dragging the icon) ,which can represent the cognitive aspect of the CPS skill. **Chat data:** all the messages in the Chat Area will be automatically stored in the log file as chat data. The chat data can represent the social aspect of the CPS performance.

V. DATA ANALYSIS

A. Coding Framework

A coding scheme of the interaction was extended based on the ATC21S coding framework [9], including two variables: **Interactive Chat-Action Pattern(ICAP):** in order to analyze the interaction of the cognitive and social aspects, it includes seven types: chat-chat-chat, chat-chat-action, chat-action-chat, chat-action-action, action-chat-chat, action-chat-action, and action-action-chat. **Participation Pattern(PP):** in order to analyze the interaction among different individuals in the triad, it contains different kinds of engaging combinations. Each triad consists of three student A, B and C, so there are four types of interaction: AB, AC, BC, and ABC.

B. Coding Rules

As shown in the Table 1, firstly we sorted all the chat and action data in one group by timestamp. Then we encoded each record, if the record was associated with the previous records(AWPR), it was "1", otherwise it was "0". Thirdly, we decoded both the action and chat data in three consecutive cells into mini-sequence with n-gram method[13][14]. Lastly, we labeled the ICAP and PP for each group. There were two coders, and the interrater reliability determining consistency among coders was found to be Kappa = .94.

TABLE I. THE CODING EXAMPLE

ID	Chat	Action	AWPR	n-gram	ICAP	PP
A	Is it ok?		1	……		
C	Be quick!		1	……		
B	I think the software engineer will not		1	111	chat-chat-chat	ABC
A	Don't push me!		1	111	chat-chat-chat	ABC
A	May the choice is too much in the type of the "possible"		1	111	chat-chat-chat	AB
B		Check the information "####"in the Information Center	1	111	chat-chat-action	AB

The CPS task performance rating: there were three levels (2, 1, 0) for each task. The CPS task performance was the sum of the scores for the three tasks.

We performed a descriptive analysis of ICAP and an independent-samples t-test the high and low task performance groups. Also, we exhibited visualized profiles of PP for the high and low task performance groups.

VI. RESULTS

A. What are the Interaction Differences between High CPS Task Performance and Low CPS Task Performance?

Fig. 2(a) shows that for the interactive patterns in terms of the ICAP, the high task performance group exhibited more than low one did, especially within the "chat-chat-chat" type, which was nearly more than three times higher compared with the other types. Fig. 2(b) shows the p-value of the t-test for each type of ICAP for the high and low task performance groups, we chose the 0.05 as the significance level, chat-chat-chat, chat-chat-action, chat-action-chat and chat-action-action stand out immediately.

B. What Aspects of the Triad's Interaction can be Good Evidences that can Distinguish between High and Low CPS Performance Groups?

Fig. 3 displays the visualized profiles of PP in high and low CPS performance groups respectively. We can easily find that the area of the figure of each group in the high task performance group was larger than that in the low one.

Besides, we can also find there were different interaction patterns according to the types of triangle, which was made up of the three vertexes—AB, BC, AC (the dashed area). For

example, in the figure (a) or (d), the dashed area was an obtuse triangle, there was a student in the center of the interaction who was often interacted with the other two partners, but the other two partners seldom interacted with each other. So the interaction of this group was "leader-follower" type. In the figure (c) or (f), the dashed area was an acute triangle, there was a loafing student who seldom engaged in the interaction. So the interaction of this group was "one-man loafing" type. Thus, this PP triangle can easily exhibit more details of the interactive pattern in the CPS, which can be also as the good evidences of different group-level CPS performance.

VII. Conclusion

In this study, based on analysis of the log stream data of the students during the CPS, more details about triad's interaction of cognitive and social aspects were shown. We made an effort to expand the coding framework of interaction within H-H approach. We proposed a new kind of visualized display method to profile the interaction pattern of the CPS process, which can provide some advice for the learning analysis dashboard related researches. In future, we need to collect a larger dataset and to consider more factors in the CPS assessment, such as the group composition, academic achievement, self-efficacy and so on [15], to reveal more details about the interaction during CPS.

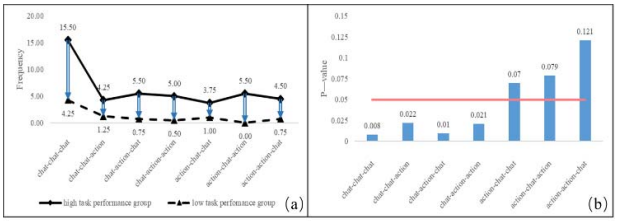

Fig. 2. The Interaction Differences between High CPS Task Performance and Low CPS Task Performance(The red horizontal straight line corresponds to a significant level of 0.05)

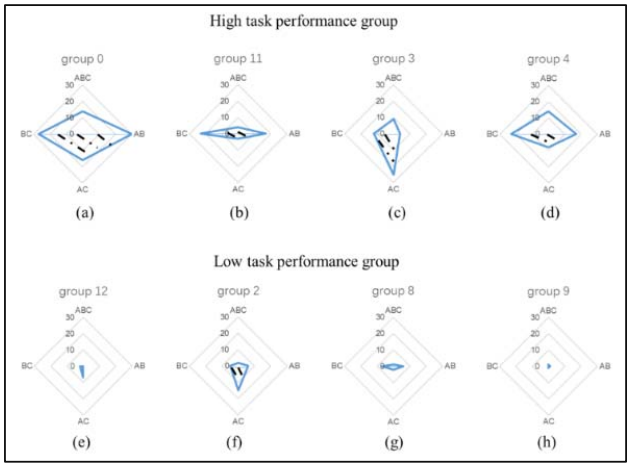

Fig. 3. Visualized profiles of the participation pattern of the interaction

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