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An analysis of student collaborative problem solving activities mediated by collaborative simulations

Chia-Jung Chang [a], Ming-Hua Chang [a], Bing-Cheng Chiu [a], Chen-Chung Liu [a, *], Shih-Hsun Fan Chiang [a], Cai-Ting Wen [a], Fu-Kwun Hwang [b], Ying-Tien Wu [a], Po-Yao Chao [c], Chia-Hsi Lai [d], Su-Wen Wu [d], Chih-Kang Chang [e], Wenli Chen [f]

[a] *Graduate Institute of Network Learning Technology, National Central University, Taiwan*
[b] *Department of Physics, National Taiwan Normal University, Taiwan*
[c] *Department of Information Communication, Yuan Ze University, Taiwan*
[d] *Jhongli Senior High School, Taiwan*
[e] *Hsinchuang Senior High School, Taiwan*
[f] *National Institute of Education, Singapore*

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ABSTRACT

Collaborative problem solving (CPS) is considered as one of the core competencies of the 21st century. Collaborative simulations which allow multiple students to participate in CPS activities in a shared simulation session are now increasingly applied to better facilitate these activities. However, the literature has shown that students' collaboration often does not lead to an effective solution to problems. Guided by the PISA CPS framework, this study thus aimed to analyze students' collaboration patterns and problem solving strategies in solving a physics problem, and to identify significant patterns which may lead to a successful or unsuccessful outcome. Multiple data sources including group discussions, problem solving activities in a collaborative simulation, and open-ended questionnaire feedback from 30 high school students were analyzed using the lag sequential analysis technique. It was found that collaborative simulation has the potential to help students situate their discussion in a joint concrete problem space, facilitating their formation of a path to solve the problem. More importantly, the results showed significant differences between the successful and unsuccessful groups in terms of their collaboration patterns and problem solving strategies. A considerable portion of the students could only apply an intuitive trial-and-error strategy, and failed to solve the problem in the end. These students showed an inability to monitor and analyze the problem solving process, and were unable to transform their discussion into an executable plan to solve the problem. Those students who applied analytical reasoning strategies were more likely to achieve a successful problem solving outcome. The implications for educational practice are discussed, and the directions for future studies addressed.

* Corresponding author. Graduate Institute of Network Learning Technology, National Central University, No.300, Jhongda Rd., Jhongli City, Taoyuan County 32001, Taiwan, ROC.
E-mail address: ccliu@cl.ncu.edu.tw (C.-C. Liu).

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1. Introduction

Collaborative problem solving (CPS) is considered as one of the core competencies of the 21st century (Griffin, McGaw, & Care, 2012). According to the definition of the OECD, CPS involves a complex process *"whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills and efforts to reach that solution*" (OECD, 2013). The emphasis of CPS is rooted in the social constructivist view of learning which asserts that in-depth learning occurs when students engage in building a shared understanding of a problem through social interactions (Jermann & Dillenbourg, 2008; Pear & Crone-Tood, 2002). It is believed that the social interactions during a problem solving activity are helpful in developing students' zone of proximal development, as the interaction is situated in a meaningful context (Lave & Wenger, 1991; Vygotsky, 1978).

To facilitate the CPS process, researchers have suggested that a dual interaction space, constituting a workspace and an online chatroom, is necessary to help students effectively organize the social and cognitive processes involved in the problem solving activity (Dillenbourg & Traum, 2006; Çakır, Zemel, & Stahl, 2009). Following the dual interaction space principle, extensive studies have incorporated simulations with collaborative learning tools such as text chatrooms to support CPS (Saab, van Joolingen, & van Hout-Wolters, 2012; van Joolingen & de Jong, 2003). These simulations and text chatrooms afford a dual interaction space wherein students effectively communicate, negotiate, and exchange perspectives by referring to concrete simulated results. It was found that these computer simulations facilitated knowledge integration processes (Taub, Armoni, Bagno, & Ben-Ari, 2015) and helped students learn analytical skills (Pedaste & Sarapuu, 2014). Such an effect may result from the fact that the simulations prompt learners to respond quickly to a concrete simulated phenomenon and support their knowledge construction processes (Saab, van Joolingen, van Hout-Wolters, & S, 2012).

However, the computer simulations utilized in these studies were individual-based, meaning that the students could not manipulate the simulations together. The social interactions in such simulations were limited to the use of the online chatrooms, and thus problem space and the social interaction space were not closely linked. The literature has indicated the limitations of the separation of social interaction space and the problem space. In such an environment, students often failed to closely interact with each other based on a solid problem situation and the interaction often led to unfavorable problem solving outcome as the discussion did not closely connect to the problem solving steps on simulations (Lin, Hou, Wu, & Chang, 2014). The interaction which is not directly linked to the problem solving may hinder the cognitive process to understand the problem (Barron, 2003; Sinha, Rogat, Adams-Wiggins, & Hmelo-Silver, 2015). This may be due to the fact that CPS involves both social and cognitive processes, meaning that students have to not only communicate, negotiate and exchange perspectives to understand a problem, but also regulate their actions to solve it (Hesse, Care, Buder, Sassenberg, & Griffin, 2015). As a result, the groups who failed to solve the problem often demonstrated less reflective discourses, such as planning and monitoring of the problem solving moves (Tan, Caleon, Jonathan, & Koh, 2014).

The recent development of Web techniques such as HTML5 has largely extended the capability of individual-based simulations to overcome the above limitations in supporting CPS. Numerous collaborative simulations have been implemented to support CPS activities (Care & Griffin, 2014; Chang et al., in press; de la Torre, Heradio, & Dormido, 2013; Jara, Candelas, Torres, Dormido, & Esquembre, 2012). The collaborative simulations of these studies have extended the capability of individual-based simulations to allow multiple students to participate in CPS activities in a shared simulation session (Jara et al., 2012). Compared with individual-based simulations, students' actions in a collaborative simulation will simultaneously influence the shared problem state, and can thus support a dual interaction space. Furthermore, the simulation can also regulate asymmetric accountabilities in a CPS activity, where students are given with different capacities in the simulation. Such a design may enhance group collaboration since only when all the members closely coordinate to manipulate the simulation can they solve the problem. Such simulations integrated with text chatrooms can support both social and cognitive processes, helping students to communicate and understand the meaning of problem solving activities in a shared simulation session (Care & Griffin, 2014; Care, Griffin, Scoular, Awwal, & Zoanetti, 2015; Lin, Duh, Li, Wang, & Tsai, 2013; Wang, Duh, Li, Lin, & Tsai, 2014).

The collaborative simulations bring new affordances and challenges for students to participate in the CPS. Recent literature on collaborative simulations suggested that students could obtain better learning performance and complete more tasks in such collaborative simulations (de la Torre et al., 2013). However, such simulations significantly increase the complexity of CPS since students need to discuss to explore the scientific concepts embedded in the problem and closely coordinate with each other to achieve a consensus problem solving strategy. How students organize the cognitive and social processes to solve a problem using collaborative simulations, and the challenges they may encounter during CPS are still unclear. Recent studies began to assess students' CPS skills by analyzing students discourse (Care & Griffin, 2014; Care et al., 2015) or multiple-choice test (Lin et al., 2015) when they interacted with a computer agent. How students' discussion and problem solving moves in the collaborative simulation may interplay with each other is still not clear.

Researchers have asserted that careful analysis of students' work in a dual interaction space, that is discussion and workspace, is necessary to reveal how the group coordinates its work and how that work is driven by the reactions of the group members' actions (çakır et al., 2009). In such a dual interaction space, students' problem solving activities and group discussion influence each other and intertwine, meaning that CPS in such an environment is a dynamic and unstructured process. Therefore, an analysis of CPS activities in the text chatrooms and the collaborative simulations is necessary to understand the interplay between students' discussion and their problem solving progress to identify the potential challenges that they face in CPS activities.