Assessing Collaborative Problem Solving through Computer Agent Technologies

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INTRODUCTION

Today, proficiency in collaborative problem solving (CPS) is requisite for success in both college and workplace, as well as the ability to perform that collaboration in various group compositions and environments. At the same time, structuring computer-based CPS assessment, specifically for large-scale programs, is challenging. In a standardized assessment situation, a student should be matched with various types of group members that will represent different CPS skills and contexts. In addition, the discourse between the group members should be manageable and predictable. The three major questions thus are: How can activities in which collaborative skills of an individual are measured be standardized? Can partners for CPS be simulated but still maintain authentic human collaboration? And, how can manageable and predictable group discourse spaces be created within the assessments? This article addresses these challenges by introducing a new methodology for scalable human-to-human (H-H) and human-to-agent (H-A) computer-based assessment of CPS, and discussing findings from an empirical pilot study conducted in three counties. Directions for future research are discussed in terms of their implications for large-scale computer-based assessment programs, teaching, and learning.

BACKGROUND

CPS is one of the two major areas that the Organisation for Economic Co-operation and Development (OECD) nominated in 2015 for major development in Programme for International Student Assessment (PISA) in addition to scientific literacy, math and reading literacy. In PISA 2015, CPS competency is defined as “the capacity of an individual to effectively engage in a 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). An agent could be considered either a human agent or a computer agent that interacts with the student. The competency is assessed by evaluating how well the individual collaborates with agents during the problem-solving process. This includes establishing and maintaining shared understanding, taking appropriate actions to solve the problem, and establishing and maintaining group organization.

An operational definition of CPS in this article refers to “the capacity of an individual to effectively engage in a group process whereby two or more agents attempt to solve a problem by sharing knowledge and understanding, organizing the group work and monitoring the progress, taking actions to solve the problem, and providing constructive feedback to group members.” First, CPS requires students to be able to establish, monitor, and maintain the shared understanding throughout the problem-solving process by responding to requests for information, sending important information to agents about tasks completed, establishing or negotiating shared meanings, verifying what each other knows, and taking actions to repair insufficiencies in shared knowledge. Shared understanding can be observed as an effect, if the goal is that a group builds the common ground necessary to perform well together, or as a process by which peers perform conceptual change (Dillenbourg, 1999). An “optimal collaborative effort” is required of all of the participants in order to achieve adequate performance in a collaborative environment (Dillenbourg & Traum, 2006). Second, collaboration requires the capability to identify the type of activities that are needed to solve the problem and to follow the stages to achieve a solution. This process involves exploring and interacting with the problem situation. It includes understanding both the information originally

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presented in the problem and any information that is exposed during interactions with the problem. The accumulated information is selected, organized, and integrated in a way that is relevant and helpful to solving the particular problem and that is integrated with prior knowledge. Setting sub-goals, developing a plan to reach the goal state, and executing the plan that was created are also a part of this process. Overcoming the barriers of reaching the problem solution may involve not only cognition, but motivational and affective means (Funke, 2010; Mayer & Wittrock, 2006). Third, students must be able to help organize the group to solve the problem; consider the abilities and resources of group members; understand their own role and the roles of the other agents; follow the rules of engagement for their role; monitor the group organization; reflect on the success of the group organization, and help handle communication breakdowns, conflicts, and obstacles (Rosen & Rimor, 2012).

STUDYING HUMAN-TO-AGENT AND HUMAN-TO-HUMAN COMPARABILITY

CPS assessment must take into account the types of technology, tasks and assessment contexts in which it will be applied. The assessment will need to consider the kinds of constructs that can be reliably measured and also provide valid inferences about the collaborative skills being measured. Technology offers opportunities for assessment in domains and contexts where assessment would otherwise not be possible or would not be scalable. One of the important enhancements brought by technology to educational assessment is the capability to embed computer-based responses and behaviors into the instrument, enabling it to change its state in response to student's operations. These can be designed in such a way that the student will be exposed to an expected situation and set of interactions, while the student's interactions as well as the explicit responses are captured and scored automatically. The use of computer agents as simulated partners in collaboration is considered as the major challenge in designing scalable assessment of CPS skills (Graesser et al., in press). An analysis of the list of challenges facing CPS in large-scale assessment programs suggests that both H-A and H-H approaches in CPS assessment should be further explored, with major focus on better understanding of possible similarities and differences between these two approaches.

Assessing Collaborative Problem Solving

Students' performance in CPS can be assessed through a number of different methods. These include measures of the quality of the solutions and the objects generated during the collaboration (Avouris, Dimitracopoulou & Komis, 2003); analyses of log files, intermediate results, paths to the solutions, team processes and structure of interactions (O'Neil, Chung, & Brown, 1997); and quality and type of collaborative communication (Foltz & Martin, 2008; Graesser, Jeon, & Dufty, 2008). To ensure valid measurement on the individual level, each student should be paired with the same number of other partners displaying the same range of CPS characteristics. This way each individual student will be situated fairly similarly to be able to show his or her proficiency in CPS. Additionally, students should act in different roles (e.g., team leader) and be able to work collaboratively in various types of environments. Thus, in a standardized assessment situation, a student should be matched with various types of group members that will represent different collaboration and problem-solving skills, while controlling for other factors that may influence student performance (e.g., asymmetry of roles).

Computer Agent Technology in Collaborative Problem Solving Tasks

Collaboration can take many forms, ranging from two individuals to large teams with predefined roles. Thus, there are a number of dimensions that can affect the type of collaboration and the processes used in problem solving. For example, there can be different-sized teams (two equal team members vs. three or more team members working together), different types of social hierarchies within the collaboration (all team members equal vs. team members with different levels of authority), and, for assessment purposes, different agents – whether all team members are human or some are computer agents. Research shows that computer agents can be successfully used for tutoring, collaborative learning, co-construction of knowledge, and CPS (e.g., Graesser,

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