Collaborative Learning through Socially Shared Regulation Supported by a Robotic Agent

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Abstract: We designed a learning environment supported by a robotic agent to facilitate learners' socially shared regulation of learning (SSRL). In collaborative reading comprehension, we designed *adaptive scaffolding* scripts by the robot and its physical embodiment for helping learners' planning, monitoring, and behavioral engagement. The cognitive and conversation analyses show that the use of note-taking strategies, engagement in collaborative argumentation, and transfer of understanding were improved by the support of the robot as a *metacognitive mediator*.

Background and Research Purpose

SSRL is a regulatory process model of collaborative learning based on preceding ideas of self-regulated learning (SRL) and co-regulated learning. In Hadwin, Jäevelä, & Miller (2011), SSRL is defined as "interdependent or collectively shared regulatory processes, beliefs, and knowledge orchestrated in the service of a co-constructed or shared outcome/product" (p. 69). In SSRL, learners are collaboratively involved in planning, monitoring, evaluating, and regulating the socioemotional, cognitive, and behavioral aspects of their learning. In this study, based on the preceding research on CBLE agents (e.g., Azevedo (Ed.), 2007), we attempted to create a socially assistive robot as an agent that provides learners with *adaptive scaffoldings* of SSRL. We consider the advantage of a robotic agent over a human to be its participatory stance in collaborative learning. Learners at any age usually recognize instructors or teaching assistants as authority figures who know everything in their class. On the contrary, a robot may be accepted as an assistant or partner by learners because robots are ordinarily not considered as intelligent as learners. Learners expect that the robot will provide information that they can exploit. Therefore, learners may maintain their intentionality in regulating collaboration. In addition, robots may have an advantage of over intelligent PC-based agents. With its physical embodiment, a robot can express its engagement in learners' collaborative learning through verbal and nonverbal channels (Breazeal, 2002).

Study Description

Thirteen students including one graduate from the same departments participated in collaborative reading comprehension, an activity structure based on the Jigsaw method that enables learners to engage deeply in collaborative knowledge construction through understanding multiple document-based resources (Oshima & Oshima, 2011). Students were first divided into four *expert* groups. In each *expert* group, three students collaboratively read and constructed their understanding of a particular article that they would explain to other students who were divided into *jigsaw* groups. Through collaboration, each student produced a summary using a Microsoft Word template provided as a handout for the explanation intended for the *jigsaw* group students. Three *jigsaw* groups were then formed, each consisting of one student from each *expert* group and one robot. Students in the *jigsaw* groups worked to integrate ideas from five different articles explained by the students and robot. The robot was in charge of explaining article #3. After discussing the five articles, the students reported how ideas from the articles were related to each other and interpreted them with reference to the basic framework of learning environments in a computer-supported collaborative learning (CSCL) system. One *jigsaw* group consisted of five students, rather than four, and two students were collaboratively assigned the same article.

Adaptive Scaffolding Scripts by Robots

Based on recent studies of SSRL (e.g., Hadwin et al., 2011), we developed three types of scripts: planning, monitoring, and behavioral engagement. For planning, robot said to the learners: "I am now going to explain line (number) on page (number) to line (number) on page (number). So, please take a look at the section before I start." After completing a section of the explanation script, robot asked learners if they had questions and if there was any part that they wanted to listen to again. Then robot said: "Please tell me which part you want to discuss later. I will remember your answer and tell you [Operators took notes of learners' answers.]." After providing its explanation, robot said parts of the content that the learners had raised and encouraged them to examine their understanding by considering their relation to the concept of the learning environment. For monitoring, robot asked learners to articulate their explanations (e.g., "Can you explain that part again?" and "Well, I could not understand what you said."), to monitor their understanding (e.g., "I wonder what others think of it.") and to integrate their understanding or ideas discussed in their discourse with the concept of learning environment (e.g., "How is your idea related to others?" and "How can you explain your idea in relation to the framework of the learning environment?"). For behavioral engagement, robot encouraged specific learner's engagement in the discourse when the operators identified the learner's inactivity (e.g., "So, what do you think, (learner's name)?"). Robot's physical movement was designed for supporting its *adaptive scaffolding* scripts function. It moved its head to slowly look at everybody while it was explaining the article. Its hands moved like a human was actively talking. In addition, we prepared buttons for moving its head toward specific learners to request their utterance. For instance, when Robot asked a specific learner to engage in discourse, the corresponding script was spoken with the robot gesturing toward the learner.

Results and Discussion

First, we found that our *adaptive scaffolding* scripts for planning facilitated learners' use of note-taking strategies. They used strategies significantly more in robot explanation than in human explanation. The developed scripts provided metadiscourse for reading comprehension, and we found that learners normally did not use this type of discourse in collaborative learning.

Second, in our analysis of collaborative argumentation, our *adaptive scaffolding* scripts facilitated learners' engagement in constructing reasoning. The proportion of learners who contributed to reasoning components in argumentation was increased in the context of human explanations. The further conversation analysis suggests that *adaptive scaffolding* scripts for monitoring and behavioral engagement functioned effectively in human–human interaction, rather than in human–robot interaction. An important role of a robotic agent in such an interaction is as a *metacognitive mediator* that prompts learners' engagement through monitoring their collaborative construction of argumentation and subsequent active behavioral engagement.

Differences in the effectiveness between the contexts of learner and robot explanations might be worth examining in further research. One possible interpretation of the results is the trade-off between the roles of the robotic agent as a *metacognitive tutor* and a *metacognitive mediator*. In the context of robot explanation, learners might recognize the robot as a *metacognitive tutor* in the human–robot interaction. Therefore, robot instructions, such as planning scripts for reading comprehension, functioned quite effectively. However, scripts for monitoring and behavioral engagement might not work well to facilitate learners' SSRL, leading to collaborative construction of argumentation because the robotic agent should have known more about the target article than the other learners. Shirouzu, Miyake and Masukawa (2002), who discussed constructive interaction, stated that collaboration is productive when different persons have different roles, such as task doer versus monitor in problem solving, and when the roles are periodically interchanged. From this perspective, the context of robot explanation in the *jigsaw* group might not have been a productive situation where humans and the robotic agent could have interchanged different roles.

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