Paper Title Collaborative Reading With a Social Robot Helps Promote Interest and Discussion (Poster 20)

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Abstract
Social interactions, like discussion of science content, support motivation and learning in that content, but can be challenging to facilitate in large classrooms. In this study, we explore the feasibility of a social robot to support interest and improve discussion in a group reading activity. To do so, we conducted a field study in three middle-school science classrooms, where groups of 6th grade students (N = 16) read a short article assigned by their teacher. **We found that groups that read with a social robot had higher situational interest scores, more often discussed answers together, and included more ideas from outside the text** when compared to groups of students completing the same activity as a traditional paper-based lesson.

Objective and Background

Socially rich learning experiences, such as discussion of science content, can support motivation and learning in that content (NAS, 2018). Interested learners experience deeper cognitive processing and persist longer through challenging activities (Renninger & Hidi, 2015). Additionally, engaging in social behaviors while learning, such as discussion, promotes deeper learning through processes such as externalizing one's own ideas or internalizing the ideas of others (Cress & Kimmerle, 2018). However, facilitating interest and discussion in classrooms can be challenging for teachers, particularly as US classroom sizes continue to increase.

A social robot may be an effective tool to provide meaningful social interactions that promote student discussion and interest (Okita, 2019). These robots can provide socially meaningful ways of presenting materials, such as asking students their thoughts about discussion questions that could impact the way students approach their learning. In this work**, our goal is to explore the feasibility of a social robot to improve student situational interest in a group reading activity and improve the amount of discussion that students engage in**, when compared to a traditional paper-based group discussion activity.

Researchers studying interest development describe *situational interest* as momentary psychological states that are triggered (*catch*) and maintained (*hold*; Hidi & Harackiewicz, 2000). Triggering situational interest leads to increased engagement and positive feelings in the moment. Maintaining situational interest over time is thought to lead to the development of individual interest, a pre-disposition to re-engage with content (Renninger & Hidi, 2019). There is a strong social element to developing interest (Bergin, 2016), where children benefit from social interactions with others who are supportive, and who demonstrate friendliness and enthusiasm, because these interactions promote feelings of relatedness (Linnenbrink-Garcia et. al, 2013).

Social interactions during learning are also thought to benefit deeper learning, where engaging with others forces individuals to activate their knowledge in ways that can be understood by others, as well as to interpret the ideas of others. Work in Computer Supported Collaborative Learning has long sought to build theory and design approaches to leveraging the relationship between these social processes, technologies to support them and learning (Cress et al. 2021). One major theme across this work is that learning through social activity benefits comprehension, knowledge construction, and synthesizing new ideas that are thought to emerge from internalizing and externalizing ideas across group members during social interaction (Clark, 2017).

Human-robot interaction (HRI) research has found that robots elicit a strong social response in people (Fink, 2012). This *social presence* of the robot can benefit cognitive and affective outcomes while learning (Belpaeme et. al, 2018). Socially adept robot behaviors including eye contact and well-timed gaze-aversion patterns can foster a sense of social presence (Andrist et. al 2014). In learning interactions, the simple social presence of a robot has been found to promote the generation of ideas (Geerts, 2021), regulate learner communication behaviors (Gonnot et al., 2019), and ease anxiety (Brown & Howard, 2014). In this study, we explore the research question: **How does engaging in a group science reading activity using typical paper-based methods compare to reading with a social robot?**

Method and Data Sources

To answer this exploratory question, we conducted a field study in three middle-school science classrooms, where 6th grade students (N = 16, 9 male, 7 female) read a short article (See Figure) on viruses or decomposition, assigned by their teacher, in groups of 2 or 3. Students were randomly assigned by classroom to work together to answer discussion questions either with questions printed on a separate sheet of paper (*control condition)*, as typically done in this classroom, or read verbally to the students by a social robot (*robot condition*). Participants in each condition had no significant differences in existing individual interest in science or self-efficacy for reading ability (See Table 1). In the control condition, two students were absent and one did not complete all study activities, so were removed from analysis. In all, we include 5 control condition students, in two groups in one class, and 8 robot condition students in four groups across two different classes.

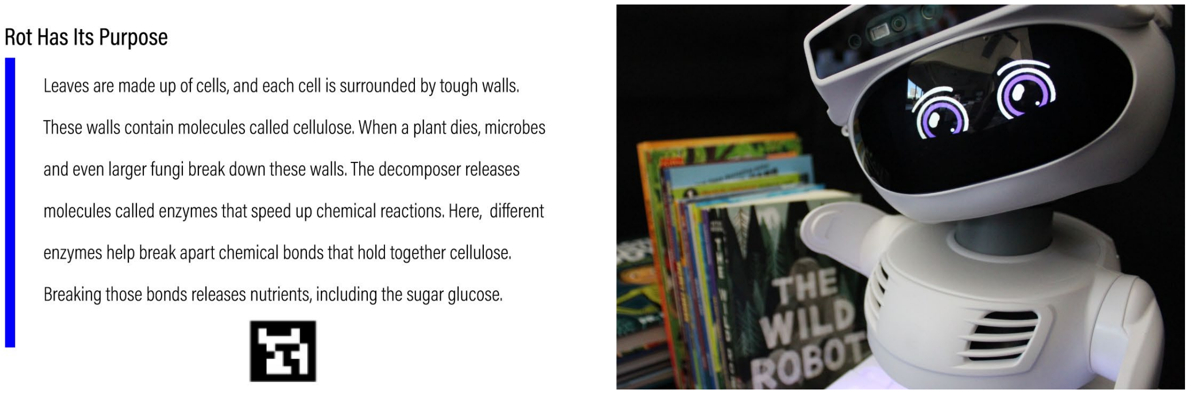

Figure 1. Sample from science article with April Tag at bottom (*left*) and the social robot used in this study developed in prior work to read with students and children (*right*).

In the **robot condition**, students read with a social robot developed in prior work (Authors, 2022; See Figure 1). Students read one of two articles, printed on paper, and scan special tags placed on each page (See Figure 1). The robot responds to each tag with preprogrammed *questions*, written by the teacher, about material on that page. Questions asked students to summarize ideas or make connections to other concepts. During this interaction, the robot presents the questions conversationally, makes small movements and facial expressions, and occasionally encourages students to discuss their answers. See Authors (2019; 2022) for more details on the robotic system. In the **control condition**, students read the same articles and questions, but the questions were presented on a separate printed page. In both conditions, students had 40 minutes to complete the activity and were instructed by the teacher to "discuss the questions, and plan to present their answers to the class."

We **audio recorded each session** using a tabletop microphone. Audio was transcribed by an automated transcription service and edited for accuracy by the research team. We analyzed the audio data using a **Reflexive Thematic Analysis** approach (Braun et al., 2022), where the first author reviewed interactions, conducted an initial round of open semantic coding, followed by additional rounds of abstract latent coding. These codes were developed and revised into a candidate theme through discussion with the authors and finalized through consensus. As emergent themes were the outcome, we did not conduct inter-rater reliability as recommended by Braun et al. (2022).

Prior to the activity, we measured baseline attitudes using previously validated scales for student interest in science (10 items; Authors, 2017) and the Reading Self-Efficacy Questionnaire (16 items; Koşar, 2022). After the reading sessions, students completed a 12-item survey about their **situational interes**t during the activity. The situational interest survey has two factors, catch and hold situational interest, based on a validated and reliable measure (Knogler et. al, 2015) with items on a scale of 1 (*strongly disagree*) to 7 (*strongly agree*). Mean scores were calculated for each measure and all were found reliable with $\alpha > 0.70$ (Crocker & Algina, 2009).

Results and Discussion

Due to the small sample size and uneven distribution across conditions, we chose to compare measures using a nonparametric Mann-Whitney U test ($\alpha = 0.05$; Mann & Whitney, 1947). We also calculated effect sizes using Cohen's d with conventional effect sizes of small ($d > 0.20$), medium ($d > 0.40$), and large ($d > 0.80$; Cohen, 1988). For catch situational interest, we found a large effect and a significant difference in scores, where the robot group ($M = 5.76$, $SD = 1.37$) was higher than the control group ($M = 3.5$, $SD = 0.83$; $W = 3.5$, $p = 0.03$, $d = 1.81$). For hold situational interest, there was also a large effect size and marginally significant difference between groups, where the treatment group ($M = 5.83$, $SD = 0.98$) was higher than the control group ($M = 4.21$, $SD = 1.04$, $W = 5.5$, $p = 0.06$, $d = 1.63$; See Figure 2).

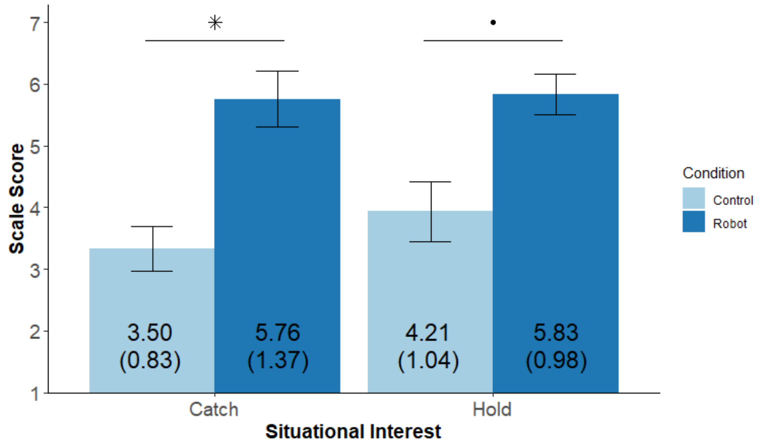

Figure 2. Bar graphs with means, standard deviation (in parenthesis) and standard errors (whiskers) comparing catch and hold situational interest scores for control and robot conditions.
* denotes significance at α = 0.05; • denotes significance at 0.10.

Table 1. Comparison of Pre-measures of interest in science and self-efficacy for reading and Outcome measurement of catch and hold situational interest. All scales range from 1 – 7.

		Condition	*Mean*	*sd*	*Wilcox (W)*	*p*	*d*
Pre-Measures	Interest in Science	Control	4.80	0.37	15.5	0.76	0.32
		Robot	5.13	1.22			
	Self-efficacy in Reading	Control	3.52	0.36	13	0.48	0.51
		Robot	3.79	0.57			
Situational Interest	Catch	Control	3.50	0.83	3.5	0.03*	1.81
		Robot	5.76	1.37			
	Hold	Control	4.21	1.04	5.5	0.06•	1.63
		Robot	5.83	0.98			

Note. Statistical significance is indicated with *0.05 and • 0.10

Our main qualitative theme was that *students in the robot condition engaged in higher levels of discussion while answering questions.* We found that students who read with the robot often worked together and responded to each other's answers, offered answers in their own words, and brought up ideas outside of the text. For example, R2 answered the question, "Where in our body do we find the most bacteria?" by saying, "In your gut." R1 added that "It's either guts or all organs," before the group concluded that 'gut' was the best answer. We found this phenomenon to be common, with some exchange of ideas occurring in every group. We also observed that students formulated answers from their own recollection or interpretation of the text, rather than searching back through the article. For example, R1's first response to the question of where viruses can be found in the text, "doorknobs," but rather than finding the exact passage in the text, R1 expanded on their answer to say, "but I'm sure we can find [viruses] anywhere." We also found students seemed to build on each other's ideas from outside the text. R3 and R4 provide an example in the exchange below:

Robot: What is rot?
R3 Oh, rot
R4: decomposition.
R5: Rot is like when something
R4: breaks down.
R5: Yeah. Like starts to break down a lot.
R4: Like if I left this pencil here and then 20 years later it would just be pile of mulch.
R5: Not really mulch. 'cause mulch.
R4: Well, mulch, like broken down wood.
R5: Yeah. And the wood would probably just be eaten by the greens, but it would just be green or green space.
R4: But I do think too… okay, so it would just be like broken down.

In contrast students in the control condition divided the questions, answered independently, and sought answers directly from the text. In these groups when a student found an answer, they typically indicated where they found it, as in C2 saying, “this paragraph it says,” or C4 saying “they said it at the end of the text.” Students would split responsibility for answering questions, as when C4 told C5, “you [get] question number two,” or negotiate who is responsible for different parts, as C5 told C4, “wait, but you're doing this [question] and then I have to do this [question] for you.” Students typically read answers directly from the text as they wrote down their answer. We found only one instance of students discussing answers together. More often discourse involved helping each other find where in the text the answers were. For example, while C5 is looking for an answer, they say, “I'm finding most of it like right here,” but C4 says C5 needs to, “read to the end,” to find the answer. Overall, the control groups seem to engage in a *divide-and-concur* approach to the activity, where students spread out responsibility for answering questions and concur with each other about their answers. Based on field notes from the study, both groups were seen passing the question sheet around the group to add separate answers – further supporting the divided approach to the activity.

Conclusion and Significance

Our goal was to examine differences during a group reading activity between typical paper-based methods and with a social robot. **We found that groups that read with a robot had higher situational interest scores, more often discussed answers together, and included more ideas from outside the text.**

The significance of these findings is that they provide evidence that the social presence from a robot contributes to situational interest in a reading activity and may better facilitate discussion and depth of answers than students completing the activity in a more standard paper-based approach. Of particular importance, is that both catch and hold situational interest was higher while working with the robot, as repeated activation of situational interest, especially hold situational interest, is believed to lead to long-term individual interest (Hidi & Renninger, 2015). This is in line with interest development theory that emphasizes the importance of social interactions for interest (Bergin, 2016). Furthermore, the effect of enhancing student discussion may indicate a social robot can support socially situated learning behaviors that learning theory suggests is associated with deeper learning. Our prior results (Authors, 2018, 2022) suggest engagement with a similar robot can be maintained over the course of two weeks, so this outcome may be sustainable, but needs further study.

This work makes a theoretical contribution to HRI, learning, and interest research by demonstrating the impact and utility of social robot interactions for interest development and supporting collaborative learning processes. We also make a practical contribution to the education community by providing a model for designing social robots to be integrated into existing science curriculum, especially in the role of supporting group discussion.

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