User Evaluation of Social Robots as a Tool in One-to-One Instructional Settings for Students with Learning Disabilities

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Abstract. Learning is more challenging for students with learning disabilities. They often require supplementary learning support such as one-to-one instruction to address academic skill gaps. In this research, we explore the impact of using assistive technology- a social robot, as an educational tool for instructors to support students with learning disabilities. The purpose of the study was to a) to evaluate the acceptance of the social robot by the users, i.e., instructors and students in a real-world educational setting; b) understand the impact of the robot's intervention on student's engagement during learning tasks over multiple learning sessions. We conducted a multi-session between-subjects study with 16 students within two conditions, control and intervention condition with the QT robot. Our qualitative analysis suggests that instructors and students showed positive attitudes towards the social robot in their one-to-one sessions. In addition, the students were more engaged with their task in the presence of the robot, and displayed fewer off-task behaviours in the intervention condition, compared to the control condition. These results suggest that a social robot can be used as an effective educational tool for instructors in boosting engagement and mitigating off-task behaviours for students with learning disabilities.

Keywords: Learning disabilities · Socially assistive robots · Assistive technology · Robot-mediated instruction

1 Introduction

Learning disabilities (LD) is a heterogeneous life-long condition that includes a range of disorders that may affect the acquisition, retention or understanding of verbal or non-verbal information. Students with learning disabilities struggle with specific academic skills such as reading, writing or math, but otherwise demonstrate normal intellectual functioning [5,13]. Students with LD require

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personalized instruction that consider their learning differences and targets their unique challenges [17]. Students with LD frequently struggle to stay focused on a task, and exhibit off-task behaviours such as work refusal, fidgeting, and off-topic conversations. Redirection strategies aid in mitigating off-task behaviours and help students stay on-task and make sustained academic progress[3]. Examples of these strategies include movement breaks, positive self-talk, and breathing exercises. [22].

In recent years, educators have explored the use of social robots to support learning for students with or without disabilities [15,21]. However, most of the research in the therapeutic context is focused on children with Autism Spectrum Disorder (ASD) [15]. Despite the pervasive use of assistive technology (AT) tools in educational settings, such as smartphones and tablet-based applications for students with LD [14], socially assistive robots (SAR) have not been explored for these students, especially in long-term interventions in real-world settings. Additionally, despite the possible advantages of AT, educators are infrequently trained or supported in using AT, yet are expected to become experts in their usage [1]. In this study, we developed an instructional protocol for the use of a social robot during one-to-one instruction for students with LD. The protocol can be used for students with a range of learning difficulties and can be employed into individualised student learning interventions without any alteration of their program.

The current work is an extension of an in-situ pilot study, conducted in May 2021 during the COVID-19 pandemic. The aim of the study was to explore the integration of a social robot as an assistive tool for instructors, providing redirection strategies in a one-to-one instruction setting with children with LD [2] This pilot study on robot-mediated instruction (RMI) was done in two phases, instruction as usual, and robot mediated instructions, both following the same procedure, except that in the robot-mediated sessions, the robot delivered the redirection strategies. The robot was operated by the instructor using an application interface, and employed via the study's instructional protocol. The results of the pilot study indicated that the intervention supported students in staying on-task, however there were limitations related to study design, such as technological complexity of the instructional protocol, and the absence of a control group.

Building from this work, the current study had an expanded scope that aimed to investigate how students with LD are impacted by a social robot as an instructional tool, and assessed the acceptance of the robot in one-to-one lessons as part of an in-situ study. Different from the pilot study, students were assigned to either a control or intervention condition.

The study poses the following research questions: RQ1: What is the level of technology acceptance the robot achieves with both students and instructors; RQ2: How does the use of a robot influence the engagement and off-task behaviours over the multiple sessions?

2 Background

With advances in technology, assistive tools have provided further learning opportunities for students with LD [4]. One-on-One interventions can benefit students with LD by targeting their needs in the delivery of instructions [23]. Socially assistive robotics (SAR) is a field that targets helping caregivers, clinicians, and educators with personalized interventions using robot [7]. SAR focuses on using a social robot to aid humans in the areas such as education and healthcare [6,20] mainly through social interaction, without any physical human-robot contact. SAR has been widely used in the treatment of children with ASD, e.g. for teaching social, emotional, and cognitive skills in a play-based scenario. For example, [27] conducted a study with the Nao robot teaching social rules through games to both typically developing children and children with ASD. Little research has been done using SAR for people with LD, specifically, in the context of academic instruction [15]. The few studies in this area include[18] who explored a model estimating the engagement of children with LD interacting with a robot and [16] who investigated the use of a social robot to improve visual motor skills in children with LD. A more recent study, [15] was conducted to assist children with LD in their reading tasks through human-robot interaction. Research has shown that social robots can be effective for students with disabilities, albeit limited research has been done on the instructors' attitude toward using robots in special education [10]. Thus, there is still a great need for more research on the acceptance of social robots from both the student and educator perspective. Technology acceptance, in particular in in-situ/field studies, are important steps towards illuminating how social robots could be used in a real-world applications for children with disabilities, cf. [19].

SAR can offer more engaging learning experiences and provide personalized support to help students' engagement [15]. Investigation of the technological acceptance of SAR is crucial, specifically, when it is used in real-world settings.

This study investigates student engagement in the presence of a social robot, exploring perceptions of instructors and students during robot-mediated sessions. The contributions of this study are as follows: 1) the integration of a social robot into an already existing program without changing the learning goals or curriculum[1]; 2) user evaluation using the technology acceptance model for the application of SAR in a real-world educational setting as part of a long-term study; 3) development of the robotic system to accommodate a range of scenarios and situations that instructors and students with LD may face in a typical session.

3 Study Method

The study was conducted at the premises of the Learning Disabilities Society (LDS), located in Vancouver, Canada. LDS provides one-to-one instruction for

[1] The existing program develops students' independence, confidence, and academic achievements through one-to-one instructions with certified instructors.

students with LD. During the intervention condition, the robot was placed on a table roughly 65 cm away from the student and instructor during their sessions (shown in Fig. 1. This study was approved by the Community Research Ethics Office[2] and the University of Waterloo Human Research Ethics Board (approval #43223).

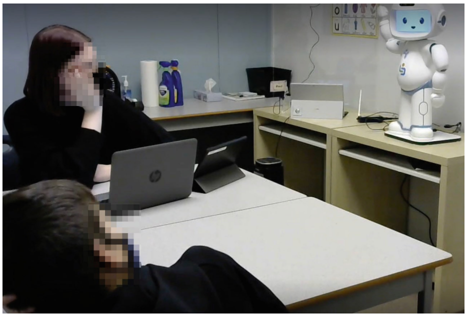

Fig. 1. Study setting, showing the child with LD and the instructor on the left and the robot on the right.

Participants: Sixteen students between 7 and 12-years old (mean = 9.6, std = 1.25) with a suspected or diagnosed LD participated in the study. Five certified instructors (holding either a bachelors, master's degree or a teaching certificate) participated in this study (mean = 27.4, std = 1.74). Participants were existing LDS students who received one-to-one instruction with the participating instructor. The students struggled with reading tasks and it was hoped that they could benefit from an assistive robot. The students were randomly assigned to one of the two conditions. Eight students participated in the *control condition*, where seven students had five sessions, and one student had six sessions. Eight students were assigned to the *intervention condition* (robot-mediated instruction); two of those students had six sessions, and five had seven sessions. One student was withdrawn after the first session in the intervention condition, since they were uncomfortable having the robot in their lesson. The variance in the number of sessions by the students was due to missed sessions. While some students attended LDS twice a week and could make up missed sessions, some students were unable to do so as they only attended once a week. All instructors participated in both conditions, and none had used social robots previously. Three instructors had two students participating in the study, and two instructors had one student participating.

[2] The Community Research Ethics Office is located in Ontario, Canada, whose mandate is to strengthen and support community based research in Canada and internationally, http://www.communityresearchethics.com.

Material: We used the QT robot[3], a small humanoid, specifically designed for children with ASD. It can perform gestures using its head and hands, accompanied by speech and facial expressions, and seems very suitable to use with children with LD. To interact with the robot, we developed a web application interface for instructors to operate the robot during the intervention sessions. The app consisted of the protocol instructors followed during session, displayed as buttons. Examples of elements of the protocol are warm-up activities, games, and breathing exercises. The application was loaded onto a tablet, which the instructor used to control the robot to lead an activity or play a game with the student (as a part of the session).

In addition, we developed a reflection worksheet for instructors and students to reflect on the academic goal of the session, including its difficulty level, and to state if the goal was reached during the session or not. Instructors also reported students off-task behaviours, engagement and the redirection strategies used on the worksheet. Additionally, students were asked to take part in a paper-based visual survey about their experience with the robot three times during the study, to gauge whether and how their opinions of the QT robot changed over the duration of the intervention period. This survey included questions regarding the robot's friendliness, intelligence, and the student's enjoyment. In order to evaluate the instructors' acceptance of the robot in their lessons, we created an online survey, on Qualtrics using the Technology Acceptance Model (TAM) [9,12,24,25] consisting of the following categories: a) Perceived usefulness; b) Ease of use; c) Intention to use the robot (their willingness toward using it); d) Attitude toward using the robot (if they see any value in using it), e) Enjoyment, and f) Process of using the robot, on a 5 point Likert scale. In addition, we asked questions to rate instructors' interest in 'Affinity for Technology Interaction' (ATI) [11] on a 6-point Likert scale. Note, the TAM model was chosen since, while not as complex as other user acceptance models that are reported in the literature (e.g. UTAUT, [8]), was deemed most suitable for this in-situ study in order to answer our research questions without putting too much effort onto our participants. TAM has also been used successfully in a recently published in-situ study with children with ASD [19].

Procedure: This study was conducted after the pilot study, mentioned above, in which we investigated how the QT robot can influence the off-task behaviours of students with learning disabilities while working on a task. In this follow-up study, using a between-participant design involving a control and an intervention condition, we focused on designing a more structured session based on the lessons learned from the pilot study. Besides, we were interested in instructor's perception toward using the robot, in addition to students perception, and performance of the students in the lessons.

Students were randomly assigned to one of the two conditions. In order to provide an opportunity to interact with the robot to all the students, the control group later participated in the intervention condition after this study. In the intervention condition, the student only interacted with the instructor during a

[3] https://luxai.com/.

one-to-one instructional session, and in the intervention condition, the student interacted with the instructor and the QT Robot. During the intervention condition, the QT robot (controlled by the instructor) took over the instructor role and led the student through the session introduction and goal setting process and provided self-regulation strategies if necessary. Students took part in the study once a week as part of their regular sessions with their instructor. Some students had more lessons in a week at LDS, but all participated weekly in our study. The instructor and the student worked on a reading task that was challenging but achievable for the student. Both conditions employed the following phases:

1- Introduction Phase
Control Condition: The instructor introduced the session, and completed a warm-up activity with the student. Next, the student and instructor set a goal for the session and the student reflected on their mood and energy level on the reflection worksheet.
Intervention Condition: The phase began with the QT robot introducing itself, and introducing the session. Then, the robot and the student did a warm-up activity together and the robot asked the student to set a goal. Note, while QT performed some activities and behaviours autonomously, they were controlled by the instructor through the application. Thus ensured that the instructor was in full control of the session.
2- Working on goal
Control Condition: During the session, the instructor redirected the student back on task as needed. If the student remained off-task, the instructor used a redirection strategy (RS). If the student stayed on task, the instructor praised the student.
Intervention Condition: Intervention sessions followed the similar procedure as the control condition, except that QT delivered the RS or praise.
3- Goodbye
Control Condition: At the end of the session, the student reflected on their goal. Sessions finished with a game, regardless of goal completion. Once the session was completed, the instructor answered a few questions about how the session went and the student's engagement
Intervention Condition: Intervention sessions followed the similar procedure as the control condition, except that QT delivered and played a game with the student.

Students also responded to questions regarding their interaction with the QT robot three times during the study. The three *data collection points* occurred after the first, fourth, and last session. Instructors completed a technology acceptance questionnaire twice during the study, after the first and last session.

4 Study Results

The results of this study are presented in order of the research questions. First, we discuss the technology acceptance results of the users. Next, we present results regarding the impact of a robot as a tool on students' engagement level and off-task behaviours by comparing the control and intervention conditions.

Table 1. Instructors' perceptions after the last session

Instructor	Experience	Benefits for instructors	Benefits for students
I1	QT is effective as a reward system and my student enjoyed the interactive portions	Helpful for getting the students to stay on track/focus and help take pressure off me to do this	Helps give them a goal to work towards and be involved in fun and engaging activities
I2	Good, I like it	More usable with younger students	Motivation in younger students
I3	QT is a fun addition to the classroom. Most students enjoy QT's presence. A distraction at times, but the more they meet it the less distracting it is	Ability to set goals with the students in a fun, interactive way. Less pressure on the student. Praise on-task behaviours or take breaks with QT	More motivated and less pressured by QT's presence. It changes student's moods positively
I4	I enjoyed using QT	The strategies led by QT are helpful. Students respond better when QT leads them than when I do	The robot's novelty made students more engaged and allowed them to enjoy the session more. My student asked lots of questions about QT it was not in our sessions. QT seemed to make them more excited
I5	Good! Helpful for maintaining engagement	Diversity in lessons, engagement, motivation tool	Diverse breaks, motivation, engagement, discussion topic

Table 2. Open-ended questions

1. *How was your experience in using the QT robot?
2. Did you perceive any benefits for yourself in using the robot as an educational tool?
3. Do you see any benefits for students in using the robot?
4. Do you have any worries and concerns in using the robot as an educational tool?
5. *Did you face any difficulties in using the robot?
6. *Did you encounter any technical problems during the session with the robot?
7. *Do you have any suggestions to improve the interaction of the robot during the session?

* *These questions were asked after the last session*

4.1 Instructors' Perceptions

Open-Ended Questions: After the first and last session, we asked open-ended questions to the instructors regarding the usage of a robot and its potential benefits to students (see Table 2). Table 1 summarizes the experience of the instructors and the benefits of using a robot for them and the students.

Only two instructors responded to questions 5, 6, and 7. Regarding difficulties, one of them did not encounter any issues in any of the sessions. However, two instructors mentioned issues with one of the games (Tic-tac-toe) in which the robot did not respond appropriately; one of them was able to address this issue by restarting the game. The other instructor mentioned that the app was sometimes slow and had to be refreshed. Related to their suggestions to improve the interaction, one of them mentioned that the students really enjoyed the gestures of the robot, however, if it had shown more gestures, the students would have been more engaged. The other instructor suggested increasing the speaking and game playing pace. The word 'goal' spoken by the robot had a strange pronunciation, which was also noticed by the students. Regarding worries and concerns, after the first session, 3 instructors had concerns related to the distraction due to the novelty effect of the robot. Additionally, sometimes the robot glitched during a game, and adjustments to the robot's program were made to reduce these issues. However, after the last interaction, only one instructor had concerns. The instructor described the concern as follows, "Sometimes the students are more concerned with QT than with the lesson. However, this has appeared to diminish over time as they become familiar with the robot."

Affinity for Technology Interaction: Instructors reflected on their willingness to interact with technical systems on a six-point Likert scale, (1: Completely disagree, 6: Completely agree). The average score for this section was 3.97 after the first and 3.7 after the last interaction, which shows medium affinity for technology interaction.The scores of the third instructor dropped after the last interaction due to some glitchy behaviours of the robot in some sessions. However, the scores of other instructors did not change significantly.

Technology Acceptance Model (TAM): Table 3 shows the result of the TAM questionnaire completed by instructors on a five-point Likert scale(1: Strongly disagree, 5: Strongly agree).

As shown in Table 3, regarding the 'Perceived usefulness' and 'Ease of use', when comparing the first and the last session, only the first instructor, gave lower scores to the robot's usefulness and ease of use while others perceived the robot to be more useful and easier to use after the last interaction. Similarly, concerning the 'Intention to use', the instructors reflected on their wish to use the robot in their current and future lessons. Except for one instructor, the others gave higher scores in using the robot. For 'Attitude toward using the robot', instructors' opinion had little change concerning the value of the robot in lessons, and the scores show general positive attitudes. Regarding enjoyment, three instructors enjoyed using the robot more after the first session compared to the last session, for the others, the scores did not change. In addition, we asked a question ‘Process of using the robot (scale 1–5 (unpleasant to pleasant))’, all the instructors provided the score 4 and there was no change in the scores between the first and the last session.

4.2 Students’ Perceptions

We asked students in the intervention condition (seven students) to reflect on their perception of the robot three times during the study with regards to the following aspects:

Enjoyment: We asked students to reflect on how much they enjoyed having the robot in class, on a 5 point scale (from “Awful” to “Fantastic”). At all three data collection points (the first, fourth, and last session), four students selected “Really good-Fantastic” and three students chose “Okay”. None of them selected “Awful” or “Not very good” anytime.

Friendliness: At all three data collection points, all seven students gave 4–5 stars (1 to 5 stars; the more stars, the friendlier) for the robot’s friendliness on a scale from 1 to 5 stars.

Intelligence: After the first session, 1 student gave “1–2”, 2 students gave “3” and 4 students gave “4” stars for the robot intelligence on a scale from 1 to 5. After the fourth session, 4 students gave “3–4” and three “4–5” stars. However, after the last session, most of the students had a very positive attitude; 6 students gave “4–5” stars, and only 1 gave “3” stars.

Robot’s Help: Students were asked if the robot helped them. After the first session, 2 students said “I don’t know”, 1 said “Maybe” and 4 said “Yes”. After the fourth session, these changed to 3 students selecting “Maybe” and 4 students “Yes”. After the last session, we got 1 “No”, 2 “maybe”’s and 4 “yes”s from the students.

Use of a Robot in the Future and How Often: Next, we asked students how often they wanted the robot in the class, in the first session, 1 student said “Never-Rarely”, and 1 “Sometimes”, and 3 “Often-Always”. After the fourth sessions, 6 students said “Sometimes”, and 1 “Often-Always”. After the last session, from those students who had not said “No” to having the robot in class, 1 student said “Sometimes” and 5 students said “Often-Always”.

Perceived Role of the Robot: Students' opinion about the role of the robot, is shown in Fig. 2. After the first session, most students perceived the robot as a Friend, the next choice was a Helper, while fewer students reported Classmate, Stranger, Teacher as the role of the robot. After the fourth session, more students tended to see the robot as the Helper and fewer students chose Friend. Interestingly, after the last session, a more equal distribution of the roles "Classmate", "Teacher", "Helper" and "None" emerged. The choice of the robot's role as a "Friend" decreased strongly during the study.

Table 3. The average score of each instructors for the different categories in the TAM questionnaire, (FI: First Interaction, LI: Last Interaction, I: Instructor ID)

I	Perceived usefulness		Ease of use		Intention to use		Attitude toward using		Enjoyment	
	FI	LI	FI	LI	FI	LI	FI	LI	FI	LI
I1	3.83	3.33	3.83	3.33	4	4.33	4	3.5	4	4
I2	3.5	4	3.5	4	4.66	4	4	4	4.6	4
I3	3.33	3.66	3.33	3.66	4.33	4.33	4.5	3.5	4.6	4.6
I4	3.5	4.17	3.5	4.16	3.33	4.33	3	3.5	5	4.4
I5	4	4.33	4	4.33	5	5	5	4.5	5	4

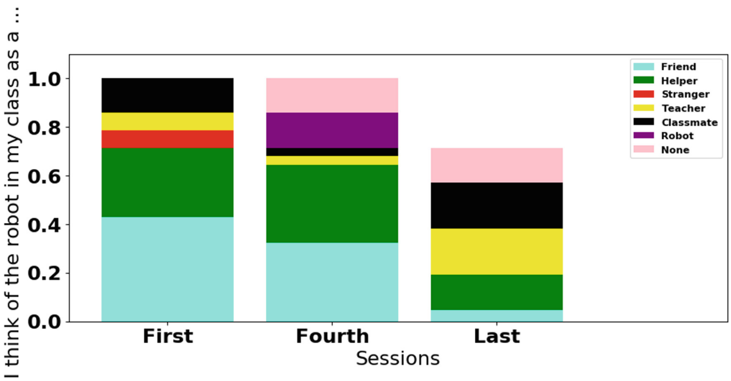

Fig. 2. The role of the robot shown at the three data collection points

4.3 Control vs. Intervention Conditions

We compared the students' reflections (completed at the beginning and at the end of every session) during the study. We measured the ratings for the sessions that the worksheets were completed (blank answers were removed from the analysis).

While we could not find any statistically significant differences between the control and intervention conditions, we observed the following tendencies:

Students were more engaged and completed their goal with a higher rate in the intervention sessions (Control: 83.8%, Intervention: 91%). Students in the intervention condition displayed fewer off-task behaviours than the control condition (Control: 51%, Intervention: 35%). The RS delivered by the robot was more successful than delivered by instructors in the control condition (Control: 86%, Intervention: 95%). Students were more engaged in the intervention condition ((Control : engaged: 50%, neutral: 29%, not engaged: 21% ; Intervention: engaged: 58%, neutral: 34%, not engaged: 7%))

5 Discussion and Conclusion

This study explored the use of a social robot in an already existing educational program, for students with LD, during one-to-one sessions with an instructor. Students were assigned to either a control or an intervention condition, and participated in multiple sessions. Conducting an in-situ study during the COVID-19 pandemic posed severe restrictions on recruitment and data collection. For example, many families preferred having online lessons during that period, and some cancelled their lessons due to sickness or moved to online after the study began in-person. Although we have video recordings of the sessions, wearing masks during lessons made behavioural analysis challenging. The duration of the study was also impacted by breaks in the school calendar. Despite the limitations of this in-situ experiment, the study design allowed for an in-depth investigation of instructors' and students' perceptions of the robot that was used as part of their program.

Students in the intervention condition held a positive attitude toward the robot from the beginning of the study. While some students gave fewer 'stars' to the robot's friendliness at the end of the study, they still wanted to have the robot in their future lessons. Moreover, their engagement with the robot did not change during the study. However, their perceptions towards the role of the robot changed. Interestingly, the role of a friend diminished and four major roles, a classmate, teacher, helper, or none emerged by the end of the study.(see Fig. 2 (RQ1).

Considering the instructor's responses to the open-ended questions, all the instructors enjoyed or found the intervention effective (See Table 1). The scores in the five dimensions of the TAM questionnaire during the study lied between 3.3 to 5, showing medium to good acceptance towards the tool. With a closer look, for the first, second, and fourth dimensions of TAM, the scores given by the first instructor lowered a bit after the last session. We believe that, this instructor had one student (who was mature) in the intervention group did not find the interaction with QT interesting. This experience likely negatively affected the instructor's opinion of the robot intervention. However, despite these lower scores, they mentioned that the robot was helpful for students to stay focused and more engaged. Overall, we did not see any significant difference in the enthusiasm of instructors to try technological devices between the beginning and end of the study (RQ1).

Comparing the results of the control and intervention conditions, the findings imply that the robot has a positive effect on students. Due to the nature of the in-situ study, and the low number of participants, statistical tests failed to show significant differences between the two conditions. While we could not find any pattern in students' engagement and goal completion over the sessions in the intervention condition, the results indicate that students were generally more engaged with their task and could complete their task with a higher rate compared to the control condition (RQ2).

The above-mentioned results helped us answer our two research questions. Concerning RQ1, the responses of the instructors through open-ended questions and questionnaires suggest that they had accepted the robot as a tool in their lessons to a great extent. Similarly, the students perceived the robot as intelligent, friendly and enjoyable, while simultaneously, showed willingness to use the robot in the future. To explore RQ2, we compared the intervention and control conditions. The results indicated that the robot helped students displaying fewer off-task behaviours and boosted their engagement during the intervention.

Robot-mediated instruction provides many challenges. Due to the wide range of needs of students with LD, it is challenging to find an intervention that suits all students. There are more complex assistive tools that can support students better, but they usually require some level of technical knowledge, which is not desirable [26]. Despite all the shortcomings, the results of the study suggest two major findings: 1) the social robot can assist student engagement and reduce off-task behaviours for students with learning disabilities, 2) Instructors can integrate the robot into the existing program with minimal technical background and training, and they generally hold a positive attitude towards the use of the robot, and its impact on students. In future work, it is recommended to 1) conduct a study with a larger group of both instructors and students during a longer-term study. 2) improve the application and the robot's skills, to be further adaptable to the needs of diverse students.

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