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Investigating the Impact of Learning-by-Teaching a Social Robot on Students with Different Prior Knowledge Levels

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Abstract. Social robots are increasingly recognised as promising assistive technologies for enhancing engagement and learning in educational settings. This study investigates the use of a learning-by-teaching (LbT) paradigm, in which primary school children tutor a small social robot during a vocabulary learning task. Students from the same year group, but with varying levels of prior knowledge, were randomly assigned to either an LbT condition or a self-practice condition using a tablet. Results indicate that children with lower baseline knowledge spent more time engaging with the material and demonstrated higher post-test and retention gains in the LbT condition. While these differences did not reach statistical significance, they suggest that the LbT approach may foster deeper, self-reflective learning, particularly among students who typically struggle with independent practice. These findings support the potential of social robots as inclusive learning companions, and motivate future work to refine interactive teaching strategies and assess their long-term impact on students with learning difficulties.

Keywords: Social Robotics, Learning-By-Teaching, Education Introduction

Children with learning difficulties, including those with autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), and specific learning disorders such as dyslexia and dysgraphia, often require additional support to thrive in mainstream educational settings. They may struggle with attention, social interaction, task persistence, or foundational academic skills, which can hinder learning and participation. In recent years, social robots have emerged as promising assistive technologies capable of addressing these challenges by providing consistent, non-judgmental, and engaging interactions tailored to each child's needs [1, 2].

Previous studies have demonstrated that social robots can effectively augment educational and therapeutic interventions across a range of learning difficulties. For instance, studies involving children with ASD show that robots can enhance social-communication skills such as joint attention and emotional recognition more effectively than human-led sessions in some contexts [3]. In the case of ADHD, robots have been used to improve attention and self-regulation, with participants reporting increased motivation and task adherence when supported by a robotic "study companion" [4]. Similarly, in academic domains, robot-assisted programs have led to significant gains in reading [5] and writing [6] for learners with dyslexia and dysgraphia.

While most interventions employ the robot as a tutor or co-therapist, a smaller body of research has begun to explore the pedagogical potential of the learning-by-teaching (LbT) paradigm, where the child takes on the role of a teacher and the robot acts as the tutee. This model builds on the well-established “protégé effect,” which posits that teaching others fosters deeper understanding and retention of knowledge [7]. Importantly, LbT can also empower children who may otherwise feel disengaged or insecure in traditional learning contexts. In a notable case study, Gargot et al. demonstrated that a child with severe dysgraphia and ADHD not only improved his handwriting after teaching a robot but also regained confidence and re-engaged with academic tasks that he had previously avoided [6].

Despite its potential, LbT remains underexplored in the context of inclusive education and child-robot interaction. Most studies to date have focused on robot-led instruction, leaving open questions about how children with varying cognitive profiles might respond to more interactive, bi-directional learning formats. Furthermore, few studies have examined how individual differences in prior knowledge influence the effectiveness of LbT with robots, particularly in ecologically valid classroom settings.

Figure 1: Children in the Learning-by-Teaching Condition.

In this study, we investigate the impact of LbT using a social robot on primary school students with different levels of prior knowledge. Drawing on the hypothesis that students with lower baseline knowledge may benefit more from teaching a robot, due to increased reflection, engagement, and scaffolding, we compare learning outcomes, retention, and behavioral engagement in an LbT condition versus a self-practice tablet condition. By situating our work within a real-world classroom and focusing on learner variability, we aim to extend the literature on adaptive, inclusive human-robot learning experiences and highlight the unique affordances of LbT for educational equity.

1 Methodology

1.1 Participants and Study Context

The study was conducted in a UK primary school and involved 53 children aged 8–9 years (Year 4). All participants were enrolled in the same year group and had received limited prior instruction in French. Ethical approval was obtained from the relevant institutional review board, and written consent was secured from school administrators and parents.

1.2 Design

The study employed a between-subjects design with two experimental conditions:

1. **Learning-by-Teaching (LbT)**: Children interacted with a humanoid robot (JD from EZ-Robot), taking on the role of the tutor. They observed the robot attempting to label body parts in French and were asked to evaluate its responses using a tablet interface that allowed them to mark answers as correct or incorrect. Figure 1 illustrates the child-robot interaction in this condition.
2. **Self-Practice**: Children engaged in the same vocabulary task independently on a tablet, without a robot present. They received feedback directly from the tablet system and could access help materials as needed.

Students were randomly assigned to one of the two conditions. To examine the role of prior knowledge, children in each condition were further classified into **Low-Baseline** and **High-Baseline** groups based on a median split of their pre-test scores.

1.3 Procedure

The study was conducted over three sessions:

- **Session 1 (Pre-test)**: All students completed a baseline assessment consisting of 12 items designed to evaluate their prior knowledge of the targeted vocabulary.
- **Session 2 (Intervention)**: Children interacted with either the robot or the tablet-based version of the game. The intervention lasted approximately 20 minutes. Interaction data, including use of the help panel and time spent per trial, were logged.
- **Session 3 (Post-test and Retention)**: A post-test with parallel structure to the pre-test was administered immediately after the intervention. A **retention test** was administered two weeks later to assess longer-term learning gains.

2 Results & Discussion

2.1 Learning Gains by Baseline Knowledge

As shown in Table 1, students with lower prior knowledge (Low-Baseline) in the Learning-by-Teaching (LbT) condition demonstrated greater improvements from pre- to post-test (M = 4.63, SD = 5.75) compared to their peers in the Self-Practice condition (M = 0.92, SD = 4.57). This difference approached statistical significance (p = .07), suggesting a meaningful trend in favor of the LbT condition for lower-performing students. In contrast, High-Baseline students showed minimal gains in both conditions (LbT: M = 0.15, SD = 3.29; Self-Practice: M = 0.4, SD = 1.65), with no significant differences observed between them (p = .61). This pattern likely reflects a ceiling effect, whereby students who entered the study with higher prior knowledge had less room for measurable improvement.

These findings support the hypothesis that students with lower baseline knowledge may benefit more from the LbT approach, potentially due to the structured opportunity for elaboration, error detection, and reflective reasoning that teaching a robot entails. For students with more developed prior knowledge, the instructional task may not have provided sufficient challenge or novelty to drive significant learning gains.

Table 1 Comparison of post-test and retention gains between LbT and Self-Practice conditions for High-Baseline and Low-Baseline students. Mean and standard deviation are reported for each group

Variable	High-Baseline			Low-Baseline		
	Learning-by-Teaching	Self-Practice	p-value	Learning-by-Teaching	Self-Practice	p-value
Post Gain	0.15 ± 3.29	0.4 ±1.65	0.61	4.63 ± 5.75	0.92 ± 4.57	0.07
Retention Gain	-0.92 ± 3.25	-3.8 ± 4.61	0.09	2.38 ± 3.81	-0.08 ± 4.41	0.12

2.2 Retention Over Time

A similar trend was observed in the retention test administered two weeks later. Low-Baseline students in the LbT condition retained more knowledge (M = 2.38, SD = 3.81) than those in Self-Practice (M = –0.08, SD = 4.41), although this difference did not reach statistical significance (p = .12). This suggests that the deeper engagement prompted by the LbT condition may have led to longer-lasting learning, even if modest. Among High-Baseline students, retention scores were negative in both conditions, indicating some forgetting over time. However, students in the LbT condition (M = –0.92, SD = 3.25) performed slightly better than those in Self-Practice (M = –3.80, SD = 4.61), with the difference approaching significance (p = .09). While tentative, this result hints that LbT may offer some protective effect against forgetting, even among more knowledgeable learners.

2.3 Engagement with the Help Panel

To better understand behavioral engagement, we analysed time spent on the help panel, which provided vocabulary support during the task, as illustrated in Figure 2. A significant difference was observed within the LbT condition: Low-Baseline students spent more time using the help panel than their High-Baseline peers ($p < .05$), suggesting that the tutoring role prompted them to engage more deeply with the learning material. This pattern was not found in the Self-Practice condition, where help panel usage was consistent across baseline groups. These results imply that the act of teaching a robot encourages students, especially those with less initial knowledge, to access support resources more actively, likely contributing to the increased learning and retention gains observed in this group.

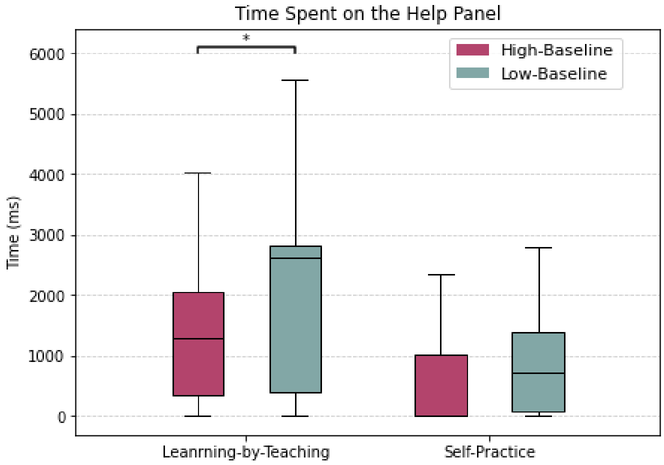

Figure 2: Comparison of the time spent on the help panel between High-Baseline and Low-Baseline students in the Learning-by-Teaching and Self-Practice conditions

3 Conclusion

This study contributes to the growing body of research exploring how social robots can function as inclusive assistive technologies in education. By adopting a Learning-by-Teaching paradigm, we shift the robot's role from tutor to tutee—addressing a notable gap in current child–robot interaction research, which largely focuses on robot-led instruction. Our findings suggest that this paradigm holds particular promise for students with lower prior knowledge, who demonstrated stronger learning and retention outcomes and greater engagement when teaching the robot.

These results underscore the potential of Learning-by-Teaching to foster self-reflection, agency, and motivation; important factors for effective support of learners who may not thrive under traditional instructional methods. As the field moves toward more personalised and adaptive educational technologies, robot tutees represent a compelling direction for future research. Developing scalable, long-term interventions that leverage this interactive model could expand the reach and impact of assistive technologies, particularly for children with learning difficulties who need tailored and empowering forms of support.

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