Fictional vs. Factual Robot Tutor Dialogue Can Shape Child Social-Emotional Learning

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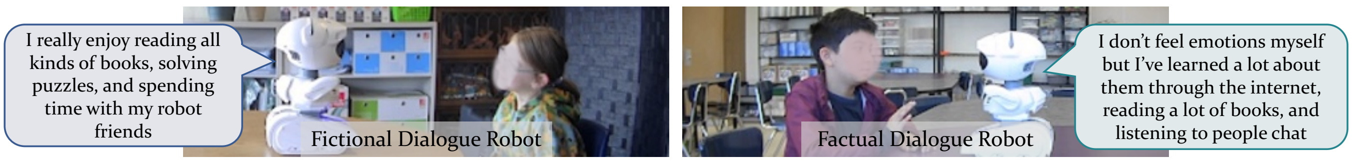

Figure 1: Fictional robot dialogue uses first person storytelling and emotional disclosures. Factual robot dialogue uses third person storytelling and no emotional disclosures.

Abstract

Social-emotional learning (SEL) is an educational framework that helps children develop the skills necessary for academic and life success. However limited resources restrict most schools to whole-group SEL instruction which may not benefit all students. In this work, we explore using social robots to address this challenge and how a robot's dialogue style can influence the effectiveness of one-on-one SEL lessons. The dialogue styles we investigate are (1) *fictional dialogue*, where the robot is human-like with emotions and discusses SEL scenarios as first person anecdotes, and (2) *factual dialogue*, where the robot is transparent, lacks emotions, and discusses scenarios from the third person. In a between-subjects study ($N = 52$) at Chicago schools, students aged 9-10 were either part of a control group, receiving no robot instruction, or received four SEL lessons across two weeks from either the fictional or factual robot. We found that students who had lessons with either robot improved more in lesson skill than students in the control. We also found that during lessons students spoke to the factual robot using more lesson concepts than those talking to the fictional robot, indicating that first person storytelling and emotional disclosure from a robot may be unnecessary for, or even hinder, SEL learning with a robot.

CCS Concepts

• **Human-centered computing** → **Empirical studies in HCI**; **User studies**; • **Computer systems organization** → *Robotics.*

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1 Introduction

Social-emotional learning (SEL) is an educational approach that helps develop essential life skills (e.g., self-awareness, relationship skills, problem solving). SEL programs are typically implemented in primary schools as a standalone non-core subject (e.g., 30-45 minutes once a week) and empower students to reach higher levels of academic success [14], manage their emotions [23, 50], build positive relationships [11, 13], and reduce behavioral problems and mental health issues [19, 23, 50]. Despite the volume of support for the benefits of SEL, implementation in classrooms can be constrained by a lack of resources, time, and personnel, as well as poor integration into educational practice [4]. As a result, SEL instruction is often limited to weekly classes that do not integrate with students' daily experiences. Furthermore, despite recognition of the critical need for individualized SEL instruction, providing it continues to be a challenge [7, 31, 60]. There is a pressing need for an SEL approach with greater flexibility and feasibility in implementation that can adapt to the needs of both students and teachers [28].

One promising approach to help children develop SEL skills while overcoming existing structural challenges is to supplement current SEL instruction with social robots. Robots are increasingly being used as educational tools to support student learning [6], teaching both academic subjects [39, 44, 49] and social skills [27, 52]. Social robots are well-suited for teaching children SEL skills as they can provide one-on-one individualized lessons with children where SEL can be taught through a more engaging back and forth discussions. Prior approaches have used robots as a means to practice SEL skills one-on-one using interactive storytelling [37, 38] and discussions about emotional art [48]. While these approaches successfully engaged children in practicing their SEL skills, they do not involve direct instruction of these skills nor do they provide feedback, both essential components of learning SEL [68]. An ideal robot led SEL lesson would teach SEL directly, using both storytelling elements and back-and-forth discussions to provide the necessary opportunities for direct instruction and individualized feedback, promoting the learning and practice of SEL skills simultaneously [57].

Given a more conversational approach to teaching SEL, the choice of robot dialogue style becomes essential, driving student engagement and potentially affecting learning gains. A common practice used to craft robot dialogue in interactions with children is fictional characterization (e.g., giving the robot emotions, opinions, and backstories [3, 30, 33, 35, 41, 42, 51, 61]), often used to help build more positive relationships between the child and robot. Fictional characterization has the potential to increase engagement in some educational contexts [35] but might be considered deceptive as robots do not possess emotions or personal histories. The recent uptick of AI chatbot usage has illuminated the need for caution when designing interactive "characters". Adults and children alike have developed deep emotional attachments to chatbots, resulting in catastrophic outcomes [8, 26]. A more transparent dialogue style may be more ethical and carry lower risk of distracting students with social behavior [32], but might come at the expense of children's trust and closeness with the robot [58]. Weighing the trade-off of potentially boosting learning gains at the expense of encouraging the development of risky emotional bonds, it may be prudent to consider what degree of fictional characterization is responsible in an educational robot - or if it is even necessary at all.

In this study, we had a social robot give a series of four one-on-one SEL lessons to students during two-week field deployments (see Figure 1). Lessons used example scenarios and discussions between the robot and the child. The robot had two dialogue styles: one where it presented scenarios as personal anecdotes and expressed having friends and emotions (*fictional dialogue*) and one where the robot presented scenarios as hypothetical stories and acknowledged that it lacks friends or emotions (*factual dialogue*). Students who had extra lessons with either robot were compared against peers in the *control* group who did not receive any additional SEL instruction. In this work we explore whether robot SEL instruction helps students learn SEL concepts, and unpack whether fictional characterization is necessary for learning or if a more factual approach is sufficient.

2 Background

In this section, we review literature on SEL, how social robots have been used in education, and the role of fiction in robot dialogue.

2.1 Social Emotional Learning

Social-Emotional Learning (SEL), an educational paradigm that addresses the social and emotional needs of students to help boost their academics overall, has been increasingly adopted by schools since its inception in the 1960s. In the 2023-2024 school year 83% of K-12 schools in the United States had an SEL program [54], most often through formal SEL instruction through standalone non-core classes (e.g., 30-45 minutes once a week). SEL programs are recognized for their tremendous benefits to students in both the short term (e.g., academic success, relationships, emotion management, and mental health [11, 13, 14, 19, 23, 50]) and long term (e.g., entry into and graduation from college, career success, reduction in criminal behavior, and civic engagement [29, 62]). However, despite the demonstrated importance of SEL skills, shortages of resources, time, and personnel present challenges to more comprehensive implementations in schools [4]. Teachers, already overloaded with academic performance expectations and managing classroom behavior, are expected to teach SEL without sufficient support and instruction. As a result, SEL programs often become prescriptive weekly activities, often in the form of whole-group instruction that can be detached from students' daily experiences [9, 43]. While this approach may be sufficient for some students, not all of them find the combination of personal subject matter and public discussions comfortable. For some, a one-on-one approach might allow them to engage in the material in a way that relieves them of some vulnerability and enables them to improve their SEL skills.

2.2 Robots in Education

Social robots have had great success deployed in a variety of educational disciplines [6]. Robots have taken on the roles of tutors (e.g., in math [49] and language learning [39]) or peer-like companions (e.g., in reading [44], storytelling [34], or handwriting [25]). Robots outperform other tutoring methods (e.g., avatars, tablets) due to a greater perceived social presence, which benefits learning gains [40, 49] and enjoyment [46]. In some cases, learning with a robot might even be preferable to learning with a human; children reading aloud to a robot felt less anxious than while reading to a human [66]. In this way, educational robots have the potential to be a "safe space" where students can approach subjects in a lower-stress setting without sacrificing access to corrective feedback.

Social robots may allow us to tailor SEL lessons to individual students' needs while also providing a more comfortable mode of engagement. Prior work has shown robots both facilitating one-on-one practice of SEL skills (e.g., conversations about emotional art [48] and narrative storytelling [37, 38]) and teaching SEL concepts to groups (e.g., co-teaching SEL [64] or assisting in SEL skill development [24]). However, these approaches do not combine individualized one-on-one instruction with feedback, which has great potential to enhance SEL learning [47, 68] and allows for SEL skills to be taught and practiced in a single session with a robot.

2.3 Use of Fiction in Robot Characterizations

Researchers often use fictional tools to engage participants, including robot backstories, self-disclosures, and storytelling. With social robots, backstories (supplying information about a robot's personal history) can be a convenient way to increase closeness and engagement with the robot [21], motivate a robot's behavior [30, 61, 65], or provide a plausible explanation for technical limitations [35]. Often, backstories take the form of a narrative introduction from the researcher [45], the robot itself [30, 61], or a combination [35]. A robot's "personal" information can also be conveyed through self-disclosures woven throughout dialogue, often with the goal to elicit reciprocal self-disclosures from a human. Reciprocal self-disclosure is the psychological phenomenon where people match the intimacy level of conversation partners when speaking about themselves [18] and is an important factor in creating close relationships [2, 12]. Self-disclosures can be quick expressions of preferences [3] or emotions [67], or sharing personal experiences [41, 42]. When self-disclosures take longer forms in the midst of an interaction, like sharing personal anecdotes, they become something more akin to first-person storytelling.

Robot backstories, self-disclosures, and storytelling exist along a spectrum of fictionality. Although some are entirely false (e.g., the robot is a student from another country [61], the robot is interested in coral reefs [30]), others can bear an element of truth, hinting at a realistic situation (e.g., the robot is hard of hearing because its ears are blocked [35]), or be entirely factual (e.g., disclosing a hardware limitation [65], detailing what a robot did that day [20]). Although numerous prior works have used robot backstories, self-disclosures, and storytelling to achieve certain effects, few have dissected whether it is merely "personal information" shared by the robot that matters or if the fictional component is essential.

A few studies have begun to investigate whether fiction is ideal in robot dialogues. Children exposed to a robot that discloses its machine-like status felt less closeness and trust towards the robot compared to one that made no such disclosure [58]. Robots telling first-person stories were perceived as more human-like, easier to work with, and trustworthy than robots that told the same stories from the third-person [55]. These studies suggest that fictional components of robot dialogue can strengthen human-robot relationships. However, these studies have robots in peer-like roles acting without explicit goals (playing a guessing game [58] or telling stories [55]). The role of fiction in dialogue has not been well explored in directed interactions like tutoring where engagement with lesson material may take precedence over the human-robot relationship.

3 In-School Observations of SEL Instruction

In preparation for our study, we partnered with 3 Chicago public schools to observe 7 SEL lessons in separate fourth grade classrooms (30-45 minutes each) and interviewed 5 teachers (30 minutes) to learn both how SEL is currently taught and which aspects of these lessons could be improved. Both the observations and interviews were approved by the University of Chicago Institutional Review Board (IRB23-1224) and Chicago Public Schools Research Review Board (2023-1918). The lessons we observed were all whole-group instruction with similar formats. A "warm up" activity involving physical movement and detail recall preceded the lesson. Teachers would then introduce the lesson topic, followed by a series of 1-3 scenarios related to the topic with discussions after each scenario. Scenarios were presented through videos, worksheets, or read aloud. To discuss scenarios, students were asked to answer questions directly or to pair off to discuss in groups and then share with the class. In interviews, teachers often mentioned a desire to provide more one-on-one time to students who needed more SEL practice, but were constrained by time and resources. Teachers found that whole-group instruction, the current SEL standard, does not work for everyone; during our observations we saw several disengaged students who were zoning out, refusing to answer questions, or, in two cases, reading a book hidden on their lap. Driven by the observation that the current standard of SEL instruction did not seem to serve all students, we wanted to design a robot to fill the gap that teachers helped us identify: one-on-one SEL instruction.

4 Method

We ran a between-subjects study where participants either did not receive any SEL lessons from the robot (*control condition*) or received 4 lessons from either a robot using fictional dialogue (*fictional robot condition*) or a robot using factual dialogue (*factual robot condition*), approved by the University of Chicago Institutional Review Board (IRB23-1224) and Chicago Public Schools Research Review Board (2023-1918). The Supplementary Material includes LLM prompts, selected transcripts, and extended method details (e.g., survey questions, grading rubrics). Pre-registration, deidentified data, and data analysis can be found in our Open Science Framework repository [1]. Code can be found in our GitHub repository [2].

4.1 SEL Lesson Format

The robot's SEL lessons were adapted from the Second Step [3] curriculum fourth grade unit on the STEP method of interpersonal problem solving (**S**ay the problem, **T**hink of solutions, **E**xplore the outcomes, **P**ick a solution). Participating classes used Second Step SEL curriculum and had already completed the problem solving unit prior to the start of this study. We adapted lesson plans designed for whole-group instruction to suit one-on-one lessons, replacing group discussions or worksheets with verbal exchanges between student and robot. We used a Google Gemini (1.5-pro) structured system prompt to design a robot capable of following a set lesson plan while also facilitating back and forth discussion with a student.

Students completed 4 SEL lessons with the robot. Lesson 1 introduced the STEP method, lesson 2 covered saying the problem, lesson 3 thinking of solutions and exploring outcomes, and lesson 4 picking a solution. Each lesson followed the same structure:

(1) **Introduction:** the robot greets the child, introduces the lesson, and recalls details from the prior lesson if appropriate
(2) **Warm Up:** the student plays a game with the robot where they perform actions and share facts about themselves
(3) **Lesson Topic:** the robot overviews the lesson topic and provides feedback on the student's current understanding
(4) **Scenario Presentation:** the robot shares a lesson scenario
(5) **Scenario Discussion:** the robot conducts a question and answer discussion providing help or feedback when needed
(6) **Additional Scenarios:** steps 4 and 5 are repeated 1-2 times with different scenarios depending on the lesson topic
(7) **Summary:** the robot summarizes the lesson and checks the student's knowledge, providing feedback when needed
(8) **Disclosure:** the robot invites the student to share a personal experience related to the lesson topic
(9) **Farewell:** the robot thanks the child and says goodbye

[1] https://osf.io/uqrwp/overview?view_only=c726a4d8a1e240b39f9fc7a0de76efc8
[2] https://github.com/SeboLab/Robot_SEL_Tutor
[3] https://www.secondstep.org/

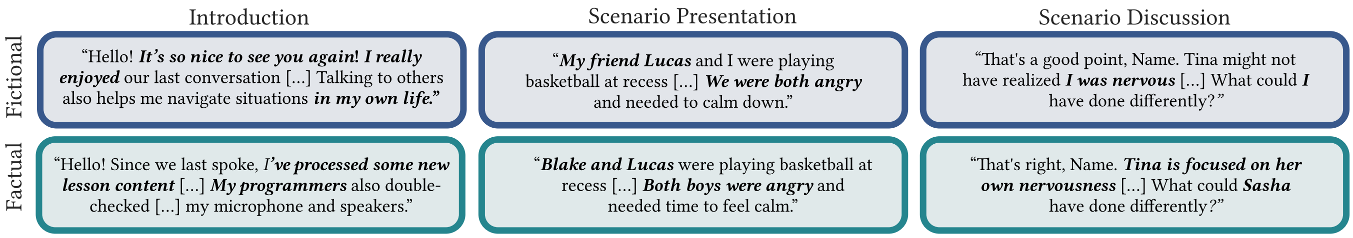


Figure 2: Dialogue examples from lesson transcripts with the fictional robot and the factual robot. Bolding indicates differences between dialogue styles, including 1st vs. 3rd person storytelling and references to friends, emotions, and preferences.

4.2 Experimental Conditions

We ran a between-subjects study to explore the role of robot dialogue strategies in one-on-one SEL lessons compared to the standard practice of SEL education. Over the course of two weeks, fourth grade students participated in four lessons with one of two robot conditions where the dialogue strategy differed, or a control condition where they did not receive additional lessons from the robot. In all conditions, students also received their typical SEL lessons with their whole class once per week or biweekly, depending on the school, allowing us to compare SEL gains from the robot-led lessons to any gains students would achieve from their standard education. Our three experimental conditions were:

Fictional Robot Condition: students complete SEL lessons with a robot that (1) presents lesson scenarios as first person anecdotes, (2) mentions friends and a life outside the study and (3) expresses emotions and preferences.

Factual Robot Condition: students complete SEL lessons with a robot that (1) presents lesson scenarios as third person hypotheticals, (2) acknowledges a lack of friends or life outside the study and (3) denies having emotions or preferences.

Control Condition: students do not complete additional SEL lessons with a robot.

As shown in Figure 2, the differing dialogue strategies were reinforced throughout the entire lesson. Although specific robot dialogue differed between conditions, the speaking voice of the robot (including tone and expressiveness), body movements, the format of the lessons, the content of lesson scenarios, and the questions asked were identical. In both robot conditions, children experienced the same lesson content in the same order.

4.3 Hypotheses

In this study we investigated how a social robot could be deployed in classrooms to teach one-on-one SEL lessons to fourth graders, and how the dialogue style used by the robot could influence children's engagement and learning. Given that social robots have a demonstrated ability to teach a variety of academic subjects [39, 44, 49] as well as social skills [27, 52], we expected that our use of a robot would successfully teach the SEL curriculum:

H_1 (SEL Skills: Robot > Control) – Students who receive lessons from either robot version will improve more in (a) general SEL skills and (b) mastery of lesson-specific SEL content.

When comparing students who received lessons from the robot, we expected those who learned with the fictional robot would perceive the first person lesson scenarios as self-disclosures from the robot, inspiring them to reciprocally self-disclose more in response [10, 18]. We also expected these students to show more closeness [2, 12] and enjoyment [56] with the robot. Therefore we hypothesized that:

H_2 (Engagement: Fictional > Factual) – Students who interact with the fictional dialogue robot will show more closeness and enjoyment and will self-disclose more with the robot than those who interact with the factual dialogue robot.

When comparing the two robot dialogue styles, we anticipated that fictional dialogue style, due to its more socially engaging nature, may lead to greater learning gains [1, 22, 63]. We hypothesized that:

H_3 (SEL Skills: Fictional > Factual) – Students who interact with the fictional dialogue robot will improve more in (a) general SEL skills and (b) mastery of lesson-specific SEL content over those who interact with the factual dialogue robot.

However, we could also anticipate that greater social engagement with the fictional robot might have no bearing on how well students learn the material despite the social focus of curriculum, given that some robot social behaviors have been shown to distract from learning [32]. If the social benefits from increased engagement have little effect on learning, then we hypothesized that:

H_4 (SEL Skills: Fictional = Factual) – Students who interact with the fictional dialogue robot will show equal improvement in (a) general SEL skills and (b) mastery of lesson-specific SEL content when compared to students who interact with the factual dialogue robot, using an equivalence bound of Cohen's $d = 0.5$.

We present H_3 and H_4 as contrasting hypotheses; this work is exploratory and we see a case for either hypothesis being supported.

4.4 Study Procedure

Prior to the study's start at each school, teachers emailed parents with study information and consent forms. Students who had parental consent then verbally assented and completed the pre-study survey. Teachers were asked to complete an SEL skills survey for each participating student. Students were randomly split equally into the three conditions - fictional robot, factual robot, and control.

During the two week study, students who received lessons from either version of the robot were pulled out from class at their teacher's discretion. During the study, teachers managed their classrooms and were not present for the robot SEL lessons. Pullouts occurred in an order such that the delay between consecutive lessons was roughly equal between participants. The study was run onsite at schools in whatever space was available (unused classrooms or a staircase landing with a table). During lessons with the robot, students were filmed with a camera and recorded using the robot's microphone. Lessons were fully autonomous except for rare technical errors (e.g., network outages) which required the researcher to restart the program, often without the child noticing. A researcher was within earshot at all times both to ensure the robot's function and to be present in the event that any disclosure from the child required mandated reporting. The researcher would intervene to ask students to repeat themselves or speak up when their utterances weren't caught by the microphone (occurring in approximately 1 out of every 20 sessions). At the end of their fourth lesson with the robot, students completed a robot-specific survey. After the two week study, participants completed a post-study survey that was identical to the pre-study survey. Teachers were also asked to complete an SEL competency survey for participating students.

4.5 Robot Design

This study used a Misty Robotics Misty II robot. We used Deepgram (nova-2) for speech-to-text, Gemini (1.5-pro) to generate text responses, and OpenAI's alloy voice for emotive text-to-speech. Our Gemini model settings ensured the robot spoke appropriately without deviating from the lesson plan (see our code for exact settings, Section 4). Though a few students did attempt to distract the robot from the lesson, it successfully redirected to stay on topic. Automatically generated summaries of each lesson were fed into prompts for subsequent lessons so that the robot could remember each child's name and details the child had shared.

4.6 Measures

We used surveys for both students and teachers to assess general SEL skills, mastery of lesson-specific SEL content, and robot perceptions, and video recordings and transcript logs from lessons with the robot to evaluate lesson progress and engagement. For inter-rater reliability checks, we used three graders and intraclass correlation coefficient (ICC) estimates using a single measure, absolute agreement, two-way random model. To account for differences in individual starting points, we used normalized gain, a learning measure that compares in individual's actual learning gains to their maximum possible gains, to measure improvement between the pre- and post-tests for each individual student i, defined as:

$$ng(i) = \frac{Score_{post}(i) - Score_{pre}(i)}{MaxScore - Score_{pre}(i)} \quad (1)$$

4.6.1 Manipulation Check. For the students who received lessons from the robot, we administered a survey containing four theory-of-mind questions adapted to be more child-friendly [53]. These questions asked the child to answer yes or no to if the robot: has feelings, has a purpose, thinks for itself, and knows what it is. While all four questions were administered for completeness, we only used the questions about feelings and knowing what it is as our manipulation checks, as these were the only constructs that we explicitly manipulated. For each question, if the child answered "yes" they received a followup question asking how much where they could answer a little, a medium amount, or a lot. These questions were evaluated numerically as levels 0-3. Students were also asked whether they thought the robot had friends: yes, no, or maybe.

4.6.2 General SEL Skill Evaluations. Students completed self - management, social awareness, and classroom belonging self-evaluation surveys from Panorama Education [15–17] using a 5-point Likert scale. Teachers were given these same questions and asked to evaluate each participating student using the same scale.

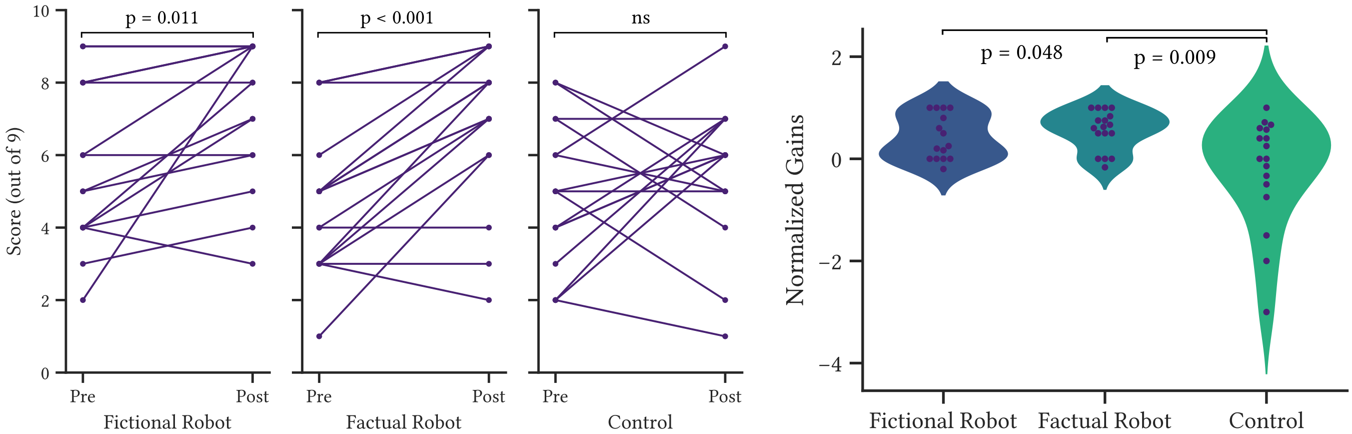
4.6.3 Mastery of SEL Lesson Content: Pre/post Test. Students completed pre- and post-tests on the interpersonal problem solving lesson content with the robot, adapted from official Second Step evaluation materials. The maximum score was 9 points, where multiple choice questions had designated answers and free-answer questions were graded by three members of the research team using a scoring rubric adapted from the official Second Step assessments. The graders reached $ICC(A, 1) = 0.911$ (95% CI: 0.833-0.955) with an overlap set of 30 randomly sampled surveys.

4.6.4 Mastery of SEL Lesson Content: Automated Transcript Assessment. We used a Google Gemini (1.5-pro) prompt to process students' lesson transcripts to assign grades for a child's mastery of lesson specific SEL skills. The grader awarded points for instances in the transcript where students displayed understanding and usage of lesson concepts. Students received an automated score divided by the number of child utterances per lesson with the robot, to account for the lesson length. We used the same LLM for analysis of child responses as we did for analyzing child speech and generating responses during lessons as it was performing similar content analysis. The automated grader's performance was validated by members of the research team who graded transcripts using the automated rubric. With an overlap set of 15 randomly sampled transcripts, the four graders (three human and one automated) reached $ICC(A, 1) = 0.899$ (95% CI: 0.792-0.96), indicating that our automated grader had good agreement with human graders.

4.6.5 Social Engagement with the Robot. In the survey given only to students who received lessons from the robot, they were asked whether they thought of the robot as a fellow student, a teacher, something in between student and teacher, or a free answer option to assess closeness with the robot. They were also asked whether they would prefer learning SEL one-on-one with a robot or with their whole class. At the end of each lesson, the robot invited students to share a personal experience related to the lesson topic. We calculated the word count from students both overall during the lessons and during the disclosures at the end as a measure of amount of self-disclosure [36]. Then, three members of the research team graded students' answers for the depth of disclosure using a sum of number of details shared, a method inspired by other works [5, 59] which use details mentioned as a proxy for depth in a statement. The graders reached $ICC(A, 1) = 0.858$ (95% CI: 0.687-0.937) with a randomly selected overlap set of 30 disclosures.

4.7 Participants

An *a priori* power analysis using G*Power recommended a sample size of 111, using effect size $f = 0.3$, $\alpha = 0.05$ and 0.80 power. Our participant pool was limited to roughly 120 students, impacted by one public school dropping out of the study and only using indirect recruiting via teachers emailing parents. We collected data until we ran out of participants ($N = 52$); a post-hoc power analysis using the effect size Cohen's $f = 0.49$ (converted from $\eta_p^2 = 0.196$ in



(a) Pre/post test score improvement

(b) Pre/post test normalized gains

Figure 3: Students who received lessons from the fictional and factual robot (a) significantly improved their SEL lesson pre/post test scores and also (b) showed greater normalized pre/post test learning gains compared to students in the control condition.

results Section 5.3.1) and $\alpha = 0.05$ resulted in a power of 0.88, which is sufficient to assess differences in the experimental conditions.

We recruited 52 students from five 4th grade classes (aged 9-10 years old, $M = 9.62$ years, $SD = 0.48$ years) at three schools in the city of Chicago, two public ($N = 41$) and one private ($N = 11$). 50% of students identified as non-white and 50% as non-male. 18 students received lessons from the factual robot, 17 students from the fictional robot, and 17 in the control group did not receive lessons from the robot. All students who learned with the robot completed all four lessons. 3 students were absent when the post-study survey was administered, leaving $N_{fact} = 17$ and $N_{fict} = 15$ survey results for students who engaged with the factual and fictional robots respectively. 5 teachers completed student evaluation surveys.

5 Results

We analyzed the repeated-measures data we collected using mixed analysis of variance (ANOVA) tests with the experimental condition as a between-subjects factor and participant ID as the within-subjects factor. When isolating analysis to within an experimental condition, we used repeated-measures ANOVAs with participant ID as the within-subjects factor. We analyzed non-repeating data using one way ANOVAs with the experimental condition as the between-subjects factor. For post-hoc pairwise comparisons, we used t-tests with a Bonferroni correction. We included school as a covariate in all models but discarded when it did not have a significant effect. We report the effect size as partial eta squared (η_p^2).

5.1 Manipulation Check

We found that students who had lessons with the fictional robot were significantly more likely to say the robot had friends than those who interacted with the factual robot ($N_{fict} = 14/17$ said yes, $N_{fact} = 15/18$ said maybe, $p < 0.001$ with Fisher's Exact Test for Count Data). Students who interacted with the fictional robot attributed it with significantly higher levels of feelings ($M_{fict} = 1.12, SD_{fict} = 0.993, M_{fact} = 0.167, SD_{fact} = 0.514, F = 12.88, \eta_p^2 = 0.281, p = 0.00106$) and lower levels of knowing it is a robot ($M_{fict} = 1.59, SD_{fict} = 1.12, M_{fact} = 2.39, SD_{fact} = 0.698, F = 5.605, \eta_p^2 = 0.165, p = 0.0155$) than those who learned with the factual robot. From these results, we can conclude that students experienced the robot dialogues as intended, perceiving the fictional robot as having friends and emotions where the factual robot did not, but identifying the factual robot as knowing that it was a robot where the fictional robot did not.

5.2 General SEL Skill Evaluations

5.2.1 Student Self-Evaluations. We saw no significant changes in how students self-evaluated their general SEL skills in *self-management*, *social awareness*, and *classroom belonging* when isolating for changes within an experimental condition or when comparing normalized gains between conditions (full statistics can be found in the Supplementary Material). Therefore, for general SEL skill evaluations, we did not find support for $\mathbf{H_1}$(a), that students who learned with the robot would outperform those who did not in general SEL skill gain. However, these general SEL skills are evaluated subjectively and develop on a longer timescale; seeing changes in these metrics from a short intervention was an ambitious goal.

5.2.2 Teacher Evaluations. 3 out of 5 teachers did not complete both pre- and post-study surveys for every student. Only 24/52 students had both a pre- and post-study teacher evaluation, 14 had only one evaluation, and 14 had no complete evaluation. For students who had full pre- and post-study teacher evaluations, we did not see a significant change in general SEL skills.

5.3 Mastery of SEL Lesson Content

5.3.1 Pre/Post Test. As seen in Figure 3a, we first assessed changes in students' mastery of SEL lesson content using their pre- and post-test scores. We found a significant improvement in scores for students who engaged with the fictional dialogue robot ($M_{pre} = 5.67, SD_{pre} = 2.26, M_{post} = 7.2, SD_{post} = 2.01, F = 8.552, \eta_p^2 = 0.379, p = 0.011$) and the factual robot ($M_{pre} = 4.65, SD_{pre} =$

Table 1: Automated assessment mean scores per utterance.

Lesson	Fictional		Factual		Total	
	M	SD	M	SD	M	SD
1	0.44	0.20	0.51	0.17	0.47	0.19
2	0.44	0.24	0.47	0.20	0.45	0.22
3	0.49	0.26	0.72	0.27	0.61	0.29
4	0.47	0.29	0.79	0.24	0.64	0.31
Total	0.46	0.25	0.62	0.26		

2.00, $M_{post} = 6.88, SD_{post} = 2.12, F = 25.614, \eta_p^2 = 0.616, p < 0.001$), but not for the control ($M_{pre} = 4.76, SD_{pre} = 2.02, M_{post} = 5.24, SD_{post} = 2.33, F = 0.493, \eta_p^2 = 0.03, p = 0.493$).

We next compared mastery of lesson content between conditions (Figure 3b) using students' normalized gains from pre/post tests, finding a main effect of condition ($F = 5.592, \eta_p^2 = 0.196, p = 0.0067$). Post-hoc pairwise t-tests with Bonferroni corrections showed students who learned with either the fictional robot ($M = 0.421, SD = 0.444, p = 0.0483$) or the factual robot ($M = 0.562, SD = 0.389, p = 0.00849$) had significantly greater normalized learning gains than students in the control group ($M = -0.213, SD = 1.07$). We did not find a significant difference in normalized gains between students who learned with either robot so we ran Two One-Sided Tests ($\alpha = 0.05$, Cohen's $d = 0.5$) to assess whether the two robot conditions are statistically equivalent (see Supplementary Material for further explanation on our equivalence test approach). We found evidence that participants in the fictional and factual robot conditions had equivalent normalized learning gains ($t(28.096) = -2.42, p = 0.011$, 90% C.I.: -0.111-0.394).

Combined, these results support hypothesis $\mathbf{H_1}$(b) that students who received lessons from the robot would show greater mastery of SEL lesson concepts than those who did not. Between our contrasting hypotheses, we found support for $\mathbf{H_4}$(b), suggesting that students who received lessons from the fictional robot would show equal mastery of SEL lesson content to students who received lessons from the factual robot.

5.3.2 Automated Transcript Assessment. We also assessed student mastery of lesson content using their verbal transcripts, where we found main effects of condition ($F = 7.759, \eta_p^2 = 0.190, p = 0.009$, where students with the factual robot scored higher than those with the fictional robot) and lesson number ($F = 7.787, \eta_p^2 = 0.191, p < 0.001$, where scores were higher in lessons 3 and 4 over lessons 1 and 2) and an interaction effect ($F = 4.556, \eta_p^2 = 0.121, p = 0.005$) on students' spoken usage of SEL lesson concepts. Mean scores per utterance can be seen in Table 1 In post-hoc pairwise tests we did not see a difference between students learning from either robot in lessons 1 and 2. However, students with the factual robot scored higher per utterance than students with the fictional robot on both lesson 3 ($M_{fict} = 0.487, SD_{fict} = 0.259, M_{fact} = 0.716, SD_{fact} = 0.272, p = 0.0157$) and lesson 4 ($M_{fict} = 0.474, SD_{fict} = 0.293, M_{fact} = 0.793, SD_{fact} = 0.236, p = 0.00118$), shown in Figure 4. Contrary to the pre/post test findings, these results support neither $\mathbf{H_3}$(b) nor $\mathbf{H_4}$(b) but rather suggest that students may have increased SEL lesson skill mastery after engaging with the factual robot instead of the fictional one.

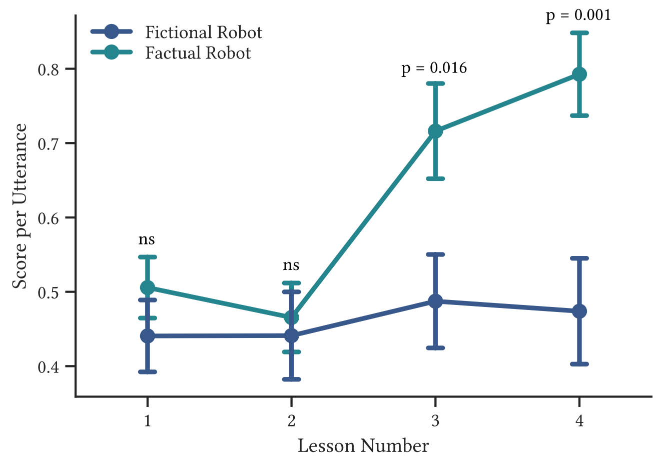


Figure 4: Students who learned from the factual robot spoke with significantly greater usage of SEL lesson concepts on the third and fourth lessons than those who learned from the fictional robot. Error bars indicate the mean ± 1 SE.

5.4 Social Engagement with the Robot

We did not find a difference between robot dialogue styles in eliciting closeness, enjoyment, or self disclosure from students. We found no difference in how students viewed the robot socially (with (17/35) viewing the robot as a teacher and (10/35) as something between teacher and peer), nor did we find a difference in their preference for learning SEL with the robot (74% of students would prefer the robot). We also did not find a difference in students' word count or depth of disclosure when asked to share a personal experience (full statistics can be found in the Supplementary Material). Hypothesis $\mathbf{H_2}$, that the fictional robot would elicit greater closeness, enjoyment, and self-disclosure, is therefore unsupported.

6 Discussion

In this study we demonstrated a social robot successfully teaching SEL one-on-one to fourth grade students aged 9-10. We designed a between-subjects study where students were either part of a control group that received no SEL instruction from a robot, or received four one-on-one SEL lessons with a robot using either fictional or factual dialogue. We examined both the overall benefits of a robot SEL intervention and how the robot's dialogue strategy affected students' learning and engagement.

Efficacy of Robot SEL Tutors. We found that students who received additional SEL lessons from the robot showed greater improvement in their mastery of the SEL lesson concepts (interpersonal problem solving) than students in the control group who did not receive any kind of supplementary SEL lessons. Although we do not compare our intervention to other tutoring methods (e.g., human or tablet), by demonstrating learning gains from a robot intervention we have highlighted a potential tool that can help address a need that teachers themselves identified - students benefit from individual attention, but schools cannot currently provide it to the level that they want. Additionally, we expanded upon prior work using robots for SEL [24, 37, 48, 64] by demonstrating the efficacy of combining one-on-one instruction with feedback, which allows students to learn and practice SEL skills simultaneously. Our work suggests that supplementing existing SEL practices with social robots in this way could be one tool to enhance teachers' abilities to provide individualized attention.

Fictional vs. Factual Dialogue. We also found that a factual approach to robot dialogue may in fact be superior to a fictional approach, even in a socially grounded discipline like SEL. Although students in both robot conditions showed equivalent gains in mastery of SEL lesson content in our pre/post test analysis, our analysis of lesson transcripts revealed that students spoke to the factual robot with greater mastery of lesson content during lessons 3 and 4 than their peers with the fictional robot. It may be that students who worked with the factual robot gained a greater mastery of SEL concepts, as reflected in the analysis of their speech. It is possible that the factual robot, being perceived as less human-like, allowed students to feel less anxious [66] and thus they engaged with lesson vocabulary more deeply. The fictional robot's displays of emotion and more social behavior could have also been distracting to students [32], leading to a knowledge gap.

However, lessons 3 and 4 are focused on evaluating and picking solutions to problems, which might come across as criticizing the robot's suggestions. The emotional self-disclosure from the fictional robot might be influencing students to treat it more like a person [55], leading them to discuss the robot's "personal" experiences without using the formal lesson terminology in an effort to be kinder or more polite. In contrast, the factual robot's emotionless nature may be creating more psychological social distance [58], allowing students to speak more objectively about potential solutions without fear of hurting its feelings. Therefore, it is possible that the students in both conditions may have gained the same level of SEL knowledge, however, only the students in the factual condition felt comfortable expressing that knowledge using lesson terminology.

Benefits to Educators. Our process for designing a robot tutor was deeply grounded in assessing the current needs of SEL educators; we spent over a year meeting regularly with teachers, principals, and counselors from schools from a diverse set of Chicago neighborhoods, as well as the Chicago Public Schools SEL board to ensure our robot satisfied the needs of potential end-users. Social robots offer us a way to augment teachers' abilities to provide students with individualized attention without taking them away from the rest of their class. In particular, robots might be especially helpful giving one-on-one reviews of material already covered in class to students who struggled to engage in whole-group instruction.

Our novel automated transcript analysis also emphasizes an interesting way that robots might be able to supply different streams of evaluation for educators. Although written tests are a common method for tracking academic performance, they may not fully capture students' learning progress - especially for students who may be nervous test-takers. We were able to use automated methods to analyze students' spoken answers to assess whether they were understanding and applying the concepts of the lesson. We did not structure our robot's method of corrective feedback around this particular style of automated analysis, but future work could implement a robot leveraging similar tactics to dynamically address gaps in learning. A robot offers the potential for real-time evaluation of student progress that can be adapted to different modalities of lessons without requiring extra time from teachers.

The Future of Fiction. Our results highlight an opportunity for HRI researchers to reconsider how they design social robot behavior. Although crafting fictional characterizations for robots is a common approach, we should evaluate whether it is a *necessary* approach. This work has shown that, at least in SEL, a fictional approach may be less effective in teaching students than a more factual approach. Given the potential unintended dangers that characterizing non-human agents can carry, it is our responsibility as a research community to carefully consider where fictionalization is used. Fiction in robot characterization exists on a spectrum in need of balance - using a more truthful approach while prioritizing responsive dialogue may be the key to fostering social engagement that does not come at the expense of unnecessary deception.

Limitations. Although our deployment of the robot involved multiple sessions over a two week period, it was still on a shorter-term than the standard SEL content delivery that students experience - further research would be needed to see if the learning gains we found persist in the long term. Long term deployments could also help clarify whether novelty held a role in the learning gains we observed, influencing students' engagement with lessons.

Although our choice of control condition accurately represents the current standard of SEL education that schools can reasonably provide, it limits our ability to compare a robot SEL tutor to an alternative (e.g., human tutor, tablet interface) and thus our results can only support one-on-one SEL interventions generally. Regardless, our results show that in the absence of alternatives social robots can address the present need for individualized SEL instruction.

7 Conclusion

Social robots offer the opportunity to augment teachers' ability to provide more individualized SEL instruction. In this work, we conducted a two-week long between-subjects study to evaluate (1) whether a social robot could successfully teach SEL one-on-one and (2) what robot dialogue style (fictional or factual) would lead to the best SEL learning outcomes. We found that students whose standard SEL education was supplemented with lessons from a robot showed greater improvement in their mastery of lesson-specific SEL content than students who did not. We also found that students who received lessons from the robot using factual dialogue applied more of the lesson concepts in their speech during lessons than those who received lessons from the fictional robot. Altogether, these findings provide justification for the use of robot tutors to supplement SEL education and offer evidence supporting factual approaches to robot dialogue when designing interactions.

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