Deploying a Social Robot to Co-Teach Social Emotional Learning in the Early Childhood Classroom

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Abstract— **Presently, programmable social robots are widely available to consumers. However, implementations outside of academic and commercial research and development are less pervasive. In this paper, we present our own efforts to deploy a social robot to co-teach the social-emotional learning (SEL) curriculum in early childhood education (ECE). We outline our approach to the process of programming nonverbal behaviors for the purpose of facilitating child-robot interaction (CRI), modifying lessons to feature the robot during scripted content delivery, and deploying the robot in Head Start classrooms. Additionally, having presented our work to various stakeholders in the ECE community, we present, throughout, our estimation of the challenges impeding widespread adoption and propose future work intended to lower barriers to implementation.**

I. Introduction

Research establishes the potential for social robots in the classroom to promote student engagement [6] [12], empower growth mindset [19], stimulate curiosity [13], and elicit social interaction [20]. Robotic solutions are one among many supplementary tools to emerge in the effort to deliver groundbreaking interventions in the classroom. Platforms familiar to the research community include KASPAR [10], Pleo [16], and DragonBot [17]. A humanoid robot is particularly well suited to the task of providing learners with more opportunities to practice the interpersonal skills they are learning in SEL instruction. Supplementing SEL curriculums with a social robot capable of modeling feelings and demonstrating emotion regulation presents a unique potential to impact developmental outcomes.

Taking advantage of the availability of an affordable and programmable social robot platform, our work aims to fully develop the co-teaching potential of the NAO (shown in Figure 2), a 58-centimeter tall, performant biped robot with 25 degrees of freedom (DOF) developed by *SoftBank Robotics* (formerly, *Aldebaran*), by improving its social qualities, namely, its capacity for perceived emotional intelligence. We endeavor to achieve this objective by maximizing the utilization of its existing modes of expression. Furthermore, the NAO robot is cartoon-like in appearance and its bright white and shiny blue color and exaggerated eyes (the prominent facial feature) are indicators to children of positive behavior intention [27]. These attributes suggest a friendliness which puts children at ease. As noted by [26], with "human-like social cues" and an "object-like simplicity", children who are otherwise apprehensive of interlocutors (e.g., children with autism) might more successfully engage in interactions with a conversational partner [16].

Figure 1. The robot demonstrates emotion regulation. *On-site at the Jackie Joyner-Kersee Center in Metro East Saint Louis, Illinois.*

We expect our work introducing the NAO robot in the collaborative role of educational assistant (co-teacher) in the mainstream classroom to aid educators with the implementation of SEL instruction will increase student engagement during lessons, boost enthusiasm for SEL instruction and practice, and promote the general acceptance of collaborative robots in the classroom over time. Beyond the long-term educational and societal impact, with each classroom visit we continue to learn more about how to streamline the process of deploying in the wild from concept ideation to lesson implementation. We are documenting our progress with the intention of providing non-programming practitioners with clear and concise procedures for developing social robot behaviors, integrating the robot into existing curricula, and deploying the robot in the classroom environment.

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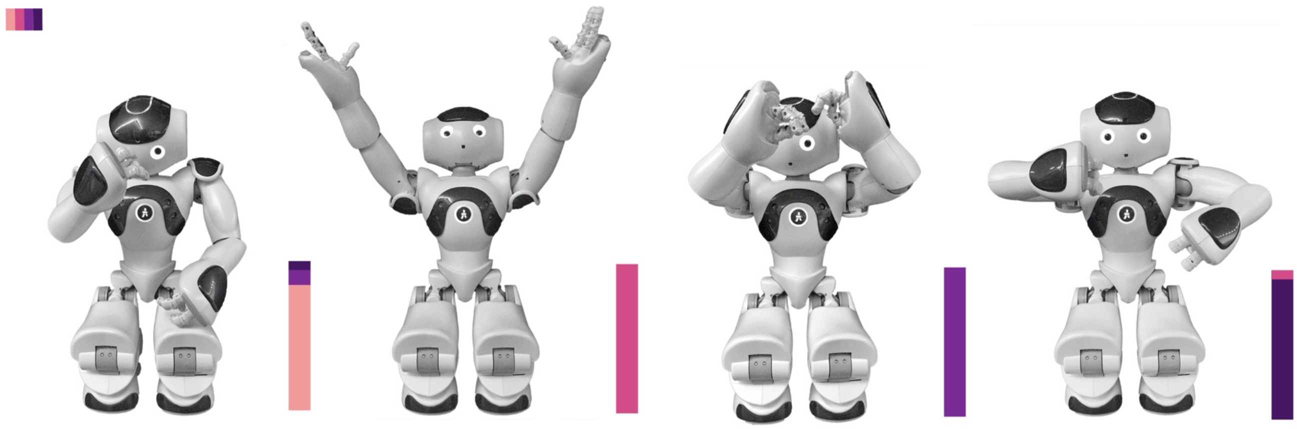

Figure 2. The potential of body language to communicate affect.
The robot responds in sadness (left), happiness (center left), fear (center right), and anger (right).

II. Developing Social Robot Behaviors

Social robots have a profound potential to provide educators with a uniquely personable and highly differentiable tool to support children with a range of social, emotional, and educational needs. The overarching objective of social robotics research is to enhance our perception of these computing artifacts as socioemotional and companionable. To improve child-robot interaction, the robot should be friendly in appearance and intention and *believable* [1] in behavior, which requires the ability to perform a meaningful and balanced repertoire of social and emotional behavior displays. Our work builds on substantial progress in the social sciences and in human-robot interaction to evaluate the social and emotional authenticity, and thereby interactive and assistive potential, of programmable humanoid robots [18] [24].

To bring the "illusion of life" [5] to the robot we focus primarily on the development of nonverbal behaviors that mimic human kinesics (bodily movement), including instances of subconscious impulse (e.g. shifting body weight), as well as verbal-nonverbal incongruence shown by [23] and [4] to heighten likeability and improve the likelihood of acceptance. Oculesics (eye movement), a subcategory of kinesics, is equally important to consider; therefore, we include eye blinking as a parallel behavior, adjusting blink rate to correspond with valence (energy) according to Russell's *circumplex* model of emotion [22].

Given our context of use, specifically social-emotional skill-building, it is necessary to develop predictable postures for the basic human emotions of sadness, happiness, fear, and anger. Drawing from [8], work by [11] demonstrates that despite kinematic constraints, the NAO humanoid robot can be programmed to convey human expressions of emotion. Others [2] [3] [9] take varying approaches to obtain similar results. Emotion displays (Figure 2) proven by our own pilot study to yield high recognition rates were selected for inclusion in the SEL lesson to model feelings. Forced-choice responses from participants (undergraduate students) in the study for sadness (85%), happiness (100%), anger (95%), and fear (100%) suggests body language alone can provide important clues to interlocutors to discern the feelings of others.

Social robot behaviors are currently programmed using the desktop application *Choregraphe*, the Graphical User Interface (GUI) Integrated Development Environment (IDE) packaged with the NAO robot. It is primarily drag-and-drop programming, but requires intensive timeline editing to synchronize movements with speech and other behaviors to animate the robot. Moreover, program flow control can sometimes require editing the Python code underlying "box" elements, restricting the authoring of social robot skills to experienced programmers. Documenting qualitative descriptions and quantitative values of the kinematics, shown by evidence to be highly successful, will help guide the process of behavior development and eliminate unnecessary guess work when it comes to animating behaviors; however, to lower the development barrier for non-programmers, improved tools that enable teachers to easily and rapidly create social robot content are needed.

III. Integrating the Robot into SEL Curriculum

Second Step[1] is a research-based, social-emotional learning curriculum for early learning, elementary, and middle school classrooms which has already been demonstrated to improve teacher ratings of social competence in elementary and intermediate grades [25] [14]. Each unit of the early learning program, specifically, is designed to develop skills for social and academic success in kindergarten and focuses on developing executive functions foundational for competence. The program offers educators scripted lessons for delivering content and suggested activities for reinforcing concepts. Our work extends some of the lessons

[1] http://www.secondstep.org/early-learning-curriculum

and activities to feature the robot, in lieu of other prescribed teaching tools (e.g. puppets), by integrating the robot into the script and providing opportunities for child-robot interaction.

Skills for Learning (Unit I) introduces the Listening Rules (*Eyes watching, Ears listening, Voice quiet, Body calm*). Empathy (Unit II) skills building emphasizes identifying one's own and others' feelings. Here, we flipped the script, allowing children to show the robot how they feel; the robot responds in-kind with pre-programmed feelings of its own, described in Section II. Emotion Management (Unit III) includes developing strategies for calming down strong feelings. We modified the *Calm It Down* activity (a choreographed song) and programmed the robot to recite the lyrics while performing the described movements.

The well-known instructional strategy of model-practice-feedback can have a powerful impact on learning outcomes [7] [21]; social robots are particularly well-suited for providing consistent examples and reliable for recurring practice. Instruction is otherwise varied—its quality dependent on the skill and experience of the given instructor.

Documenting these modified lessons and providing an archive of developed content that includes scripted robot behaviors associated with each lesson will give teachers access to robot-ready resources for quicker deployment.

IV. Deploying the Robot in the Classroom

We visited Head Start classrooms at the Jackie Joyner-Kersee Center in Metro East Saint Louis, Illinois (Figure 1) to field test our concept. Important technical details to consider on-site include evaluating the space for safe operation of the robot (the NAO robot requires a 60 centimeter in diameter operating space) and access to power sources (the NAO robot battery life under active use is 60 minutes), networking options for troubleshooting and remote control (the NAO robot can be manually updated using *Choregraphe*, a Secure Shell (SSH) connection, or the robot's web page), and coordinating with classroom staff to provide smooth transitions and appropriately accommodate children with special needs.

We pre-programmed the robot behaviors and scripted speech to be timing-based or triggered by touch. This afforded the instructors demoing the lesson to have greater control over the pace and timing of instruction. Early on we considered speech recognition as a means to prompt the robot; unfortunately, the NAO platform is limited in its ability to reliably respond in noisier environments. We conjecture the hardware (microphones with a limited frequency range) and its placement (microphones positioned in close proximity to cooling fans) are a factor in degraded performance of its built-in speech recognition software. To overcome limitations of the platform's default sound source localization and speech recognition, hardware and software changes are required; however, evidence suggests suboptimal performance might be an option for CRI. Research has proven children better relate to robots that do not try *too* hard [15].

Until commercially available social robots are equipped with more robust environmental sensors, remote control is currently the most viable option for triggering behaviors and directing program sequence in the classroom environment. See Table I of Appendix for a more complete conceptual (non-qualitative) assessment, modelled by [10], of the NAO platform.

V. Conclusion

Commercially available social robots are more widely available and more affordable, offering early-adopters more practical options to obtain access to cutting-edge learning tools and develop novel applications for education. However, for social robots to become more ubiquitous in the classroom, there are a number of features that are still lacking, which make some platforms inaccessible to the non-programmer. Our work aims to minimize barriers to develop social robot behaviors by determining the kinematics and timing of social behaviors, shown by research-based evidence, to be highly successful. We recognize the benefit of having access to qualitative and quantitative descriptions of these behaviors to help guide the process of behavior development and eliminate unnecessary guess work when it comes to animation and authoring. Therefore, we are documenting our work to provide others with access to reliable content. Additionally, we recognize that to lower the development barrier for non-programmers, the available animation and authoring tools packaged with the NAO robot require simplified features to automate and streamline the creation of believable and more robust social robot skills for human interaction.

Figure 3. Updating curriculum materials to include robot content. *Image (left): Second Step Early Learning Feelings Card* [2] *reprinted with permission from Committee for Children.*

2 http://www.secondstep.org/Purchase/Product/all-products/second-step-early-learning-feelings-cards

Our work seeks to extend our understanding of how social robots can be effective tools to engage young children in social and academic skills building activities, increase understanding of concepts, and improve competencies. Initially, we perceived our biggest challenge to be the development of believable emotion displays for a minimally expressive social robot. We believed the robot's lack of facial expression to be a significant limitation. In the classroom, we observed that when children were prompted to demonstrate an emotion to the robot, the universal response was to make the corresponding "face", as depicted in Figure 3 (left). The lesson *objective* is to notice *body* cues, yet children consistently relied on facial expression to convey the solicited emotion. In contrast, the robot could produce *only* body language. Unexpectedly, this fact could get children focusing more frequently on body cues to identify feelings.

We have already shared our early work with stakeholders in the early childhood education community at the 2017 Early Childhood Innovation Summit in Salt Lake City, Utah hosted by the National Head Start Association and at the 2017 Tech and Early Ed Incubator in Austin, Texas hosted by the HeadStarter Network. The response to social robots in early education has been resoundingly positive. Notably, the primary anxiety amongst potential adopters was not the cost of social robots, but lack of in-house technical expertise to program them. With the right authoring tools and robot-ready resources, social robots for the classroom have a strong potential to be the ubiquitous collaborative partners we imagine for the future.

VI. Future Work

We will conduct further studies to quantitatively measure the impact of introducing a social robot in the early learning classroom on learner engagement during lessons and enthusiasm for robot-mediated instruction. We will evaluate child on-task behavior and poll children and their teachers to determine the extent to which a collaborative social robot is accepted in the classroom. We will collect teacher evaluations of student behavior and social-emotional competence following robot-mediated instruction.

We will complete efforts to utilize the robot throughout the model-practice-feedback loop by developing reinforcement behaviors and defining feedback production rules. We intend to compile a database of social robot content and robot-ready resources, including qualitative descriptions and detailed kinematics of social robot body language, scripted speech, and modified materials featuring the robot, as depicted in Figure 3, to supplement robot-mediated instruction. Furthermore, to lower the development barrier for non-programmers we are collaborating with an industry partner, *Semio*[3], to assist in the development of animation and authoring tools that will enable and empower practitioners to deliver innovative and compelling instruction.

[3] https://www.semio.ai/

Appendix

TABLE I. Conceptual Assessment of the NAO Robot

Category	***Rating***	***Comments***
Affordability	High	NAO robot list price of $9,000 USD Transport case list price of $520 USD
Ease of setup /transport	Average	Boot time (approx. 1 minute) Shutdown (approx. 20 seconds)
Facial/head expressiveness	Low	Only two degrees of freedom: Head (Yaw/Pitch)
Expressiveness of arm gestures	High	Six degrees of freedom: Shoulder (Pitch/Roll), Elbow (Roll/Yaw), Wrist (Yaw), Hand (Grasp)
Openness of software	High	Open Source since 2011
Ease of programming /operation	Average	IDE, Libraries (Python/C++ SDK), and Cross-platform build tools
Manipulation abilities	Low	Push, pull, and grasp with limited grip
Speed of Movements	Variable	Timeline default of 25 fps Walking speed up to 0.6 km/h
Precision of Movements	Low	Limited to 25 degrees of freedom Movements lack subtlety
Sensory abilities	Average	Cameras, Gyrometer, Accelerometer, MRE, FSR, Infrared (emitter /receiver), Loudspeaker, Microphone
Aesthetics	High	Cartoon-like (familiar and friendly), child-sized (non-threatening)

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