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RESEARCH PAPER

Educational Robots for Social and Emotional Learning

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Abstract

Embodied agents are agents that display human-like behavior while interacting with their environment. Educational robots, which are embodied agents, or more specifically knowledge agents, are extensions of the learners. The robot interface is physically, mentally, and socially human-like and can be programmed to exhibit behaviors that replicate interconnected physical, mental, and social characteristics. As such, they provide a compelling social and emotional learning teaching and learning tool. Social and emotional learning is the process through which children and adults acquire and effectively apply the knowledge, attitudes, and skills necessary to understand and manage emotions, establish and achieve positive goals, feel and show empathy for others, establish and maintain positive relationships, and make responsible decisions. This article explores the space between robots as embodied agents and social and emotional learning.

Keywords: embodied agents, educational robots, social and emotional learning

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1. Introduction

In 1562, King Philip II of Spain performed a miracle. Actually, he appeared to have commissioned an automaton of a friar to be created by Juanelo Turriano, an engineer and inventor. Like a robot, an automaton is a machine that automatically performs a sequence of operations. In this case, the automaton performed the movements associated with a prayer, the mea culpa, seemingly on its own. The automaton is in the Smithsonian collection and still works to this day [1]. Because this automaton repeatedly performs this prayer, one could argue that it is a model of how to perform the prayer, like a primitive educational robot.

Today, educational robots are more sophisticated, but whether they are simple or not, they act as embodied agents. Embodied agents are objects that display human-like behavior while interacting with their environment. Robots, which are autonomous embodied agents, have been used for instruction with evidence that interaction with a physically autonomous embodied agent can facilitate learning. Indeed, they can actually help us to see what we are learning. In the early 1970's, a research group at MIT under the direction of Seymour Papert invented an educational robot in the form of a turtle which did just that.

Since the robot interface is physically, mentally, and socially human-like, it can be programmed to exhibit behaviors that replicate interconnected physical, mental, and social characteristics. As a result, educational robots appear to be compelling social and emotional learning (SEL) teaching tools. The Collaborative for Academic, Social, and Emotional Learning (CASEL) defines SEL as the process through which children and adults acquire and effectively apply the knowledge, attitudes, and skills necessary to understand and manage emotions, establish and achieve positive goals, feel and show empathy for others, establish and maintain positive relationships, and make responsible decisions [2].

SEL is increasingly being prioritized nationally as well as internationally, particularly in response to and recovery from the COVID-19 pandemic. One way through which we can facilitate the SEL process is by incorporating new forms of educational technology that are particularly effective for this endeavor. One of the newest types of this technology is embodied in the form of robots. This article explores the space between educational robots and SEL, from embodiment to metaphors.

2. *Embodiment*

Robots can be viewed as embodied agents, which are objects that display human-like behavior while interacting with their environment. Autonomous embodied agents, like educational robots, have been utilized for instruction with evidence that interaction with a physically autonomous embodied agent can facilitate learning, particularly when compared with virtual agents. Furthermore, the physical embodiment of educational robots allows them to be used for content or students that require something tangible and also increases the kind of social behavior that is beneficial for learning [3]. But educational robots have much more to offer, so it is worth considering how we can meaningfully utilize robots in our educational endeavors.

Some roles put educators in positions that enable them to incorporate technology for distinct purposes. Educational technologists and learning scientists who are driven by an embodied view of human cognition are designing learning experiences that promote multisensory processing by utilizing technology, including tangibles and manipulatives like robots [4]. Indeed, the robot interface is ideal as it is physically, mentally, and socially human-like and can be programmed to exhibit behaviors that replicate interconnected physical, mental, and social characteristics.

Because learners can program educational robots to perform specified actions, they demonstrate a particular kind of embodiment. Using coding and robotics in educational settings, simplified by the use of robotics kits like those listed in Table 1

Table 1. Educational robotics kits.

Product name	Manufacturer	Coding languages	Type of language	Grades
Dash Robot	Wonder Workshop	Blockly	Block/visual coding	1–6
Ozobot Evo	Ozobot	Color Codes, Blockly (OzoBlockly), JavaScript	Block/visual coding, text coding	K-12
micro:bit V2	micro:bit Educational Foundation	Scratch, MakeCode, Swift	Block/visual coding and text coding	2–10
Bee-Bot	Terrapin	N/A	N/A	PreK-2
Edison Robot	Microbric	Blockly, Scratch, Python	Block/visual coding, hybrid coding, and text coding	K-8
Finch Robot 2.0	BirdBrain Technologies	FinchBlox, BirdBlox, Snap!, MakeCode, JavaScript, Python, Java, Swift, Kotlin	Icon-based, block/visual coding, hybrid coding, and text coding	K-12
NAO Robot V6	Softbank Robotics	Blockly (Choregraphe), Java, Python, C++, C#	Block/visual coding, text-based	9–12
Marty the Robot V2	Robotical	Scratch Jr., Scratch, Python	Icon-based, block/visual coding, and text coding	K-8
Cue Robot	Wonder Workshop	Blockly and JavaScript	Block/visual coding and text coding	6–8
Root Coding Robot	iRobot Education	Blockly and Python	Block/visual coding, hybrid coding, and text coding	PreK-12
Cubetto Robot	Primo	N/A	N/A	PreK-2
Blue-Bot	Terrapin	N/A	N/A	PreK-2
Tello EDU Drone	DJI	Scratch, Swift, and Python	Block/visual coding and text coding	3–12
databot 2.0	databot	Scratch, Python, Arduino	Block/visual coding and text coding	7–12

Table 1. (Continued)

Product name	Manufacturer	Coding languages	Type of language	Grades
Root rt0	iRobot Education	Blockly and Python	Block/visual coding, hybrid coding, and text coding	PreK-12
mBot-S	Makeblock	Scratch, C, and Python	Block/visual coding and text coding	3–8
NAO V6 - AI Edition	Softbank Robotics	Python	Text coding	9–12
UKIT Beginner	UBTECH Education	Blockly and Python	Block/visual coding and text coding	3–8
Tuff-Bot	Terrapin	Blockly	Block/visual coding	3+
Hummingbird Bit	BirdBrain Technologies	BirdBlox, MakeCode, Snap!, Python, and Java	Block/visual coding and text coding	4–12
Cubelets	Modular Robotics	Blockly and C	Block/visual coding and text coding	K-12
Create 3	iRobot Education	ROS 2 and Python	Text coding	8–12
UKIT Advanced	UBTECH Education	Blockly and C/C++	Block/visual coding and text coding	7–12
Strawbees STEAM Classroom	Strawbees	Scratch and C++	Block/visual coding and text coding	3–8
DJI RoboMaster TT	DJI	Micro Python, Arduino, Python	Block coding, graphical coding, and text coding	6–12

(adapted from Eduporium [5]), falls into a category of instructional embodiment known as surrogate embodiment, which occurs when a user gives instructions via a program [4]. These instructions can do more than just tell the robot what to do.

The instructions that we give to a robot via coding are not just a one-way form of communicating a set of directions. The educational robot in the form of a turtle, invented by the research group at MIT under the direction of Seymour Papert in the early 1970's, utilized surrogate embodiment when children used basic programming to maneuver the turtle, and its movement showed what they had learned while the programming showed their thinking and, even beyond surrogate embodiment, the turtle acted as a knowledge agent, an extension of the child, while the computer became a way for them to express their inner state [6]. This extension and expression is remarkable in itself, but could also facilitate the development of skills beyond those that are traditionally considered to be academic.

The window into the inner state of the learner leads to the idea that a knowledge agent, like an educational robot, can help to address the widely acknowledged imperative for SEL to be integrated with academics and reputable professional organizations including the National Association of Education for Young Children (NAEYC); Collaborative for Academic, Social, and Emotional Learning (CASEL); and the Association for Supervision and Curriculum Development (ASCD), recognize social-emotional development as essential to successful academic achievement and personal fulfilment across the lifespan [7]. Of course, specific skills should be addressed at developmentally appropriate stages.

The need for social-emotional skill development is apparent through adulthood, from early childhood education through professional development and lifelong learning. Young children, in particular, need help with identifying and managing their emotions along with social and emotional support to nurture their development and growth [8]. Educators who serve young children should consider what the best practices are for addressing these needs.

The first step in helping children to develop these skills is to determine what kind of content needs to be communicated and what methods work best for delivering such content. Schools and organizations that educate children should use evidence-based content and delivery methods to teach social-emotional skills [8]. The content as well as the delivery, if it is designed and developed thoughtfully, can directly address gaps and needs present at the targeted developmental stage.

3. Metaphors

Instructional design efforts, including curriculum development and educational technology selection, aim to address specific as well as overall social-emotional skill development. Hof suggested that we start by simulating intangible structures like thinking and feeling, beginning with simple structures and increasing their complexity over time [6]. Coding and robotics provide an opportunity to simulate both thinking and feeling, for example by writing a program, which can be seen as analogous to thinking, that tells a robot to move slowly in a seemingly aimless trajectory to illustrate a feeling of sadness, while also allowing for teaching via multiple modalities.

In an educational setting where robots are utilized as teaching tools, learners receive content through multiple channels and employing multiple modalities, like audio, visual, and tactile, can help students to not only learn conceptual content faster and easier but also help them to develop a deeper level of understanding [9]. This multimodal approach is facilitated by the use of educational robots.

Considering educational robots as embodied agents allows us to view this multimodal approach from another angle. For example, by making a robot move we not only perform an action but also gain the experience needed to represent the minds of others and, because psychology is embodied and computational psychology reflects the specific form of our bodies, psychology is therefore grounded in the characteristics of an agent's body [10]. Thus, if psychology is indeed grounded in the characteristics of an agent's body, then children may be able to see themselves as represented by educational robots.

If children can see themselves in educational robots, they may also be able to see their inner selves. De Graaf and Malle [11] suggested that people may assume what the mental state of a robot is just as they would for a human, to explain their behavior by trying to figure out why they did what they did. They went on to explain that when people think behavior is intentional they often explain it by referring to the individual's mental state, and the resulting explanations can help them to practice identifying the causes of particular kinds of behavior and figuring out what it means, inform how they perceive and evaluate others, and help them to regulate their own behavior when interacting with others. These are all essential social-emotional skills.

Part of the development of these skills is the formation of mental representations. Observing an agent's behaviors can facilitate the construction of mental representations that the learner can utilize when previous representations do not fit a particular situation that they may encounter [6]. The formation of mental representations for social-emotional concepts is ideal for enabling learners to apply what they have learned to novel situations, and the learner's ability to apply what they have learned is an indicator of their depth of understanding.

The formation of mental representations can be further facilitated by the use of metaphors. Indeed, Foglia and Wilson suggested that metaphors are not only useful for expression but also reflect our experience as embodied entities that navigate our environment in particular ways [10]. Therefore, we should be able to apply what we learn in one domain to another like the robot realm to that of humans, if we develop an appropriate level of understanding.

Metaphors can help us to develop that level of understanding. The connections we make through metaphors allow us to take what we learn about one subject area and apply it to another, creating new thought processes, or frameworks [12]. These frameworks can help children to take what they learn from their observations of educational robots and effectively apply it to situations they may encounter in their own lives.

Childhood is, after all, filled with new experiences in which we encounter many abstract concepts. Metaphors use embodiment as a springboard for abstraction,

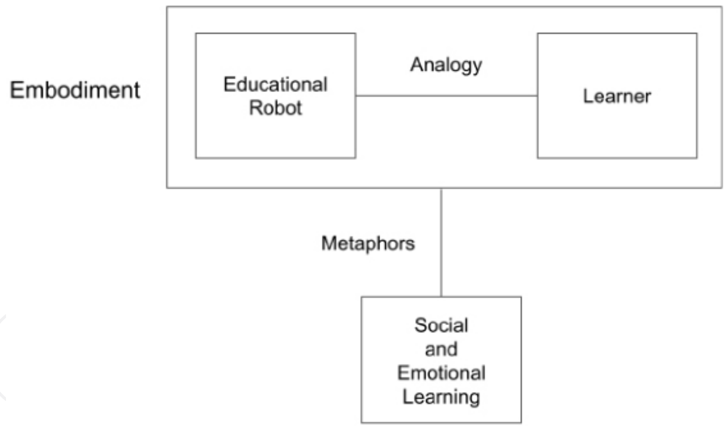

Figure 1. Link between embodiment and social and emotional learning.

provide a framework for our thought processes, help us to find meaning in new subject areas, and influence the way we see those subjects [13]. In this way, we may even see metaphors as a potential link between embodiment and SEL, as depicted in Figure 1, where the abstract concepts are in the area of social-emotional skills.

These social-emotional skills can develop simultaneously with computational thinking skills. Computational perspectives reflect the ever changing views that students have about the world, including the way they see themselves and others [9] and educational robots can be utilized to develop both social-emotional and computational thinking skills.

As children develop, even beyond the realms of computational thinking and social-emotional skills, and technology advances, we can not only increase the complexity of the content but also utilize more sophisticated robots. We can progress from using educational robots as manipulatives in the classroom to using them as peers or even tutors and teachers. In peer-to-peer relationships, robots act as beginners, allowing the students to teach them, which can make them appear to be less intimidating than tutors or teachers and can also support learning by improving confidence as well as outcomes [3]. In this way, the humble robot that began as a simple tool for demonstration can evolve into a partner in our educational endeavors.

Robotic manipulatives can facilitate the development of hand–eye coordination and fine motor skills while students are engaged in teamwork and collaborative activities, and when combined with coding and robotics they provide a playful way for children to learn diverse content from physics to art, while students develop meaningful projects in an open and creative learning environment [14]. Indeed, educational robots can serve as a particularly effective vehicle through which educators can help children to develop more than just traditionally academic skills.

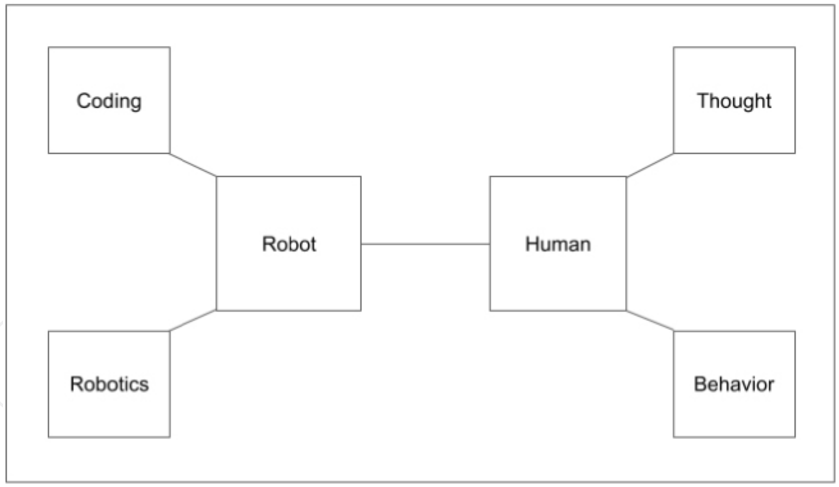

Figure 2. Analogous relationship between robots and humans.

While educational robots are usually seen as a natural fit for Science, Technology, Engineering, and Math (STEM) education, they are particularly beneficial in areas where the analogous relationship between robots and humans, as depicted in Figure 2, can serve to illustrate abstract concepts like human thought and behavior. Scientific evidence gathered over a period of decades indicates that the most important missing ingredient in education today is making sure that all children have the social-emotional skills to enable them to thrive [8] and since educational robots, including their components of coding and robotics, are analogous to humans, they are indeed a compelling set of tools that deserve further consideration.

Furthermore, the imperative for SEL is not likely to diminish, particularly as we continue to face significant challenges worldwide. Therefore, 21st century education must support the construction of resilience [7]. That resilience, along with a wide range of social-emotional skills, can and should be nurtured wherever education takes place.

4. Conclusion

Embodied agents, like educational robots, are more than tools that can be incorporated into traditional academic instruction merely for technology's sake. Technology that enables embodied interactions offers an enormous range of opportunities and deserves major consideration and investigation into how it can be applied in mainstream classrooms [4]. In an ideal world, educators would have easy access to educational robots, along with every other tool they need to maximize the effectiveness of instruction.

Of course, educational settings have limited budgets. So, for now, the use of robots is also limited, but hopefully the physical embodiment that they offer will help them to rise above competing learning technologies in the future, as Belpaeme *et al.* projected [3].

We have come a long way from primitive teaching tools like the mechanical monk. However, it is clear that King Philip II of Spain was on to something. Modern educational robots, from the simplest to the sophisticated, provide an increasingly effective way to teach academic content as well as social-emotional skills. Our ability to see ourselves in these robots, including our thoughts and behaviors, provides a unique opportunity to teach, learn, develop, and potentially even heal. Further research should explore the mechanisms through which educational robots can help with the development of social-emotional skills and possibly even with the delivery of therapy.

Conflict of interest

The authors declare no conflict of interest.

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