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# Supporting Meaningful Learning Experiences with Button-Operated Robots in Early Childhood Settings

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## Abstract

Bringing together recent research on button-operated robots in early childhood settings and developmentally appropriate practices, this chapter details strategies for the integration of robots. Educators are encouraged to design and implement robotics experiences that are intentional, active, constructive, cooperative, and authentic (Howland et al., 2012). To achieve these aims, educators should embed challenges within play-based activities and empower children to set and achieve their own goals. Additionally, educators can support children's active engagement by selecting a button-operated robot that gives clear feedback and by offering just-in-time support as children address errors in their programs. For constructive learning, educators should prompt children to articulate their programming accomplishments and support their reflection with multimodal materials. When designing the activities, educators should intentionally consider how the activity, materials, and environment may invite or discourage cooperation amongst children. Finally, authentic experiences with button-operated robots in early childhood settings should be play-based and naturally connected to the classroom context.

## Keywords

experiential learning, robots, early childhood education, research

## Disciplines

Early Childhood Education | Educational Technology

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## INTRODUCTION

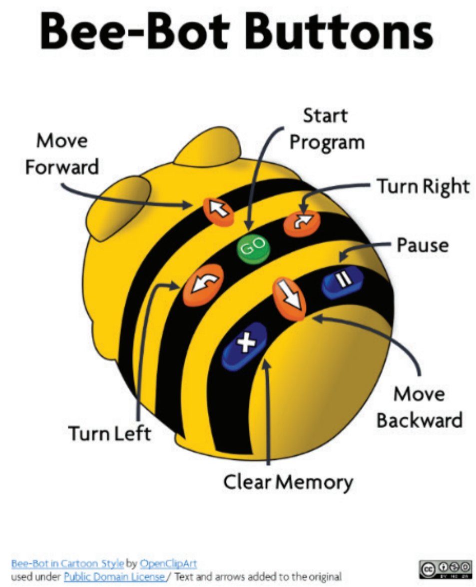
In this era of one-to-one devices, humanoid robots, and artificial intelligence, technologies play an increasing role throughout our society, impacting even the lives of young children. Amid concerns about the negative impacts that the pervasiveness of technology can have on young children's development (American Academy of Pediatrics Council on Communications and Media, 2016), the National Association for the Education of Young Children (NAEYC) has encouraged caregivers to *responsibly* and *intentionally* use technology to support learning and development (2020). The fast-paced nature of technological innovation, however, regularly surfaces discussion about how to integrate teaching methods and technologies in ways that results in responsible, intentional, and effective practices.

There are many different robots designed for use in preK–12 classrooms, and each has their own way for students to program them. The basic idea of programming a classroom robot is communicating students' step-by-step directions (i.e., algorithms) to the robot. This programming can be done in different ways, depending on the type of robot. For example, some robots use a scanner to read an algorithm. Other robots require an externally connected device to send them an algorithm. With a button-operated robot, such as the Bee-Bot illustrated in Figure 1, children program the robot tangibly by manually pressing its buttons to communicate their algorithms. Due to their accessibility to even very young students, button-operated robots have sparked much recent research about their place within a preschool learning environment (McCormick & Hall, 2022).

Since button-operated robots are increasingly used in pre-school settings around the world (Terrapin Logo, 2023), this chapter offers an overview of initial research on their integration with young children. Based on these research findings and the authors' own related studies and experiences, the chapter will detail recommendations for how to intentionally and effectively incorporate button-operated robots to promote learning.

**Figure 1**

*Example of a Button-Operated robot*




## RESEARCH REVIEW

Plowman et al.'s (2010) influential research showed that pre-school children, when playing with computers, could develop content knowledge, technical skills, and dispositions to help sustain their learning. As more recent research extends to other technologies in pre-school settings (Hamilton et al., 2020), similar positive outcomes are evident in the literature on children's interactions with button-operated robots (Misirli et al., 2019). In their review of literature on robotics in preschool settings, McCormick and Hall (2022) noted that most studies observed sequences and events as learning outcomes. These computational terms closely align with the common curricular goals of following steps and identifying cause/effect relationships. Furthermore, preschool children have demonstrated significant gains in their spatial relations knowledge after playing with button-operated robots (Angeli & Valanides, 2020). Therefore, initial research establishes strong potential for button-operated robots to promote children's achievement of learning outcomes (i.e., content knowledge).

The idea of young children playing with button-operated robots might initially seem frivolous, but recent research has also documented the development of their technical skills or ability to operate specific technologies through the use of such robots. Notably, however, Newhouse et al. (2017) found that children developed the technical skills to use robots without much adult support but did not tend to achieve other learning outcomes without scaffolding by an adult. While button-operated robots may be valuable additions to preschool learning environments, Newhouse et al.'s (2017) results highlight the importance of appropriate teaching methods. For example, play and guided interaction from adults are critical supports for young children's positive interactions with digital technologies (Mehta et al., 2020; Plowman et al., 2008). Additional strategies will be detailed in the next section.

## IMPLICATIONS

Drawing together recent empirical work on guiding young children's play with button-operated robots and developmentally appropriate practices (Alqahtani et al., 2022; Hall & McCormick, 2022; NAEYC, 2020), the actionable steps in this section will be organized around Howland et al.'s (2012) five characteristics of meaningful learning: intentional, active, constructive, cooperative, and authentic. This framework was selected for its alignment with NAEYC's (2020) position statement that, "When truly integrated, uses of technology and media become normal and transparent—the child or the educator is focused on the activity or exploration itself, not the technology" (p. 13). Making learning more meaningful with button-operated robots, therefore, involves strategies that recenter children's engagement with meaningful activities, exploration, and play.

### Intentional

The first step toward meaningful integration of button-operated robots is to promote engagement with a problem that children want to solve (Howland et al., 2012). The goals for this kind of intentional engagement are to empower children to solve meaningful problems with tools in their environment, and to give them agency to select and solve the problems (Palmér, 2017).

**Table 1**

*Supporting the Intentional Use of Robots*

| Instructional Approaches | Highlighted Lesson | Additional Resources |
|---|---|---|
| • Select a learning outcome within the content area or developmental domain.<br>• Determine if robots can help children achieve the selected learning outcome.<br>• Design challenges that promote curiosity and exploration.<br>• Create opportunities for children to have choice and voice in the activity.<br>• Incorporate materials that foster imaginative and creative play.<br>• Consider what indicators of learning will be demonstrated through children's play with the robot. | The Bee-Bot Mail activity highlights the intentional use of robots. Note the alignment of learning standards and how the robot supports these goals. Children should have some experience with robots prior to this lesson. This will help them build pre-requisite skills for navigating the robot on the grids (e.g., basic operations, turning the robot). | This openly licensed book chapter, Computational Thinking, discusses computational thinking as a set of problem-solving skills and offers a plethora of resources for intentionally using robots and other tools to foster these skills at various grade levels. The lesson planning resources table at the end of the chapter is especially helpful as it lists several resources designed for grades preK-2. |

#### *Embed Challenges within Invitations to Play*

Play is essential for young children's development, and educators should design experiences that are stimulating, inviting, and filled with choices (NAECY, 2020, p. 22). Rich problems or challenges can be incorporated within these experiences that invite children to investigate and extend their learning (Murcia & Tang, 2019). For example, Hall and McCormick (2022) invited pre-school children to explore how a button-operated robot could help deliver mail throughout the town. Directions and resources for this activity are included in Table 1.

#### *Encourage Children to Set and Achieve Their Own Goals*

In Figure 2, children were trying to program their mail-carrying robots to travel through a cardboard tunnel. There were several obstacles in this environment, but many children were drawn to this tunnel. The two children in this figure set an initial goal of moving a single robot through the tunnel. After achieving this goal, they set a new goal to have two robots move through the tunnel together (Hall & McCormick, 2022). The environment, materials, ratio of devices to children, and classroom routines can all influence what goals children set. For example, the presence of this cardboard tunnel and the one-to-one ratio of robots to children invited the interactions in Figure 2. Meaningful activities, through intentional design, should encourage children to identify and pursue a goal they want to achieve with their robot.

**Figure 2**

*Children engaging the invitation to play*

### *Align Early Learning Standards and Child-Generated Goals*

While the activity in Figure 2 could lead to different goals, most child-generated goals involved moving a robot from point A to point B. An early computer science standard is for children to follow an algorithm to complete a task (New York State Education Department, 2020). In this invitation to play, the children had agency to select their tasks and to then create the accompanying algorithm. Therefore, the likely child-generated goals supported their achievement of the associated early learning standard. An intentional approach, therefore, will consider how the activity's design can nurture child-generated goals that align closely with the intended learning outcomes.

## Active

There is a strong emphasis that young children's engagement with technology should be active. Children should be able to manipulate the tools and explore how they work, control objects in the surrounding environment, and construct meaning by observing the effects of their actions (Howland et al., 2012). NAEYC and the Fred Roger Center for Early Learning and Children's Media (FRC) proposed these active interactions should support various forms of play, creativity, and exploration (2012, p. 7). The nature of button-operated robot activities is active, and the following strategies will support young children's learning from these active experiences.

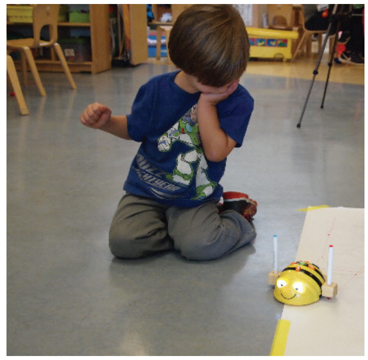
**Table 2**

*Supporting the Active Use of Robots*

| Instructional Approaches | Highlighted Lesson | Additional Resources |
|---|---|---|
| • Focus on the children doing the actual work of manipulating the robot.<br>• Ask questions that help students make sense of the feedback they receive from their actions.<br>• Guide children's thinking about the robot's behavior by providing hints and cues, or by pointing out what peers have done.<br>• Provide just-in-time support as children are debugging errors in their programs. | The Oh the Places Bee-Bots Go activity highlights questioning strategies that can support children's meaning-making when actively using robots. In this activity, robots are integrated in a pre-school blocks center. Facilitators can use the provided question prompts to guide children's thinking about their robot's movement through the blocks. | This website gives a concise introduction to debugging programs in language that is friendly for young children: What Is Debugging?<br>This blog post includes many debugging strategies that can be adapted for use with young children and button-operated robots: 10 Best Practices for Helping Students Debug their Code |

**Figure 3**

*Child observing the robot*



### *Select Robot that Provides Clear Intrinsic Feedback*

Intrinsic feedback is the information one naturally receives from an action they performed. For example, when a child presses a sequence of buttons on the robot, it behaves in a certain way. Button-operated robots can provide this intrinsic feedback in many ways: making a sound or blinking lights to confirm a button is pressed or that an action has been completed, physically moving in the ways that have been communicated, or leaving a trail of where it has traveled (Alqahtani & Hall, 2022). Children interpret robots' actions differently, however, and do not always associate it correctly with how they pressed the robot's buttons (Hall & McCormick, 2022). In Figure 3, the child's hand to his chin and clenched fist indicate that he is noticing the robot is moving beyond the parameters of the paper. The robot's movement provides feedback that too many forward buttons may have been pressed. Another child in this study observed that the robot did not move after pressing the "Go" button several times. While feedback (i.e., non-movement) can indicate different actions are required, children may need additional support to respond with a new action.

### *Scaffold Children's Debugging Process*

Unfortunately, a child's sequence of steps for the robot may sometimes have an error. When robots do not behave as expected, debugging skills become necessary. Debugging is the process of identifying and correcting errors in a program. To identify the errors, it is necessary to help children link the robots' actions with the buttons that were pressed (Hall & McCormick, 2022). This need for debugging signals that the child may be reaching beyond what they can perform proficiently on their own. As such, educators should offer just-in-time support or scaffolding for children who are trying to identify and fix errors in their algorithms (Palmér, 2017). Scaffolding may take various forms (e.g., hints, cues, modeling, peer support, adapting activities and resources), but knowing when it is needed and how to individualize it are essential to supporting children's active use of robots (Murcia & Tang, 2019; NAEYC, 2020).

## Constructive

While educators must ensure that children's experiences with button-operated robots are active, meaningful learning should be a constructive process as well. Aside from manipulating and observing robots, children should express what they have achieved and reflect on their experiences (Howland et al., 2012). Prompting children to articulate their accomplishments can support their social and language development while also sparking their thinking and enhancing their learning (NAEYC, 2020; NAEYC & FRC, 2012). Murcia and Tang (2019), for example, noted that children's engagement and time spent with robots in their study were positively influenced by, "educators' questioning strategies and openness to listening to children's ideas" (p. 11). The following strategies are intended to assist with eliciting children's thinking and listening to their ideas.

**Table 3**

*Supporting the Constructive Use of Robots*

| Instructional Approaches | Highlighted Lesson | Additional Resources |
|---|---|---|
| ● Create opportunities for children to talk about and make sense of their experiences with robots.<br>● Ask questions and encourage children to explain what they did, and how the robot behaved.<br>● Challenge students to articulate what "worked" when their robot behaved as they expected.<br>● Point out places where the robot did not behave as expected and ask questions to prompt reflection.<br>● Encourage children to draw pictures or maps of their robots' movements to explain their algorithms. | The Programming Bee-Bots to Draw Geometric Shapes lesson uses children's drawings and reflection questions to support the constructive use of robots. The article includes directions and files (.stl and .obj) for 3D printing a belt that attaches to Bee-Bots and holds markers. Children can then talk about the drawing their robot made. The questions on page 6 prompt children to reflect upon and discuss what they have achieved. | The Digital Technologies Hub has created multiple robotics lessons for use in early childhood settings. Of note are the varying ways their lessons and resources encourage children's reflection and meaning making. Class discussions and cloze activities are examples of the varied strategies employed throughout their lessons. |

**Figure 4**

*Child pondering the robot activity*

### *Prompt Children to Articulate Their Accomplishments*

Many studies have demonstrated the benefits of asking children to explain what and how they achieved a goal with their robot. Hall and McCormick (2022) noted this was part of the meaning-making process for children in their study, and Alqahtani et al. (2022) had pre-service teachers facilitate conversations with children about what they had achieved with their robot. Given the importance of such discussions and reflection, children should be encouraged to articulate their understandings and accomplishments. See Table 3 for a lesson that purposefully incorporates questions to stimulate children's conversation about what they achieved with their algorithm and how a change in their algorithm would affect their drawings.

### *Support Children's Reflection with Multimodal Materials*

Since button-operated robots store the child-generated algorithms in their internal memories, the algorithms can seem invisible to students. This invisibility can hinder reflection and debugging. However, there are several strategies for making the algorithms visible through varying modalities. The San Francisco Unified School District (2023) has created a series of templates and cards that can visualize children's plans. In other cases, children have drawn their algorithms on paper or combined drawings with arrow cards (Alqahtani et al., 2022; Palmér, 2017). Finally, Alqahtani and Hall (2022) developed a "belt" attachment that could hold markers and visualize the robot's path. Using strategies like these to make the algorithms visible can strongly support students' reflection.

## Cooperative

Conversation and collaboration are key to meaningful learning experiences with robots and critical to a healthy early learning environment (NAEYC, 2020). As children learn to cooperatively work together, they learn to care for one another and the community. When robotics activities are designed intentionally, they can foster this cooperative atmosphere and support goals across domains and subject areas (Howland et al., 2012).

**Table 4**

*Supporting the cooperative use of robots*

| Instructional Approaches | Highlighted Lesson | Additional Resources |
|---|---|---|
| • Consider making "robot time" a group activity rather than an individual activity.<br>• Emphasize cooperation and collaboration by assigning roles.<br>• Have children change roles regularly to vary their experiences working with robots.<br>• Give children prompts or story starters to foster teamwork for sharing about what the robots are going to do.<br>• Ask children to create and share different algorithms that achieve the same objective. | The Let's Help Debug! lesson is designed for children to engage as pair of programmers. They learn to take turns with the robot and how to help a partner identify and fix errors in an algorithm. In this cooperative activity, children are formally introduced to a single role (i.e., Driver) while practicing their skills of communication and debugging. | Computer Science in San Francisco has a series of lesson plans for grades K-2 which scaffold toward higher levels of cooperative programming. Eventually, children work in groups of four and have designated roles (i.e., Driver, Navigator, Debugger, and Designer). These roles can be used along with the provided lessons or adapted for use with other robot learning experiences. |

### *Design Activities to Nurture Conversation*

Research has uncovered stereotypes of programmers as isolated individuals and has found that most coding apps for young children do not support collaboration (Papadakis, 2020; Radloff & Hall, 2022). Meaningful experiences, however, should encourage conversation and can be designed with that aim. For example, children can be asked to work with a partner to create a story using their robot or choreograph a dance routine with a team of robots (Flannery & Bers, 2013). Although each child had their own robot in the block lesson shared in Table 2, they were challenged to collaboratively construct a world out of blocks for their robot to traverse. The activity, therefore, can be designed to foster conversation when children are working with their own robot or shared one with a friend.

**Figure 5**

*Cooperative filming of robots*

### *Setup Classroom Environment to Cultivate Collaboration*

There are many formats (e.g., whole groups, small groups, stations) for organizing learning experiences. Educators can influence learning outcomes by strategically leveraging different learning formats throughout the day. Stations or small groups have worked well to encourage collaboration with button-operated robots (Alqahtani et al., 2022; Hall & McCormick, 2022). Children may engage in parallel play at a station, observe their peers, and attempt copy their sequences; or they may collaborate on a combined problem and share a robot. Alternatively, Figure 5 shows children collaborating to produce a Bee-Bot film during their self-directed play time. Self-directed play has been shown to support learning how to use robots, and making the robots available during these times could spark moments of shared creativity (Newhouse et al., 2017). Additionally, assigning roles on a programming team has been recommended to support collaboration with K-2 learners (Alqahtani & Hall, 2022; Williams, 2017).

## Authentic

Play is essential to children's development, and pretend-play with technologies can be a way to practice skills that transfer to new contexts (NAEYC & FRC, 2012). Therefore, a play-oriented approach can create an authentic context for the integration of button-operated robots (Howland et al., 2012).

**Table 5**

*Supporting the Authentic Use of Robots*

| Instructional Approaches | Highlighted Lesson | Additional Resources |
|---|---|---|
| • Utilize existing classroom stations and add robots to the rotation.<br>• Encourage students to program their robots to act out a story they have heard or one they have created.<br>• Challenge children to develop creative programs for their robots (e.g., making the robot dance along with music, having a robot fashion show where the robot takes a turn down the runway, having a robot race around a track).<br>• Supply various materials for children to create an obstacle course and have their robots navigate it (e.g., applying masking tape to the floor to make robot routes, building mazes with interlocking bricks, or creating cities with wooden blocks or magnetic tiles).<br>• Provide opportunities for self-directed play where children can explore robots in ways that interest them personally. | Code-IT has published several resources for supporting the integration of button-operated robots. Their Introduction to Programming through Guided Bee-Bot Play module illustrates how play can be an authentic context for integrating robots. After beginning with time for unstructured play, children engage in eight guided-play experiences. Most of these activities pair robots with common classroom materials, and accompanying task cards can help guide children's play. | The Incorporating Robotics Across the Curriculum article from Edutopia includes specific suggestions for teachers interested in integrating robotics into active learning experiences across a variety of curricular areas, from math and science to language arts and social studies. Ideas for performance tasks and sample lesson plans are included. |

### *Play!*

The many forms of play, which NAEYC has listed as "self-directed, guided, solitary, parallel, social, cooperative, onlooker, object, fantasy, physical, constructive, and games with rules" (2022, p. 9), can be used to connect characteristics of meaningful learning in a way that is natural and highly beneficial. Planning for play-based integration of robotics may not need to stray far from the established norms and context. For example, existing classroom stations (e.g., blocks/construction, dramatic play, and arts) can be the basis for integrating button-operated robots in a variety of ways that are authentic and seamless (Hall & McCormick, 2022). Whether adapting lessons from this chapter, modifying an existing classroom station, or designing new play-based experiences, the strategies in this chapter can infuse the experience with meaning—making learning with button-operated robots more intentional, active, constructive, cooperative, and authentic.

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## APPENDIX

**Table 6**

*Web Addresses for Resources that were Hyperlinked in the Chapter*

| Resource | Web Address |
|---|---|
| All lessons and resources that were highlighted in the previous tables are included in this shared folder. | https://bit.ly/highlightedlessons |
| 10 Best Practices for Helping Students Debug their Code | https://mrtower.wordpress.com/2020/07/09/10-best-practices-for-helping-students-debug-their-code/ |
| Code-IT | http://code-it.co.uk/beebot |
| Computational Thinking | https://edtechbooks.org/k12handbook/computational_thinking |
| Computer Science in San Francisco | https://sites.google.com/sfusd.edu/k-2cs/home?authuser=0 |
| Digital Technologies Hub | https://www.digitaltechnologieshub.edu.au/ |
| Incorporating Robotics Across the Curriculum | https://www.edutopia.org/article/incorporating-robotics-across-curriculum/ |
| What Is Debugging? | https://www.theschoolrun.com/what-debugging |