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Chapter 10

Dancing, Drawing, and Dramatic Robots: Integrating Robotics and the Arts to Teach Foundational STEAM Concepts to Young Children

Amanda Sullivan, Amanda Strawhacker and Marina Umaschi Bers

Abstract In recent years, there has been an increasing national focus on the importance of Science, Technology, Engineering, and Math (STEM) education for young children beginning in kindergarten. This chapter explores the newest acronym, "STEAM," which integrates the Arts with STEM education. While many assume the "A" in STEAM refers only to the fine arts, the full potential of STEAM goes beyond aesthetics to include language arts, culture, history, and the humanities. The emerging domain of robotics offers playful strategies for engaging young children with the technology and engineering components of STEM. Additionally, when implemented thoughtfully, robotics is a creative medium with the power to engage young children in the arts and humanities. KIBO is a newly developed robotics construction set specifically designed for children ages 4–7 years to learn foundational engineering and programming content in a hands-on, open-ended way—no screen-time required! This chapter presents vignettes of three interdisciplinary robotics curricular units that utilize the KIBO Robotics Kit: (1) *Dances from Around the World*, (2) *Art-Making Robots*, and (3) *Superhero Bots*. It highlights strategies for taking a child-focused approach to robotics education by drawing on student interest in music, visual arts, and literature when exploring foundational technological ideas.

Keywords Robotics · Early childhood · Humanities · Arts · STEAM

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10.1 Introduction

> The difference between science and the arts is not that they are different sides of the same coin [...] or even different parts of the same continuum, but rather, they are manifestations of the same thing. The arts and sciences are avatars of human creativity.
>
> —Mae Jemison, doctor, dancer, and first African-American woman in space

Science, technology, engineering, and mathematics (STEM) education has been of growing importance to educators and researchers working with young children. In recent years, there has been a particular focus on addressing the "T" of technology and "E" of engineering in early childhood education through robotics and computer programming applications. This is partially due to federal education programs and private initiatives making computer science and technological literacy a priority for young children in a growing number of countries worldwide (e.g., U.S. Department of Education 2010; UK Department of Education 2013). However, as technology has grown in prevalence in schools and at home, some researchers and educators have also expressed concern that excessive usage of computers and digital technologies may actually stifle children's learning and creativity through passive consumption of media (Cordes and Miller 2000; Oppenheimer 2003). In order to address these concerns, there is a growing body of work on how technology can be used to foster positive behaviors and engage children as *creators* rather than *consumers* of digital content (Bers 2012; Resnick 2006). One way to do this is by explicitly integrating the arts, self-expression, and identity exploration with traditional technology and engineering curricula for young children.

Over the past few years, there has been growing enthusiasm about integrating the arts with STEM in early childhood settings. This trend is clear in school curricula, new educational initiatives, and even in popular children's media. In the 43rd season of *Sesame Street* (which was aired from 2012 to 2013), the television show continued its introduction of STEM education with the addition of arts, introducing viewers to the acronym of STEAM (Science, Technology, Engineering, *Arts*, and Mathematics) for the first time on the show (Maeda 2012). This milestone for the STEAM movement was achieved surprisingly quickly, as it was only one year prior that Elmo was interviewed on CNN about the importance of STEM (Maeda 2012).

The STEAM movement was originally spearheaded by the Rhode Island School of Design (RISD) but is now widely adopted by schools, businesses, and individuals (STEM to STEAM 2016). In some ways, it is surprising that the STEM education movement has not always included an integration of the arts. Historically, there have been a countless brilliant innovators, such as Leonardo Da Vinci and Frank Lloyd Wright, who have woven together the fields of art and science seamlessly in their work. Many modern innovations have also resulted from an integration of the arts with STEM. For example, the computer chips that run almost all of our digital devices are made using a combination of three classic artistic inventions: etching, silk screen printing, and photolithography (Root-Bernstein 2011). Today, it is estimated that Nobel laureates in the sciences are seventeen times likelier than the average scientist to be a painter, twelve times as likely to be a poet, and four times as likely to be a musician (Pomeroy 2012). This is likely because the arts, such as science, technology, engineering, and mathematics, are rooted in a similar mindset of curiosity and creativity.

It is clear that the arts have a place in the exploration of technology and the sciences, but *how* educators bring these fields together effectively can be a challenging question, particularly during the early childhood years (ages 4–7 years) when teachers are already juggling a large load of foundational content that needs to be covered. This chapter describes how robotics can be used as a creative medium for young children to playfully explore STEAM content in a developmentally appropriate way. It presents three illustrative vignettes that highlight different interpretations of the "A" in STEAM, all using the newly developed KIBO robotics kit developed by the DevTech Research Group at Tufts University and KinderLab Robotics (Sullivan et al. 2015). The goal of this work is to provide readers with examples of how robotic tools like KIBO can facilitate STEAM learning in a natural way that can easily tie in with content educators are already teaching. Additionally, it demonstrates examples of how STEAM curricula can be implemented in different learning environments such as formal classrooms, camps, and extracurricular clubs.

10.2 Literature Review

10.2.1 Moving from STEM to STEAM in Early Childhood

Historically, early childhood education has focused on building foundational numeracy skills and an understanding of the natural sciences when it came to STEM (Science, Technology, Engineering, Mathematics) education for young children (Bers 2008; Bers et al. 2013). In the growing national-level discussion around STEM, the question of how to teach technology and engineering has become more pressing (UK Department of Education 2013; US Department of Education 2010). New education policy changes, commercial products, and non-profit organizations are promoting a message that highlights the benefits of computational thinking, digital citizenship, and technological literacy (Bers 2012; Hobbs 2010; Hollandsworth et al. 2011; White House 2011; Wing 2006). However, this increased focus on children's usage of computers and digital technology has also sparked some concern that children's natural play and creativity may be stifled by these tools (Cordes and Miller 2000; Oppenheimer 2003). Adding the arts to STEM-based subjects, such as computer programming and engineering, may enhance student learning by infusing opportunities for creativity and innovation (Robelen 2011).

This concept of promoting creativity and expression through technology is articulated in a newer acronym called "STEAM" (Science, Technology, Engineering, *Arts*, Mathematics) that is growing in popularity (Yakman 2008). The "A" of STEAM can represent more than just the visual arts, but rather a broad spectrum of the humanities including the liberal arts, language arts, social studies, music, culture, and more. For example, Maguth (2012) proposed that social studies content should also be integrated into a STEM-focused curriculum in order to promote the development of well-rounded citizens prepared for voting on ethical and social issues related to STEM. New technologies, such as programmable robotics kits described in the following section, offer innovative ways to integrate the arts with traditional technology and engineering content.

10.2.2 Robotics in Early Childhood Education

Early childhood is an important time to explore the arts and play, as children need hands-on experiences to construct their own learning (Papert 1980). Although robotics and programming can seem rigid, there is much room in these fields for creativity and innovation (Resnick 2006). Digital media, when designed within developmentally appropriate guidelines, can afford children the same opportunities for exploration and construction that traditional learning tools offer (Bers 2008). In research trials with simple robotics and programming languages, children as young as 4 years old demonstrated understanding of foundational engineering and robotics content, (Bers et al. 2002; Sullivan et al. 2013; Sullivan and Bers 2015; Cejka et al. 2006; Perlman 1976; Wyeth 2008). In addition to mastering this new content, programming interventions have been shown to have positive benefits for children's developing numeracy, literacy, and visual memory, and can even prompt collaboration and teamwork (Clements 1999; Lee et al. 2013).

New developmentally appropriate technological software and robotic kits have evolved in the tradition of educational manipulatives such as Froebel's "gifts," Montessori materials, and Nicholson's loose parts, and like their predecessors, these tools allow children to explore their understanding of shape and number, spatial relations, and proportion (Kuh 2014; Nicholson 1972; Resnick et al. 1998; Brosterman 1997). However, cognitive development is not the only area of growth for young children, and "screen time" is a serious concern for learners at this age (American Academy of Pediatrics 2003). Robotics curricula are now being developed to address children's need to move, dance, and push their physical boundaries. For example, when constructing a robot with many parts, children may exercise fine motor skills, and when observing a robot's movements, children are compelled to move and dance along, developing their hand-eye coordination and gross-motor activity (Resnick et al. 1998).

10.2.3 The KIBO Robotics Kit

KIBO is a robotics kit designed specifically to playfully introduce young children (ages 4–7 years) to foundational engineering, programming, and computational thinking concepts through tangible "screen-free" activities (Bers 2017; Sullivan et al. 2015). KIBO was created based on research by the Developmental Technologies Research Group at Tufts University and made commercially available through funding from the National Science Foundation (NSF) and a successful Kickstarter campaign (Sullivan et al. 2015). KIBO is unique as compared to its counterparts on the commercial market because it engages children with both building with robotic parts (KIBO's hardware) and programming KIBO to move with tangible programming blocks (KIBO's software). KIBO is designed based on years of child development research at Tufts University and is intended explicitly to meet the developmental needs of young children (e.g., Sullivan and Bers 2015; Sullivan et al. 2015; Kazakoff and Bers 2012). The kit contains easy-to-connect construction materials including wheels, motors, light output, a variety of sensors, and wooden art platforms (see Fig. 10.1).

KIBO is programmed to move using a tangible programming language that consists of eighteen interlocking wooden programming blocks and 12 parameters (see Fig. 10.2). With just eighteen blocks, children are able to master increasingly complex computational thinking concepts such as repeat loops, conditional statements, and nesting statements (Bers 2017). These wooden blocks resemble familiar early childhood manipulatives such as alphabet blocks and contain no embedded electronics or digital components. Instead, KIBO's main body has an embedded scanner that scans the barcodes on the programming blocks in order to "read" the program the child has

Fig. 10.1 The KIBO robot with sensors, light output, and sample block program

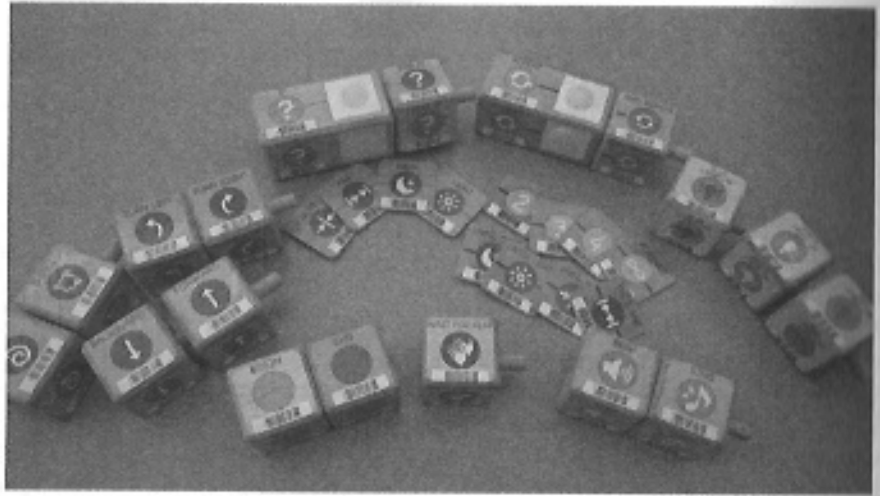


Fig. 10.2 KIBO's tangible programming language

created. Once the program has been scanned, it is saved on the robot instantly. No interaction with a computer, tablet, or other screen-based software is required to learn programming with KIBO. This tangible approach to computer programming is developmentally appropriate for young children and is aligned with the American Academy of Pediatrics' recommendation that young children have a limited amount of screen time per day (American Academy of Pediatrics 2003).

10.2.4 Exploring STEAM Through KIBO

The KIBO robot is well suited to exploring a variety of STEAM concepts. From a technology and engineering perspective, children can use the kit to learn about basic electronic elements they encounter everyday but may not understand, such as wires, batteries, computer chips, motors, sensors, and light bulbs. Additionally, children can explore foundational programming concepts such as sequencing, repeat loops, and conditional statements in order to make their robot move.

Along with these robotic and programming components, the KIBO kit also contains art platforms that can be used for children to personalize their projects with craft materials in order to foster STEAM integration. Unlike KIBO, many robots for young children come out of the box already decorated to look like a toy or creature. For example, the Beebot (a programmable floor robot developed for preschoolers) is designed to look like a bumblebee. The Wonder Workshop robots Bo and Yana (robots programmed through an ipad application) are round and blue with large eye in the center, resembling a friendly creature. KIBO on the other hand does not look like anything until the child places his or her imagination on it. It does not have a face and is constructed of neutral colors and wooden materials, in the style of Reggio-Emilia child manipulative design (Strong-Wilson and Ellis 2007; Kuh 2014). Like an unsculpted wad of play-dough, KIBO looks and feels differently each time the child uses it, which makes the robot ideal for an integration of the arts (see Figs. 10.3 and 10.4). The following section will provide three vignettes of the KIBO robot as it has been used in different types of playful learning settings to explore STEAM content.

10.2.5 Designing STEAM Curricula with KIBO

It can be challenging to design STEAM activities for young children that not only promote technological content, but also foster elements of personal and interpersonal skills that are critical to early childhood development. Bers' (2012) Positive Technological Development Framework (PTD) provides a framework to guide educators in the creation of effective pedagogy and classroom practices. The PTD framework is rooted in the field of applied child development and is based on the Positive Youth Development framework created by Lerner et al. (2005) and Constructionist theory (Papert, 1980). PTD focuses on enhancing positive skills and behaviors in children by describing "6 Cs" that the digital world offers to promote healthy development in our youth: communication, collaboration, community building, content creation, creativity, and choices of conduct. Each of the vignettes in the following section feature curriculum that was developed with these 6 C's in

Fig. 10.3 Sample KIBO construction

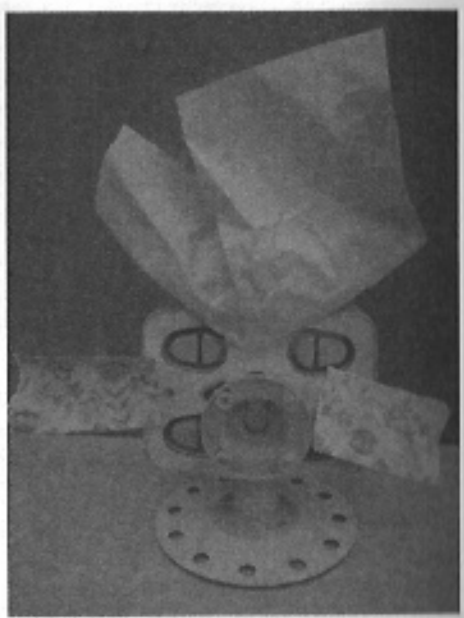


Fig. 10.4 Sample KIBO kinetic sculpture

mind. They provide examples of children not only engaging with content creation through robotics and the arts, but also communicating with one another, sharing their work with a larger community, and creatively following their passions.

10.3 Vignette 1: Art-Bots

10.3.1 Curriculum Overview

Children can gain their first taste of the art world by exploring, manipulating, and playing with tactile and visual art materials. From finger-painting to sculting clay, art has traditionally been a core component of early childhood education (Althouse et al. 2003). In the early childhood years, the visual arts are typically composed of drawing, painting, arts and crafts, and sculpting with materials such as clay and play-dough (2003). This exploration of drawing, painting, and crafting naturally aligns with elements of STEM such as geometry, engineering sturdy structures, and iteratively bringing designs to life. In the Art-Bots curriculum, the visual arts are integrated in two specific ways: (1) through the design and decoration of the KIBO robot and (2) by programming KIBO to draw and paint on paper. This curriculum focuses explicitly on the technology, engineering, math, and art components of STEAM.

10.3.2 Educational Environment

The art-making robots activity can apply to a variety of educational settings including classrooms, clubs, and at home. In this example, Art-Bots were explored in an extracurricular Saturday extracurricular club called the "Saturday STEM Series." Over the course of five weeks, the Saturday STEM club met once a week for a six-hour period to explore different concepts such as the engineering design process, animations and storytelling, robotics, programming, and more. Unlike formal school classrooms, this STEM series was open to a mixed-age group of children in Kindergarten through second grade. Therefore, the series was typically made up of a diverse group of approximately 10 children including boys and girls from both public and private schools ranging from 5 to 7 years old. This mixed-age learning setting more closely resembled a Montessori classroom or an informal play environment than a traditional classroom.

10.3.3 STEAM Concepts Explored

This STEM-Saturday session was scheduled as a culmination to prior sessions that introduced foundational KIBO robotics and programming concepts. Children were already familiar with this robotic kit and basic concepts of coding and engineering. For this reason, this activity was not an introductory robotics exploration, but more like creative free play using a familiar technological tool.

10.3.4 The Engineering Design Process

The Art-Bots curriculum introduced young children to the engineering design process by giving children the challenge of building a 3-dimensional structure on top of KIBO's art platforms. This structure could be motorized or static, but needed to be secure enough that when KIBO executed a program the structure stayed securely connected to the robot. This encouraged children to focus on the steps of the engineering design process. In particular, children practiced testing and improving their robot by trying out various types of materials, testing out different programs, and experimenting with ways to attach the structures to their robot.

The engineering design process provides children with a cyclical way to satisfy their budding curiosity about the world by asking questions or posing problems that they are personally interested in investigating (see Fig. 10.5). Early childhood is an ideal time to begin teaching engineering concepts because children are naturally inquisitive about the world around them and are motivated to explore, build, and discover answers to their big questions. The engineering design process refers to the iterative process engineers use to design an artifact in order to meet a need (Bers

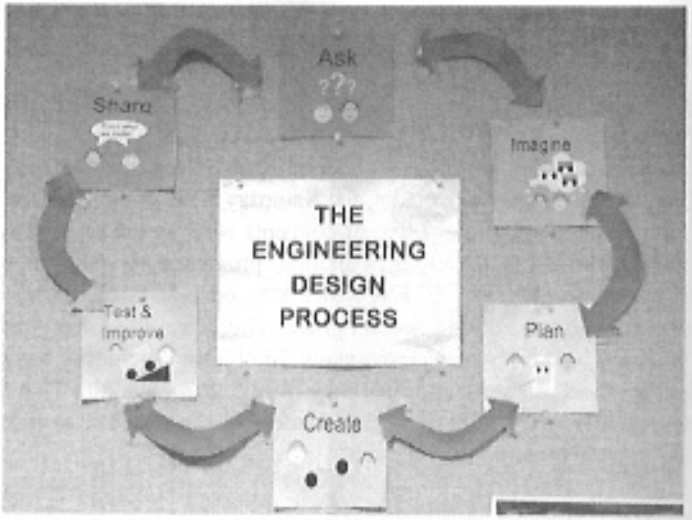


Fig. 10.5 Engineering design process classroom poster

2010). Although it is a fluid process, its steps typically include some variation of the following: identifying a problem, looking for ideas for solutions and choosing one, developing a prototype, testing, improving, and sharing solutions with others (MA DOE 2006). The curriculum adapted this definition for use with children ages 5–7 years. The STEM-Saturday instructors paid particular attention to the steps of testing and improving, which require problem solving and perseverance, critical skills for young children's social and emotional development.

Children were given access to a range of materials including paper, play-dough, legos, tissue paper, cardboard, and other recycled and craft materials. They were given open-ended prompting about the type of structure they could create; therefore, the challenge was interpreted in a variety of ways. While some children created little kinetic sculptures of things such as people and animals (see Figs. 10.6 and 10.7), other children created more abstract decorations (see Figs. 10.8 and 10.9).

10.3.5 *Geometry*

Once children felt comfortable with artistic design and decorating their robots, the unit continued with an exploration of creating lines and shapes through movement. Children brainstormed the different two-dimensional shapes they were familiar with and practiced drawing squares, circles, trapezoids, diamonds, and more on paper. Then, they were presented with this question: Can KIBO draw any of these shapes? As a group, the class made hypotheses as to which shapes KIBO could or could not

Fig. 10.6 Human-inspired KIBO decorations

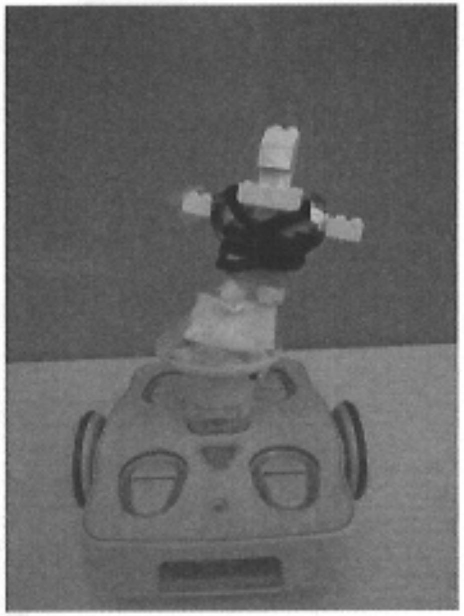


Fig. 10.7 Animal inspired KIBO decorations

Fig. 10.8 Abstract KIBO decoration

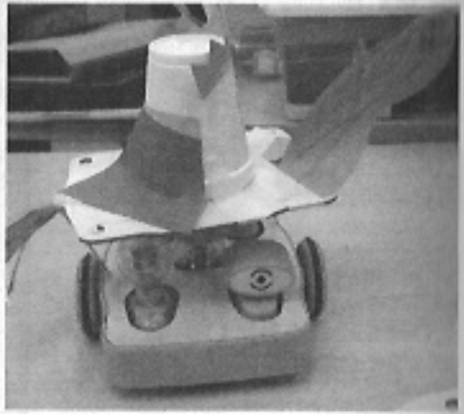
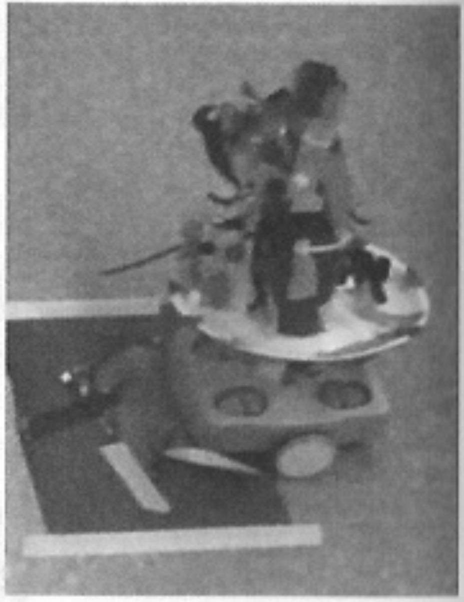


Fig. 10.9 Mixed-media KIBO decoration



draw with its current programming language. This led to a group dialogue on KIBOs ability to draw a circle, with some children arguing that KIBO's straight-line movements could not allow for a curved shape.

To test these hypotheses, the group returned to the engineering design process to plan how they would test and improve their hardware creations so that KIBO could draw (i.e., attaching pens and markers securely to their KIBO, see Fig. 10.10) and how they would create programs that would make KIBO draw the different shapes (i.e., which blocks would make KIBO draw a square versus a circle, see Fig. 10.11). After a few experiments with robots and children's own movements, the group agreed that KIBO could make curves using "turn" movements and its "spin" block (see Fig. 10.12). This moment of math exploration, driven purely by children's curiosity, is reminiscent of the turtle-geometry described by Papert (1980), in which he discusses how children using LOGO who made many small straight lines eventually discovered that by changing angles, they could create different shapes and even curves and circles.

Fig. 10.10 Children programmed their robot to draw a straight line on paper

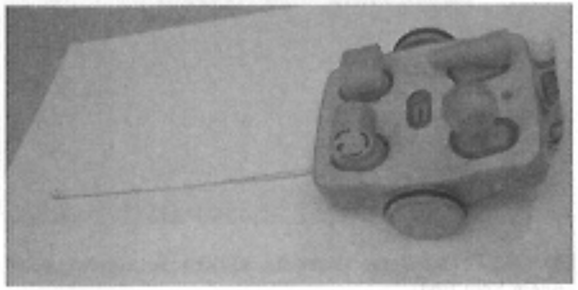
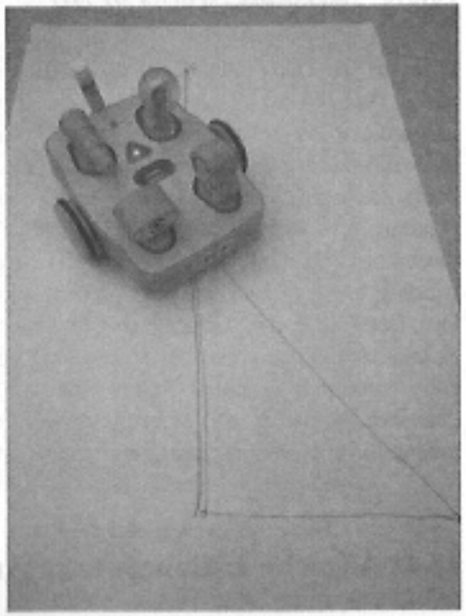


Fig. 10.11 Children combined lines to create shapes such as triangles, stars, and squares with KIBO



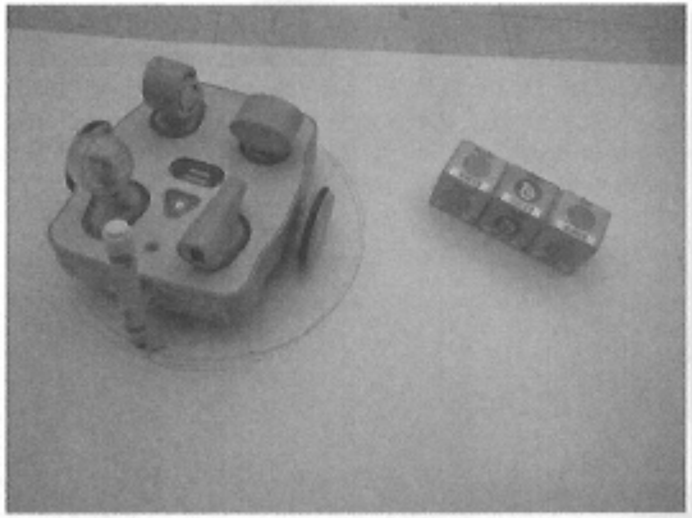


Fig. 10.12 This figure shows the KIBO robot drawing a circle and its accompanying program (Begin Spin End)

10.3.6 Creating Works of Art

Last but not least, the Art-Bots curriculum focused on artistic expression and design (see Fig 10.13). As a group they investigated different artistic styles such as watercolor paintings, abstract art, and photo-realism as expressed by favorite picture book illustrators such as Eric Carle and Lois Ehlert. Children were then given time to freely create any illustrations they chose using KIBO to guide their art materials. In planning how to make their "robot artists," children considered the techniques that illustrators might use to achieve different effects (e.g., short movements and long winding brushstrokes), and the programming blocks necessary to capture the same look (see Fig. 10.14). Children moved their own arms and bodies, and spoke out loud as they considered what they were doing and how they would instruct a machine to carry out these motions. Again, this recalls the self-reflective thinking strategies described by Papert, who argued that these "meta-cognitive" learning opportunities are unique to programming and robotic experiences (Papert 1980).

10.4 Vignette 2: Dances from Around the World

10.4.1 Curriculum Overview

In this vignette, the arts are explored with KIBO through a formal curricular unit called "Dances from Around the World." The Dances from Around the World unit is designed to combine music, culture, dance, and language with programming and engineering content. While the Art-Bots activity was completed during one six-hour Saturday session, the Dances from Around the World unit was covered over the course of approximately seven weeks in a formal school setting. Each

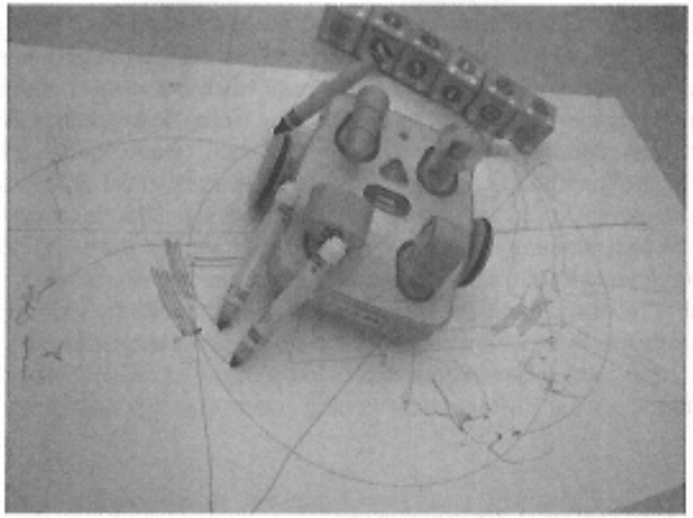


Fig. 10.13 Children created visual works of art using traditional art tools attached to the front and sides of KIBO

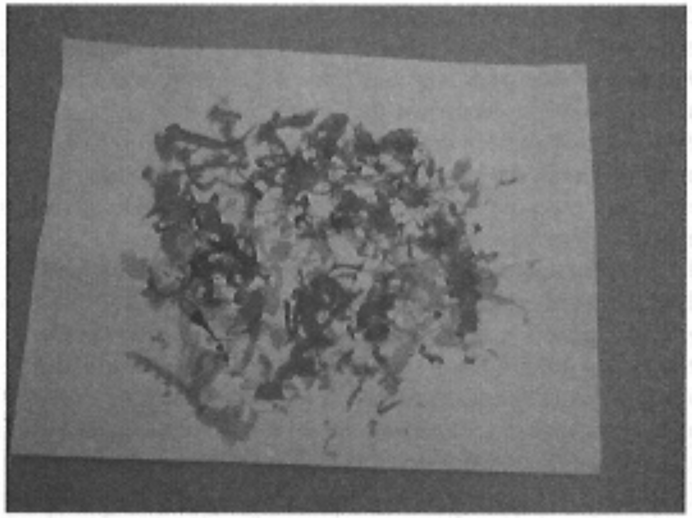


Fig. 10.14 This painting was made using paintbrushes taped onto KIBO

week, teachers introduced new robotics and programming concepts, from basic sequencing through conditional statements, to their students within the curriculum's music and dance theme. For example, in order to teach the concept of sequencing, children programmed their robots to dance to the Hokey-Pokey with them.

Lessons took place for approximately one hour once a week, leading up to a final project. For the final project, students worked in pairs or small groups to design, build, and program a cultural dance of their choosing. This involved not only robotics and programming knowledge, but also research into the music, the history and cultural relevance of the dance, and facts about the country in which the dance originated. The unit culminated in a dance recital for both the children and the robots to perform in together. Finally, their hard work was celebrated when they received certificates showcasing their knowledge of KIBO robotics and engineering.

10.4.2 Educational Environment

The Dances from Around the World curriculum unit was developed by the DevTech Research Group at Tufts University. It has been used with a variety of schools, camps, and after-school programs across the USA. The unit is now freely available on DevTech's online community the Early Childhood Robotics Network (http://www.tkroboticsnetwork.ning.com) and is therefore available to educators nation and worldwide to adapt and use in their own classrooms. The unit was originally developed for use in an urban public school in Boston, USA, during the piloting phase of the KIBO robot. However, it was recently adapted by five preschool centers in Singapore integrating robotics into their classrooms for the first time. The Singaporean preschools serve as the setting for this vignette.

In order to address the growing need for promoting technological literacy in early childhood classrooms, Singapore's newly launched PlayMaker Programme was released as part of a master plan to introduce younger children to technology (Digital News Asia 2015; Chambers 2015). As part of the PlayMaker Programme initiative, approximately 160 preschool centers across Singapore were given innovative new technological toys that engage children with robotics, programming, building, and engineering including: BeeBot, Circuit Stickers, and KIBO robotics (Chambers 2015). In addition to the new tools, early childhood educators also received training at a one-day symposium on how to use and teach with each of these tools (Chambers 2015).

For the five centers exploring KIBO, the Dances from Around the World unit was chosen because it ties in naturally with the multicultural and bilingual Singaporean community. Singapore has four official languages (English, Mandarin, Tamil, and Malay) and a bilingual education policy where all students in public government schools are taught English as their primary language. However, students also learn another language called their "Mother Tongue," in addition to English. This mother tongue might be Mandarin, Malay, or Tamil depending on the community the school is located in. Because Singaporean children speak different languages and have different cultural backgrounds, the Dances from Around curriculum easily integrated into the cultural appreciation and awareness units already taught in the preschool classes.

10.4.3 STEAM Concepts Addressed

Students covered different STEAM concepts each week, primarily related to technology, engineering, music, and culture. For their final dancing robots, children worked in groups of 2–3 and utilized their existing knowledge of KIBO to create robotic projects that represented the cultural tradition of their choosing.

10.4.4 Music and Dance

Throughout the curriculum children were invited to listen to music drawing on a variety of cultural styles. Varied examples of music and choreographed dances from international traditions, such as the Chinese Lion Dance and Indian Bhangra, were presented to children during play and lesson times. While listening to songs, children spontaneously danced along and became inspired by the videos they had watched with their classmates. This exploration of sound, rhythm, and performance led children to consider dance and elements of movement. They explored behind-the-scenes elements of performance, such as the dancers underneath the Chinese Lion costume.

Later in the curriculum, children became dance choreographers and directors as part of their robotic exploration. Children and teachers chose songs from the class's earlier music explorations and programmed their robots to complete special dance moves in time to the songs. After their robot was programmed the way they wanted, children choreographed their own moves to act out along with the robot. In this way, children explored elements of stage production, as they practiced being live performers, creative directors of the performance, and even the engineers who ensured that the technology and equipment (i.e., the robot and program) were ready for the show.

10.4.5 Repeat Loops and Patterns

While children were free to choose from any of the blocks in KIBO's programming language, many chose to use the Repeat blocks in order to choreograph a dance for their robot that included repetition and patterns. Repeat loops are a foundational concept in computer programming that refers to a sequence of instructions that is continually repeated until a certain condition is reached. In the lessons leading up to the final project, children explored what it means to repeat something and how to do this with KIBO's Repeat blocks. The repeat loops are considered an advanced KIBO programming concept because it requires mastery of a new syntactical rule: KIBO will only repeat what is *between* the "Repeat" and "End Repeat" blocks (See Fig. 10.15). Finally, the Repeat loops must be modified with parameters that dictate how many times the sequence will repeat. These can be numerical parameters or sensor parameters. For example, with a numerical parameter, a child might program KIBO to shake three times. With a sensor parameter, a child might program KIBO to shake until it senses it is near something.

As children worked on their final projects, they drew on their knowledge of Repeat Loops in order to create programs that matched the songs (or clips of songs) their robots would be dancing to. In order to match the song's duration, children experimented with different number parameters that would achieve the correct length of KIBO dance time. Other children used the Repeat blocks to create a dance with only certain dance moves that were repeated, and others that happened just once. The end result was a diverse display of complex robot choreography with a mix of repeated and isolated dance moves.

10.4.6 *Expressions of Culture*

Children and teachers used the Dances from Around the World curriculum to explore the Chinese, Indian, and Malay cultures that comprise most of the population of Singapore. This manifested itself in different ways for the varying preschool classrooms. For example, some classrooms spent time learning about the foods, clothing, and languages unique to each culture in addition to the music and dance. Children were also encouraged to think about and explore their own cultural backgrounds through discussions with their families at home.

Fig. 10.15 This photograph shows a sample KIBO program using repeat loops. In this program, KIBO would shake 3 times, but only beep once because the Beep block is outside of the Repeat loop

For the final dance recital, students found a variety of ways to express the culture that inspired their dancing robots. Some groups focused on cultural "clothing" for their robot by using arts, crafts, and recycled materials to create performing costumes for KIBO (see Figs. 10.16 and 10.17). Others focused primarily on programming dance moves to accurately resemble the actions of the dance they studied. Still other groups took a more immersive approach to representing the culture they explored with their robotics projects. These students wore clothing to represent the culture of their dance, learned portions of songs themselves, and danced along with their KIBO robots at the recital (see Fig. 10.18).

Fig. 10.16 Child-made KIBO costumes for recital

Fig. 10.17 Child-made KIBO puppets for recital

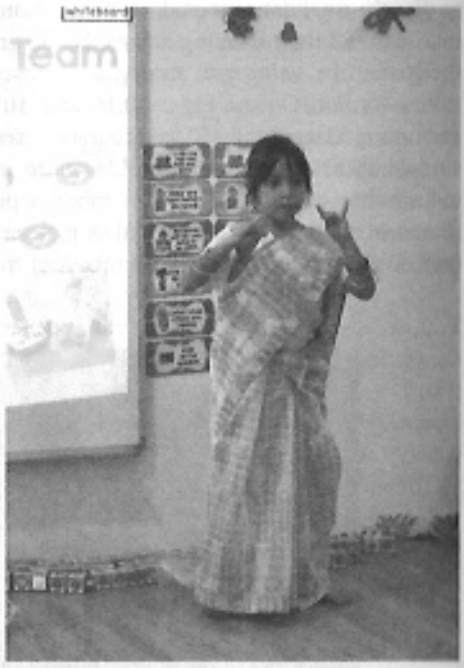


Fig. 10.18 Child wears traditional Indian clothes while performing a dance with KIBO

10.5 Vignette 3: Superhero Bots

10.5.1 Curriculum Overview

From Superman to The Incredibles, children have always had a fascination with superhero (and super-villain) characters (Jones 2008). The Superhero Bots unit incorporates an exploration of programming and robotics (with a special emphasis on sensors) and integrates it with an investigation of superheroes from an interpersonal perspective. This unit leans more on the humanities and civics portion of the arts, by engaging children in discussions of leadership and decision-making. Also, since superheroes are typically rooted in back-stories and sagas involving other characters and important moments in their lives, this unit involves drama and storytelling elements that enrich the meaning of the robotic creation that children produce.

10.5.2 Educational Setting

The Superhero Bots curriculum was recently implemented in a one-week robotics summer camp for children entering kindergarten through second grade. The camp met for five half-days (approximately four hours each day) and culminated in an open-house showcase of the children's work that parents, families, friends, and babysitters were invited to attend. Each camp group consisted of approximately 8–10 children and was taught by a college undergraduate or graduate student studying education and technology.

The camp atmosphere provided an informal play and learning environment, which made the superhero content appropriately light-hearted and fun. With the loosely structured days, counselors had time to indulge in extended fantasy and free-play time, which added to the joy of the content. In addition to the time spent on deeper discussions of story structures and personal character, children crafted silly superhero masks and capes, and imagined superhero powers and identities for themselves. This imaginary play helped inspire the robotic constructions that students created for their final projects.

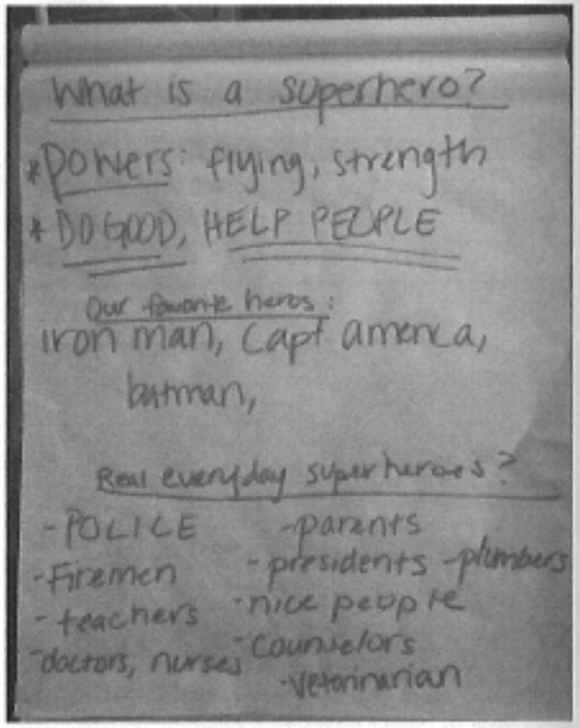
10.5.3 STEAM Concepts Addressed

Children attending this camp were able to spend several hours at a time exploring the robotic components (interspersed with non-robotic games and activities), and they quickly progressed to the more complex elements of the KIBO. Children in the robotics camp explored how to program the sound, distance, and light sensor modules to react to stimuli using conditional "If" statement blocks. In this way, they were able to create interactive robotic creations that could react to the surrounding environment. This exploration of advanced programming blocks was integrated with a discussion on what it means to be a hero and rehearsals for their showcase at the end of the week.

10.5.4 Identity and Civic Engagement

When beginning to work on the superhero projects, the children had a group discussion with their counselor in order to answer this question: What makes someone a hero? Initially children focused on super-abilities such as flying, super strength, and invisibility. However, when prompted to think of some super villains or classic "bad guys" who *also* had many of these super-abilities, the children came to a new conclusion: superheroes strive to "do good" in the world. This child-led discussion naturally came to the conclusion that there are also "everyday superheroes" in the world and they brainstormed a long list that included firefighters, teachers, doctors, and even their parents and friends to inspire the superhero robots they would design for their projects (see Fig. 10.19).

While many superhero movies and shows portray conflicts as black and white, good or bad, the children in this camp came to a conclusion that everyone faces choices each day and that even good people can make mistakes and bad decisions. Finally, they talked about the ways that they can be "everyday heroes" through their



What is a superhero?
*Powers: flying, strength
*DO GOOD, HELP PEOPLE

Our favorite heros:
iron man, Capt america,
batman,

Real everyday superheroes?
-POLICE -parents
-Firemen -presidents -plumbers
-teachers -nice people
-doctors, nurses -Counselors
-Veterinarian

Fig. 10.19 Children's ideas about what makes a superhero

choices in actions such as being a good friend, helping at home, and recycling. These actions were used to help children brainstorm their own superhero characters and personalities that would be brought to life through KIBO.

10.5.5 Sensing Robots

The sensor components of the KIBO robot are among the most complex and engaging parts of the KIBO kit. To introduce the concept of a sensor, counselors first discussed human body parts and our own five senses that allow us to take in information about our environments. Similarly, KIBO's distance, light, and sound sensors allow the robot to take in information about the environment.

Because the children had already expressed their fascination with their favorite superheroes' powers, the sensors were introduced as KIBO's "super senses" that allow it to perform extraordinary tasks. As children were designing their Super Bots to react to the environment in order to help others, they took into consideration the skills that KIBO's different sensors provide. For example, one boy used the KIBO's ear-shaped sound sensor and the accompanying Wait For Clap block. This, he explained in his accompanying story, was how his robot hero "listens for calls for help." Another child used the light sensor to detect when it was dark out. When KIBO sensed it was dark, it was programmed to turn on a helpful bright light (using KIBO's light output) to patrol for "bad guys" and guide others to safety (see Fig. 10.20). By using the superhero context which was engaging to the campers, children were motivated to use these complex robotic and programming elements in order to continually improve and refine the design of their robots.

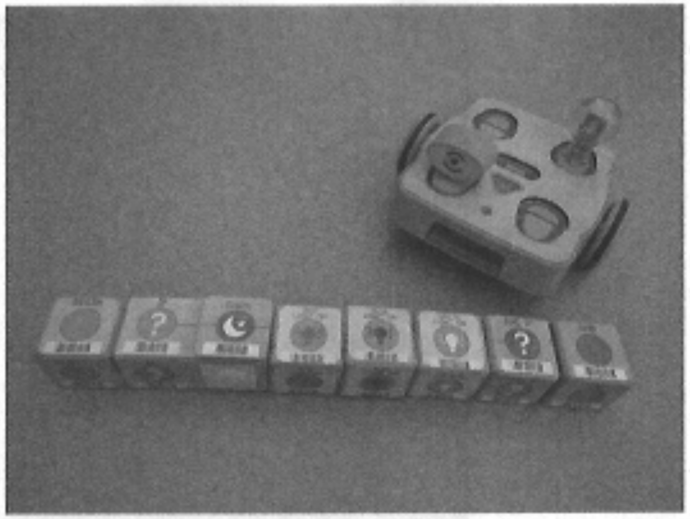


Fig. 10.20 Robot with light sensor and light output, and program to turn on lightbulb in the dark

10.5.6 Storytelling and Drama

With their knowledge of KIBO's special sensing abilities as well as a discussion about civic engagement and what it means to be a hero, children let their imaginations run wild as they planned out their own KIBO robots. This process involved discussion and brainstorming, drawing characters, and planning out the KIBO programming blocks that would be used to bring their superhero robots to life. They used arts, crafts, and recycled materials to build their final superhero robots and spent several hours working to program their robot in a way that would showcase its special abilities (see Fig. 10.21).

During this process, the counselors also encouraged children to engage in dramatic free-play that involved making capes, dressing up as superheroes, and constructing an imaginary world populated their favorite heroes. They were also encouraged to think of a story for their super KIBOs, and they read popular children's books around the superhero theme for inspiration. Children were prompted

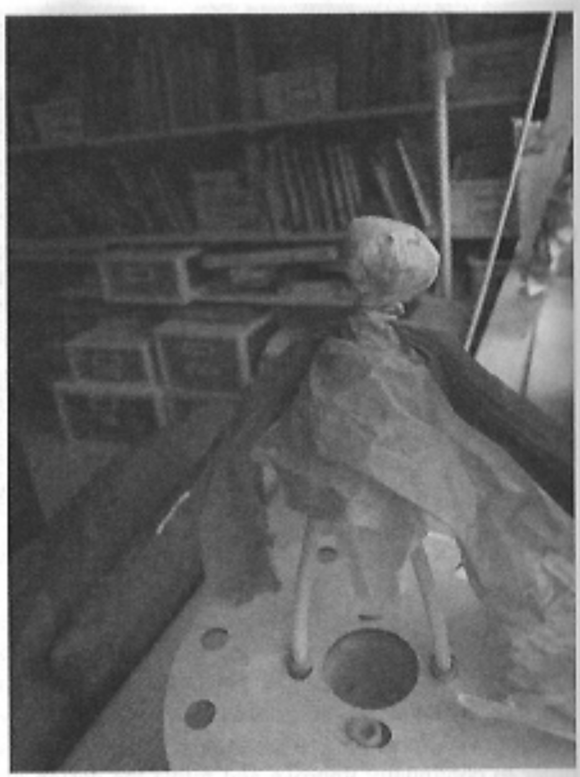


Fig. 10.21 Example of KIBO superhero design

to come up with a beginning, middle, and end of their superhero robot stories and use their program to represent one scene from their story. Along with the programs, children wrote, narrated to a counselor, or drew their completed stories to share with one another. Children came up with both individual and full-group superhero tales.

Throughout the week of the camp, there was also an air of excitement as campers knew that on the last day they would be performing their superhero stories, showcasing their robots, and sharing their knowledge with a crowd of guests made up of their families and friends. This provided an external motivation to complete their robots and stories to the best of their abilities. It also provided an opportunity to take their superhero stories from a written and/or illustrated format, and expand it with some performance elements. The camp groups held several rehearsals to practice songs they had made up, share the superhero stories they invented as a class, and give demonstrations of their robots. The campers focused on projecting their voices, conveying the emotion and personalities of the characters they invented, and properly demonstrating the technical elements of KIBO. In the end, the showcase served as a joyful celebration of the kids' hard work and dedication to their projects.

10.6 Discussion

10.6.1 *Strengthening STEM Curriculum Through the Arts*

The core element present throughout these three vignettes was the use of the arts to strengthen the STEM learning and exploration that was already happening with KIBO. For example, in the Art-Bots unit, children explored visual art by programming robots to create drawings. In this case, working toward their artistic goal (be it a shape, letter, or abstract picture) prompted them to explore mathematical concepts such as geometric paths, straight and curved lines, and angles. This also prompted a deep exploration of sturdy building and iterative engineering design.

Research has shown that music and movement can be beneficial to young children's development (Andress 1980; Lillard 2005). The Dances from the Around World unit invited children to investigate movement and music from different cultures. Although children themselves might not be able to act out all of the ritualistic dances, they were able to break apart complex steps into smaller parts that even a KIBO robot could do. In this way, children exercised their sequencing skills, a foundational skill for both developing numeracy and literacy as well as computer programming.

Finally, storytelling and drama were used to strengthen the KIBO unit on superheroes. In this camp, dramatic play offered children the chance to use symbolic representation through engaging in make-believe play with familiar objects such as blankets representing capes, and legos representing cities to protect. Dramatic play can also prompt literacy development when it involves the use of reading and writing materials (Christie 1990; Fields and Hillstead 1990). In the superhero robots camp, children explored books and stories with their counselors, created lists and brainstorms, and developed their own sequential stories using a combination of writing, drawing, and speaking. The stories provided a context for the programs the children made for their superhero KIBOs, and prompted them to think logically and sequentially when constructing these programs. Throughout this process of programming and storytelling, children were immersed in a world of fantasy and role-playing that captured their attention for intensive learning in the form of light-hearted play.

10.6.2 *The Educational Environment*

The three vignettes in this chapter highlighted a range of different types of teaching and learning environments. In the Art-Bots curriculum, we saw educational technology specialists leading longer workshop-style explorations for a mixed-age group of children. The Dances from Around the World curriculum showed formal early childhood educators teaching sequential lessons in their classrooms each week over the course of nearly two months. Finally, in the Superhero Bots curriculum we saw college student counselors leading a play-based exploration of robotics and the dramatic arts. Each of these environments offered different strengths to the STEAM content being taught. In the STEM-Saturday club, children played at being "scientists" engaged in secret experiments, with volume and buoyancy, map-making, and bridge construction being some of the many exciting mysteries they explored along with KIBO robotics. The Dances unit, which lasted almost two months, gave children the space to bring cultural inspiration from home to inform their song and dance performances. The Superhero Bots curriculum offered its own playful approach, with counselors and kids using robots as part of a week-long imaginative play experience.

When designing an educational environment for young children, it is important to consider a few questions. First, what are the educational needs of the students? Before designing any kind of educational experience, especially one that involves technology, it is important to identify your learning goals and determine how technology and the arts will serve to *enhance* children's learning rather than *distract* from it. In the case of the three vignettes in this chapter, the use of KIBO robotics served as a technical medium to teach foundational engineering and programming content. But it also served to help bring big ideas about culture, identity, and the visual arts to life in a tangible and interactive way that held the attention of the kids.

Secondly, educators will want to consider the resources available to them. Using the KIBO robotics kits as an example, if a classroom only has 1–2 robotics kits, setting up a robotics center or a technology corner might be the most effective environment for learning. Children in the Dances from Around the World curriculum worked effectively in groups of 2–3 children. While this did spark some of the usual conflicts and discomforts that characterize group work with preschool aged children, it also provided an opportunity for practicing collaboration, communication, and troubleshooting conflict in an authentic way.

Finally, educators should consider the physical space where the children will engage with the new technology. Teachers leading the Dances curriculum used different spaces to achieve different ends, giving children small, isolated work areas to become acquainted with the robot kit, and bringing them to large open areas where they could move freely when they were choreographing and practicing their robot dances. In any environment, it is important to consider ways to help the children feel ownership and safety, by posting their hand-drawn robot designs, or displaying robotic and art objects to further inspire children's designs.

10.6.3 *The Teacher's Role*

These vignettes predominantly highlighted the children's experiences and the products they made throughout the three curriculum units. However, it is important to highlight the adult's role in the classroom when working with technology and arts. Each of these units took a *constructionist* approach to teaching and learning. Constructionism is the idea that people learn effectively through making things (Papert 1980; Ackermann 2001). When considering that children learn through making tangible objects as well as testing their own theories and ideas, this puts teachers in a special role. In these types of learning environments, it is often useful to think of the teacher as more of a facilitator than an instructor. For example, in the Superhero Bots camp, the counselors followed the discussions and interests of the children and used these conversations to help guide the expectations for their final robotics projects. Similarly, when it came to providing technical support to children grappling with difficult concepts such as sensors and repeat loops, teachers from all three units worked to provide prompts, examples, and demonstrations rather than step-by-step answers and tutorials. This type of facilitation allowed the children to have their own "aha!" moments while making discoveries about the technology.

This Constructionist approach to teaching and learning is aligned with Bers (2012) Positive Technological Development (PTD) framework, which guided the development of each of the curricular units presented in this chapter. Through the PTD approach, children not only gained skills related to technology, math, and the arts, but they also gained interpersonal skills from working in groups and sharing materials. Children learned how to effectively share their thoughts and ideas with the greater community. For example, in both the Dances and Superhero curricula, the units culminated with a showcase that was open to friends, parents, and family members to learn about KIBO from the children. In this way, robotics and the arts were in service of greater early childhood developmental needs such as community building and fostering a caring and supportive environment for playful inquiry.

10.7 Conclusion

There is often a misconception that the end goal of science and technology curricular interventions is to prepare children to grow up and become scientists, mathematicians, and engineers. Quite the opposite, the goal of the PTD approach to STEAM education is to provide young children with a mindset that is applicable to a range of subject matter and experiences they have during their schooling years and beyond (Bers 2012). While STEM career fields are rapidly growing in the USA, in future decades, many of our best leaders may come from art and design backgrounds (Maeda 2012). Whether today's kindergarteners grow up to become ballerinas, inventors, designers, or teachers, their success will be rooted in an ability to problem-solve and think creatively. By integrating the arts with technical and scientific fields starting in early childhood, young children grow up with the abilities they need to be well-rounded thinkers in any domain they pursue.

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