

# KIBO Robot Demo: Engaging Young Children in Programming and Engineering

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## ABSTRACT

Robotics offers a playful and tangible way for young children to engage with technology and engineering concepts during their foundational early childhood years. This paper describes the development of KIBO, a newly created robotics kit for children ages 4-7 developed at Tufts University through funding from the National Science Foundation. Designed explicitly for very young children, the KIBO kit has gone through several design iterations based on feedback from teachers and children over the past three years. The newest version of KIBO allows young children to become engineers by constructing robots using motors, sensors, and craft materials. Children also become programmers by exploring sequences, loops, and variables. In line with screen-time recommendations for young children, KIBO is programmed to move using tangible programming blocks- no computer, tablet, or screen required.

## Categories and Subject Descriptors

K.3.2 [Computer and Information Science Education]: Computer science education; I.2.9 [Robotics]: Commercial robots and applications

## General Terms

Documentation, Human Factors, Design.

## Keywords

Robotics, programming, engineering, education, early childhood.

## 1. INTRODUCTION

The importance of engaging young learners in technology and engineering education has been receiving increased attention with the release of new learning standards and best practices for integrating technology into early childhood classrooms [3; 12; 14]. As part of this push to teach technology and engineering to young children in a developmentally appropriate way, robotics and computer programming initiatives are growing in popularity amongst early childhood researchers and educators [4]. Robotics and computer programming in early childhood education can support the development of a range of cognitive and social milestones [6]. For example, research has shown that computer programming can help young children with variety of cognitive skills, including number sense, language skills, and visual

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memory [9]. Educational robotics kits have become a new generation of learning manipulatives that help children develop a stronger understanding of mathematical concepts such as number, size, and shape in much the same way that traditional materials like pattern blocks, beads, and balls do [8; 13].

Despite these benefits, there are still very few commercially available robotics kits specifically designed for young children in their foundational early childhood years (pre-kindergarten through second grade). The KIBO robot presented in this paper was developed in order to fill this gap in the availability of engineering tools for young children.

KIBO fosters the following learning goals in young children: 1) foundational engineering concepts of sturdy building and construction, 2) foundational programming skills of sequencing, repeat loops, and conditional branching, and 3) open-ended creativity and artistic design [5]. With KIBO, young children can become engineers by playing with motors and sensors, and programmers by exploring sequences, loops and variables. Additionally, robotics gives children the opportunity to become artists, inventors, and storytellers by creating and sharing personally meaningful projects that react in response to their environment [6; 7; 10].

## 2. DESIGN FEATURES

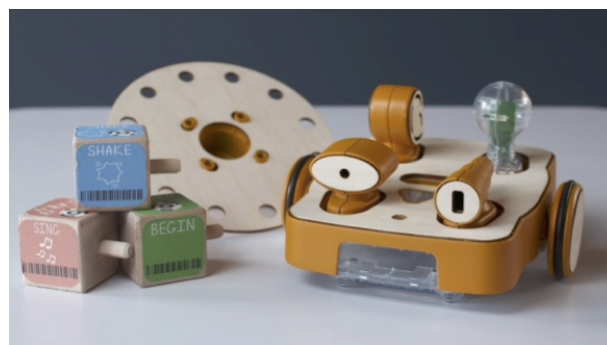


Figure 1. KIBO robot, art platform, and three programming blocks

KIBO's life started as the KIWI prototype created by the Developmental Technologies Research Group at Tufts University through funding from the National Science Foundation (NSF). Through NSF funding and a successful Kickstarter campaign, KIWI was made commercially available through KinderLab Robotics in 2014 and renamed KIBO. Now, KIBO is a robotics construction kit that involves hardware (the robot itself) and software (tangible programming blocks) used to make the robot move. KIBO is unique because it is explicitly designed to meet

the developmental needs of young children. The kit contains easy to connect construction materials including: wheels, motors, light output, and a variety of sensors (See Figure 1 on the previous page). In addition to these robotic components, the KIBO kit also contains art platforms that can be used for children to personalize their projects with crafts materials.

KIBO is programmed to move using interlocking wooden programming blocks (see Figure 2). These wooden blocks contain no embedded electronics or digital components. Instead, KIBO has an embedded scanner in the robot. This scanner allows users to scan the barcodes on the programming blocks and send a program to their robot instantaneously. No computer, tablet, or other form of “screen-time” is required to learn programming with KIBO. This is aligned with the American Academy of Pediatrics’ recommendation that young children have a limited amount of screen time per day per day [1; 2].



**Figure 2. Each KIBO programming block has a different barcode. The robot’s embedded scanner reads each barcode and sends the instructions to the robot.**

KIBO’s programming blocks are tangible, so they can be shared easily and manipulated by young users with limited fine motor capacity. This programming language was inspired by early ideas from tangible programming [11]. In contrast to graphical programming, which relies on pictures and words on a computer screen, tangible programming uses physical objects to represent the same concepts. Wooden programming blocks are naturally familiar and comfortable for children, in the tradition of learning manipulatives already used in early childhood classrooms to teach shapes, size, and colors.

### 3. RESEARCH AND DEVELOPMENT

#### 3.1 Early Prototypes

All design decisions for KIBO were based on research and feedback from children, teachers, and child development specialists. Over the past three years, KIBO has gone through several design iterations and has been tested in numerous public and private schools as well as in summer camp and lab settings. This testing was used to inform the re-design of KIBO to make it enjoyable and appealing to kids ages 4-7 while also ensuring it is sufficiently challenging.

Early prototypes of KIBO were created based on prior research with commercially available robotics kits. The first KIBO prototype (then called “KIWI” or Kids Invent with Imagination) required use of a computer to program its actions (See Figure 3). This prototype still used tangible programming blocks, however, it required a webcam and computer to take pictures of the blocks

and send the program to the robot through a USB cable. This robot was constructed out of solid wood and opaque blue plastic.



**Figure 3. Early KIBO prototype required a computer for programming.**

#### 3.2 Research with Teachers

Data was collected from 32 early childhood educators in 2013 on their attitudes, opinions, and experiences about robotics to inform the design of KIBO [5]. These teachers were exposed to an early prototype of KIBO and they participated in interviews and focus group discussions to help inform changes to the research team’s concept of the KIBO robot.

Teachers were generally excited to use robotics with their students and were drawn to the materials used in the first prototype. They particularly liked the use of wood as it reminded them of other early childhood manipulatives. However, they also pointed out several impediments presented by the original design of KIBO. The teachers’ feedback indicated that programming the robot should use minimal computer equipment. Teachers felt this was important from both a logistical standpoint (for example, some teachers indicated they did not have enough computers in their classrooms) and a developmentally appropriate standpoint (for example, some teachers worried about screen-time or about children manipulating a keyboard and mouse).

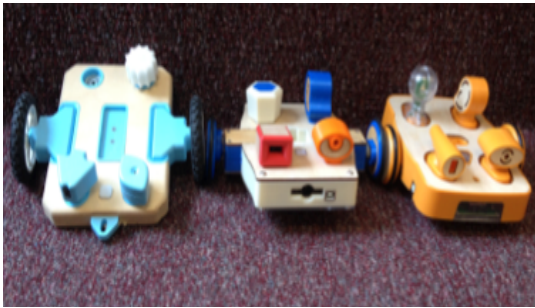
#### 3.3 Research with Children

Pilot testing, focus groups, and educational interventions with children informed the research team’s criteria for the developmentally appropriate design of KIBO. This criteria included the following: 1) robotics parts should be physically and intuitively easy to connect, 2) programming the robot should need the minimum amount of computer equipment, and 3) children should be able to attach a variety of crafts and recycled materials to the core robotic parts.

In addition to these general criteria, the research team pilot tested each KIBO prototype with children to see how intuitive the different components were to recognize. For example, children were shown different designs for the sensors to determine which aesthetic was easiest for them to understand. Researchers also observed children building the KIBO robot and programming it to ensure the design of the robot and the programming language was sufficiently challenging for four to seven year olds.

Data was collected from children using KIBO in formal classroom environments to determine how well it was suited to the three educational goals of the kit: 1) teaching foundational engineering concepts of sturdy building and construction, 2) teaching foundational programming skills of sequencing, repeat loops, and conditional branching, and 3) open-ended creativity and artistic design. The data indicated that the first version of KIBO was very successful in engaging children in foundational programming skills. However, the first kit (pictured in Figure 3) included robotic parts that were very easy to construct and did not sufficiently engage children in problem-solving or creative artistic design. This led to further evolution of the kit to provide more ways for children to build and create with KIBO. New parts were prototyped to allow children to incorporate building and designing with arts, crafts, and recycled materials along with the robotic components.

### 3.4 The Evolution of KIBO

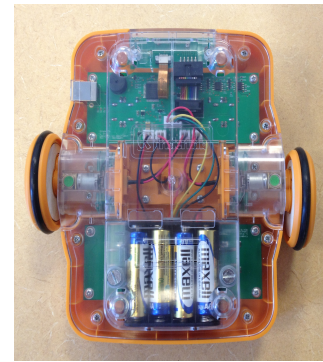


**Figure 4. The three iterations of KIBO, from the earliest prototype (left) to final design (right).**

KIBO was redesigned for a third time to incorporate the feedback from children and teachers (see Figure 4 above). The aesthetic features of KIBO have remained purposefully plain throughout each design iteration. This “unfinished” look invites children to complete the robot using their own imaginative designs. Much like a blank canvas or un-sculpted clay, KIBO inspires children to design a personally meaningful project each time they use the robot.

The latest version of KIBO includes an embedded scanner, therefore eliminating the need to use a computer. This directly addresses the teachers’ concerns about availability of computers in early childhood classrooms and screen-time recommendations for young children. Additionally, instead of having a “magical black box” with the electronic components of the robot hidden, the newer KIBO prototypes include a clear plastic bottom, allowing children to see the wires, batteries, microprocessor, and other parts involved in making the robot move (See Figure 5). Furthermore, the wheels are designed to connect to the motors in two different ways, prompting children to test how changing the wheels’ orientation makes the robot move differently.

The latest version of KIBO presented here also includes newly re-designed sensor and output components to address earlier pilot testing with children. For example, the distance sensor (which many children could not intuitively recognize) was changed to look like a telescope. Initial pilot testing with the new distance sensor demonstrates that children have an easier time associating the concept of distance with the telescope than prior designs of this sensor.



**Figure 5. Transparent bottom panel to display the inner workings of the KIBO robot.**

Two new art and design platforms were also added to give children options for more complex building with KIBO: 1) a static wooden stage and 2) a motorized platform connected to a center motor port on top of the robot (See Figure 6). These platforms provide a place for children to decorate and personalize their robotics projects with arts and recycled materials. Additionally, while the original robot prototype only allowed children to create a vehicle-style robot that moves along the floor, the motorized stage allows for more versatility in design; children can construct kinetic sculptures and animated dioramas. This provides new ways to address KIBO’s original educational goal of teaching foundational engineering principles such as sturdy building and the iterative design process.



**Figure 6. Decorated KIBO robot with art platform attached.**

### 3.5 Future Work

The newest version of the KIBO robot will be tested again with children in schools and camp settings in order to evaluate the current design. Additionally, testing will continue to determine if new design features should be added. For example, there is a possibility for adding new sensors as well as new programming blocks to expand the functionality of KIBO. The research team is also beginning to prototype versions of KIBO that will track children’s progress in programming. This will allow parents and teachers to see what blocks children are scanning, what types of mistakes are commonly made, and which programming concepts presented difficulties to the child.

Finally, the research team is also developing new curricula, teaching materials, and assessments to accompany KIBO in the classroom. These materials include games, songs, and activities that do not require use of the robot or blocks, but reinforce the concepts introduced by KIBO.

#### 4. CONCLUSION

Research shows that young children can learn programming and engineering at a very early age [4]. This is possible when children are given tools that are developmentally appropriate, that encourage open-ended play, and that allow the integration of technical skills with expressive arts, math, and literacy. The KIBO kit was developed collaboratively with teachers, children, and a research team consisting of designers, engineers, and child development specialists.

Unlike other toys and products, KIBO continues to evolve with the children, parents, and teachers who use it. KIBO has gone through multiple iterations over the years and continues to change to meet the needs and interests of the early childhood community. Educational robotics kits like KIBO have demonstrated that products can be created for young children that provide all the entertainment of a toy or game and all the open-ended educational possibilities of an instructional tool.

#### 5. ACKNOWLEDGMENTS

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