Exploring Programming and Robotics in Early Childhood Classrooms

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This exploratory research project is based upon the need for STEM learning experiences in prekindergarten classrooms. Currently, there is a gap between what students are expected to know and be able to do at the prekindergarten level as compared to the K-12 level in relation to their STEM skills and knowledge. STEM content, especially technology and engineering which focus on the development and application of tools, machines, materials, and processes to help solve problems, are not typically emphasized in early childhood education. To close this expectation gap, there is a need for learning experiences concentrating on technology and engineering in early childhood classrooms. Helping children develop engineering “habits of mind” and 21st century skills such as problem solving, creativity, and communication is a significant step in preparing the future STEM workforce.

Perspective and Theoretical Framework
Research indicates that using technology as an instructional tool enhances children’s learning and educational outcomes (Beauvois, 1997; Soloway et al, 1997; Gonzalez-Bueno, 1998; Hanna & de Nooy, 2003). Specific skills such as problem solving, literacy, creativity, and motivation are positively influenced when children have access to technology in their learning environments (Drayton, Falk, Stroud, Hobbs & Hammerman, 2010; Suhr, Hernandez, Grimes & Warschauer, 2010; Weston & Bain, 2010). Robotic manipulatives help children learn about abstract mathematical and science concepts in a concrete way and assist in the development of technological fluency through the introduction of engineering and programming (Rogers & Portsmore, 2004).

Findings from research regarding young children’s use of robotics and programming show (a) young children are able to master basic programming skills as well as improve in other academic content areas (Bers, Seddighin & Sullivan, 2013); (b) prekindergarten children take longer to understand and use robotics and programming concepts and skills than older children and they need more practice; (c) prekindergarten children find sequencing a longer program more challenging than a shorter program and work at a slower pace than older children; and (d) tasks that require prekindergarten children to
simultaneously complete three cognitive tasks may be too heavy a load for them to carry out successfully.

Scaffolded instruction, also referred to in educational settings as the gradual release model, is an effective approach for moving classroom instruction from whole group delivery to student-centered collaboration and independent practice (Fisher and Frey, 2007; Pearson & Gallagher, 1983; Wood, Bruner & Ross, 1976). This model includes a plan of instruction that presents learners with opportunities to engage in complex tasks that would otherwise be beyond their current abilities. Scaffolding makes learning more accessible for children by changing complex and difficult tasks in ways that make these tasks manageable, and within the student’s zone of proximal development (Vygotsky, 1978).

**Project Goals**

Children will have opportunities to use all aspects of problem solving in a programming context using an iterative process. Activities are embedded in developmentally appropriate engineering practices, using a 4-step engineering design cycle, and focus on building foundational skills. Thus, children will share their ideas and designs with others, revise their program/project as necessary, see failure as a learning opportunity, and try again. Programming provides many opportunities for children to individually and cooperatively solve problems. As children incorporate more programming blocks, the programs become longer and more complex, representing a continuum of challenges for the prekindergarten children.

Project learning experiences will provide problem-solving activities and challenges for prekindergarten children that are aligned with state and national standards. Aligned with the Next Generation Science Standards Framework (NGSS, April 2013) vision that all students should learn the engineering core ideas in the context of engineering practices, children will learn to use, with support, a 4-step engineering design cycle (Ask, Think, Try, and Share) and NGSS engineering practices. These experiences will lead to children’s use of NGSS K-2 engineering practices to: define a problem, plan and conduct an investigation, compare predictions to what was observed, use tools to design and build a device that solves a specific problem, make a claim about the effectiveness of a solution supported by relevant evidence, and communicate information orally or in writing. Prekindergarten children are capable of learning about and using these practices with support.

Project activities are aligned with NCTM standards (National Council of Teachers of Mathematics, 2000), in number and operations, algebra, geometry, and measurement, as they apply to prekindergarten – Grade 2 children. Project experiences also target Florida Early Learning and Developmental Standards for 4-Year Olds (FLDOE, 2013) related to literacy, mathematics, science, and social studies. By engaging in the programming and learning challenges, children develop the:

- Understanding of relative position and magnitude of ordinal numbers and their connection to cardinal numbers
- Ability to recognize, describe, and extend patterns
• Ability to describe, name, and interpret direction and distance navigation
• Understanding how to measure using non-standard units
• Ability to initiate, ask questions, and respond in a variety of settings
• Increased vocabulary to describe many objects, actions, and events
• Language to share experiences, predict outcomes, and resolve problems
• Motivation to write and knowledge of purposes for writing
• Ability to describe the location of people, places, and things using positional words
• Use of tools and equipment for investigating

The Robot
KIBO is a robot developed by DevTech, Tufts University, and commercially available at KinderLab (Figure 1). It was selected for use in this project because of the following characteristics:
• Designed specifically for 4- to 7-year olds, thus is developmentally appropriate;
• Uses tangible programming wooden blocks;
• Has an embedded barcode scanner that requires no screen interface;
• Uses light, sound, and distance input sensors and light and sound output sensors;
• Has stationary and rotating attachable art platforms that allow children to transform KIBO’s appearance for use in creative projects.

![Figure 1. KIBO and the tangible programming blocks](image)

Research Design, Participants, and Methods
The three-month intervention involved university researchers working collaboratively with six prekindergarten teachers. Approximately 60 children in three child care centers between the ages of three and five years old experienced project activities facilitated by researchers. The researchers visited the participating prekindergarten classrooms two days per week for an hour each day. Researchers implemented the lessons during the morning instructional block. Lessons began with a short whole-group instructional activity followed by rotating the children through small-group instruction. Small groups consisted of no more than six children, with each pair of children working with a KIBO.
While working with the children, researchers collected data for lesson refinement and observational data to measure child outcomes. A table of specifications was created to determine what children were expected to know and be able to do as a result of participating in the learning experiences. Three categories of cognitive tasks were identified in the instructional design process including Mechanical Use, Skilled Use, and Complex Use. Table 1 describes the tasks associated with use.

In addition, participating teachers attended a workshop lasting three hours designed to provide information and demonstrations on how to use KIBO prior to the start of the project. These teachers were given KIBO robotic kits to keep in their classrooms for the duration of the project, so children could use KIBO even when the researchers were not present.

Researcher reflection notes, child assessments, and teacher surveys were used to evaluate project implementation over the three-month period. Researcher reflection notes from each lesson included information regarding what the children had learned and could demonstrate along with aspects of the lesson that could be revised and improved for the next iteration. Surveys were given to participating teachers at the beginning of the project and again at the end of the project. The survey items ask teachers to report the ways that they use KIBO in their classrooms, the importance of KIBO use in their classrooms, and descriptions of KIBO activities. The project also included an end-of-the-project workshop in which teachers could share stories or ideas with the group about KIBO implementation. Child assessments were informal observations completed by the researchers during the lessons and recorded to keep track of the children’s progress in regards to their knowledge and skills about programming and the expected outcomes delineated in the table of specifications.

Table 1. Table of Specifications

<table>
<thead>
<tr>
<th>Cognitive Tasks</th>
<th>Mechanical Use</th>
<th>Skilled Use</th>
<th>Complex Use</th>
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</thead>
<tbody>
<tr>
<td>Prekindergarten children will know:</td>
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<tr>
<td><strong>Problem</strong>: Something that you want to be different than the way it is</td>
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<tr>
<td><strong>Solve</strong>: An answer to a problem</td>
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<td><strong>Design</strong>: A plan for how something is made or built</td>
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<tr>
<td><strong>Technologies</strong>: things made to solve problems</td>
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<tr>
<td><strong>Robots</strong>: Robots are machines; can have moving parts; and not all robots look alike</td>
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<tr>
<td>Prekindergarten children will know:</td>
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<tr>
<td><strong>Moving parts</strong>: Wheels, platform</td>
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<tr>
<td><strong>Main board</strong>: Processes the bar code that tells KIBO to do something</td>
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<tr>
<td><strong>Scanner</strong>: Reads the bar code to KIBO</td>
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<td><strong>Wheels</strong>: Circular objects that move when the motors move</td>
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<tr>
<td><strong>Motor</strong>: Makes KIBO move</td>
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<tr>
<td><strong>Tangible blocks</strong>: Hold the bar codes and connect together to make a program</td>
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<tr>
<td>Prekindergarten children will know:</td>
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<td></td>
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<tr>
<td><strong>Ask</strong>: Identify a problem</td>
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<tr>
<td><strong>Think</strong>: Brainstorm ways to solve the problem and choose one</td>
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<tr>
<td><strong>Try</strong>: Try out your solution</td>
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<tr>
<td><strong>Share</strong>: Describe what happened (if your solution worked or not) and what you would do differently next time</td>
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</table>
Evidence of Mastery:
Children will be able to:
• Give an example of a problem
• Identify characteristics of a robot

Evidence of Mastery:
Children will be able to:
• Recognize the KIBO components when shown a picture and describe the function of each.
• Select the appropriate block corresponding to a robot action

Evidence of Mastery:
Children will be able to:
• Identify the 4 Steps (Ask, Think, Plan, Share) and correctly match examples to the 4 steps
• Use Begin, End, and at least 1 Motion and 1 Output block to make a program that solves the given problem.

An example of a lesson plan (whole group, small group, and materials), a record of the children’s performance during that lesson, and a copy of the researcher reflection notes for that lesson are provided below.

Table 2. Lesson Plan Example for Lesson #2

<table>
<thead>
<tr>
<th>Learning Experience Design Format: Round 1 - Lesson #2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives:</strong> Students will learn that:</td>
</tr>
<tr>
<td>• Engineers use a problem solving process.</td>
</tr>
<tr>
<td>• Engineers design by making a plan.</td>
</tr>
<tr>
<td>• Engineers design technologies.</td>
</tr>
<tr>
<td>• As engineers, we will use a technology. Our technology is a robot called KIBO.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated Time: 10 minutes</th>
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<tbody>
<tr>
<td>Actual Time: 14 minutes</td>
</tr>
<tr>
<td><strong>Hook:</strong> Did anyone make a plan with a partner and build something in the block center?</td>
</tr>
</tbody>
</table>

**Whole Group Activity:** Review song: Engineers Solve Problems.
“Let’s look at some of the technologies engineers design to solve problems: Pgs. 8-9 in the book *Engineers Solve Problems*. Use the example of a pencil sharpener. Ask how a fan, light bulb, clock and umbrella (all examples on pg. 9) might solve a problem.
Introduce KIBO: KIBO is a technology. KIBO is a robot. Have KIBO ready to spin and light up. Ask what other robots they can think of? Let students give some examples. Explain that KIBO is one kind of robot. (Put KIBO back in his box, out of sight). “We are going to be working with KIBO, starting next week. We will be solving problems using KIBO.”

**Closure:** “What do engineers do?” (Solve Problems)
“In just a few minutes we are going to help someone solve a problem.”

**Transition** to small group/guided practice.
Small Group Activity: How many of you know who Elmo is? We are going to watch a very short movie about Elmo and see what his problem is. Be sure you watch and listen very carefully because we are going to help Elmo out. Show the 2 minute video clip Elmo Joins In and stop the video after: There are only 3 costumes. (Use iPad) https://www.youtube.com/watch?v=uuWoYld3790

Ask, “What do engineers do?” (Solve Problems)
“That’s right! So, let’s help Elmo solve his problem.”
Show the EDC/Solve it 4 graphic (large poster) and teach the song Ask, Think, Try and Share using the song chart. Read the vocabulary card ask and say, “What is Elmo’s problem?” (He wants to fit in, be part of the group but there are only 3 costumes).
Read the vocabulary card think and say, “Let’s think of some ways we could help Elmo. Let’s make a plan.”
Sing the second verse of song: Engineers Solve Problems: THINK, THINK, THINK…
“With your partner, think and make a plan with your partner about some ways Elmo could join the group.”
SHARE: Wow, you came up with more than one way! I wonder how I can remember your plan, and your plan? (Point to each student).
Introduce the EDJ: (Hold up one of the student engineer journals).
“When engineers make a plan, they write it down. Why do you think they write it down? Yes, so they can remember it, and change it, and make it better. We are going to draw and write about our plans…in our very own journals – starting next week!”
Provide each set of partners with one type of technology and remind them that you talked about technologies that engineers design to solve problems. Ask each pair of children to decide what their technology is and what problem it solves. Have the children share each of their technologies and the problems they solve.
Using the poster, review the steps of the Solve It 4.

Check for Understanding:
• Can name the steps in the Solve It 4 looking at the poster.
• Can name the technology (robot) that we are working with in this project (KIBO).

Closure: Next week we are going to learn about KIBO. What is KIBO? Yes, KIBO is a robot and a technology. You will be working with a partner as we learn how to make KIBO work.

Extended Practice:
Ask teachers to review the vocabulary words ask and think throughout the week.

Table 3. Record of Children’s Task Performance for Lesson 2
<table>
<thead>
<tr>
<th>Child</th>
<th>Can name the 4 steps in the Solve It 4 looking at the poster.</th>
<th>Can name the technology (robot) that we are working with in this project. (KIBO)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Student 1</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Student 2</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Student 3</td>
<td>AB</td>
<td>N</td>
</tr>
<tr>
<td>Student 4</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Student 5</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Student 6</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Student 7</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Student 8</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Student 9</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Student 10</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Student 11</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Researcher Reflection Notes Lesson 2

<table>
<thead>
<tr>
<th>Did the lesson go as intended?</th>
<th>• The lesson went as intended</th>
</tr>
</thead>
</table>
| Which instructional materials/strategies engaged the students? | • The children answered many ways to solve the paper mess problem  
• No one made a plan with a partner in the block center  
• Book was more engaging today – and provided good concrete examples of technologies  
• Kids want to use KIBO  
• The songs were engaging |
| What changes or additions to the activities are needed? | • This lesson was too choppy, we went from problems to technologies to KIBO to the 4 steps of Solve it 4.  
• The video does not work well in small group when displayed on the computer – too much other noise going on in the classroom. |
| Was more or less time needed for the lesson than we had planned? | • Timing was too short in whole group and small group– again, the last group went more quickly (they were figuring things out as the other group was working) |
| Did we achieve the intended child outcomes? | • I had 10 children present in the one class.  
• Not much more work is needed for kids to identify the 4 steps |
| What questions or problems did the students have? | • They still don’t have an real understanding of what a plan is or how to make a plan with a partner or the Solve It 4 |
| Which programming blocks were children able to use in programs at the end of this lesson? | Not applicable |
| Other: | • Although the kids did well with the activities and remained engaged, we need to revisit the sequence and intent of this lesson. It does not flow and I feel that we can make this come together in better ways. |

Conclusions

Researchers indicated that the majority of children met the learning objectives across the lessons. Researchers also reported that the children were highly engaged when participating in the lessons. By the end of the three-month project, most children could create and scan a simple program for KIBO.

Teachers reported that children were highly engaged when using KIBO. They also indicated that children learned valuable skills through their experiences with KIBO such as persistence and collaboration. Teachers described scenarios in which children worked together to solve problems when programs were not scanned properly and continued to try possible solutions until KIBO was programmed correctly.

The researchers have begun the process of revising the lessons based on the feedback from teachers, the reflection notes, and the children’s performance on the programming tasks. This curriculum is designed to improve STEM instruction at the prekindergarten
level by introducing children to programming and robotics content, while also maximizing children’s opportunities to solve problems and work collaboratively.
References


