Assignment 1: Understanding Statistical Inferences

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Mainstream Media Article

In a 2017 THE Journal article, multimedia editor Joshua Bolkan discusses the results of a 2016 ProQuest survey entitled, "Toward an Information Literate Society" (Appendix A). According to the article, which provided a link to the actual survey results (Appendix B), 217 ($N = 217$) librarians from "university, community college, high school and public libraries" in North America were surveyed. The article nor the survey results state how the survey sample was collected nor the type of study that was conducted.

From this quantitative survey, it is concluded that 83.4% of the librarians who completed the survey believed that "information literacy affects college graduation rates" and 97.2% believe that "information literacy contributes to success in the workforce" (Toward an Information Literate Society, 2016). However, more than half of those surveyed, do not believe that their library supports information literacy instruction, offers specific information literacy-promoting platforms to their users, or feel that their library's reference collection plays a large role in supporting information literacy instruction. While the article and survey results indicate that 217 librarians were surveyed, we do not know the actual number of librarians who completed the survey and are included in the results.

In his article, Joshua Bolkan indicates the percentages obtained in the various categories indicated in the survey. The accompanying survey results display the statistical information using bar graphs. The bar graphs indicate the librarian's responses to the eight survey questions in percentages but do not indicate the number of librarians who responded to each question.

This article accurately reports the survey results according to the ProQuest report but fails to report the research and sampling methods.

Scholarly Article

Elkin, Sullivan, and Bers (2016), conducted "a pilot experience in a preschool robotics program at a public school in Rhode Island" (p. 170) (Appendix C). The study sought to answer research questions about the ability of preschool aged children to learn about programming with KIBO robotics through a short-term intervention. The researchers conducted a "nine-hour introductory robotics and programming curriculum" with seven preschool classes over a three-month period (Elkin, Sullivan and Bers, 2016, p. 174). Following the instruction, students were assessed using "a KIBO programming task (called "Solve-It")" to ascertain their acquired knowledge of programming (Elkin, Sullivan and Bers, 2016, p. 174). The sample for this study, 64 (N = 64) low-income, Hispanic children was obtained from seven classrooms in an urban public preschool. All of the students in all seven classrooms participated in the curriculum activities but were not required to participate in the assessment. The researchers did not elaborate on how the school or classrooms were chosen for this study. With a mean age = 4.83 at the time of the assessment, the preschoolers ranged in age from 3 to 5 years old (Elkin, Sullivan and Bers, 2016).

In the assessment portion of this study, each child was asked to "code" their robot using paper versions of the KIBO coding blocks to answer a problem presented to them in four Solve-It tasks. Each task was scored on a 0-6 rubric with a score of 6 being completely correct. Percentages correct on each of the four Solve-It tasks were calculated on two variables: % correct (Syntactically and Story) and % correct (Syntactical). Mean scores and standard deviations were also calculated. Solve-It one, Easy Sequencing, had a mean score of 4.67 with a standard deviation of 1.653. Solve-It two, Hard Sequencing, had a mean score of 4.08 with a standard deviation of 2.043. Solve-it three, Easy "wait-for" Command, had a mean score of 4.84

with a standard deviation of 1.827. Solve-it four, Easy Repeats with Numbers, had a mean score of 3.72 with a standard deviation of 1.845. All sixty-four (64) preschoolers participated in the assessment however, only sixty-one (61) completed all four tasks in the assessment. The researchers did not give any indication as to why three of the participants failed to complete all four Solve-It tasks. From this analysis, the preschool students were successful in programming the KIBO robot and scored higher on Solve-It tasks one and three than two and four as their mean scores were higher on those two tasks. The researchers felt the reduced number of blocks needed for those two tasks might have contributed to their higher scores.

The researchers also conducted a "one-way independent sample *t* test" to determine if the mean scores between the older and younger students had a significant difference (Elkin, Sullivan and Bers, 2016, p. 182). Students were placed in either the "younger" or "older" group based on a median split (median = 4.91) (Elkin, Sullivan and Bers, 2016). Of the sixty-four (64) original participants, 59 ($N = 59$) were included in this portion of the assessment as "five of the students did not provide their birthdays on the consent forms" (Elkin, Sullivan and Bers, 2016, p. 182). The younger group had 29 students, and the older group had 30 students. The results of this analysis, as indicated in Table 4, show that the two variables, Solve-It 1 (Easy Sequencing) and Solve-It 2 (Hard Sequencing), both have low p-values ($p = .006$ and $p = .029$, respectively) signifying a statistically significant difference between the younger and older students.

From this study, the researcher concluded that programming with KIBO and some aspects of its proprietary programming language could be utilized with children as young as three years of age. The students were more successful completing tasks which were easy and required fewer than five steps and had a more difficult time on the loop tasks which required more steps (Elkin, Sullivan and Bers, 2016). The statistical evidence presented in this article supports their conclusions as mean scores were higher for the easy tasks and the p-value for loops (p = .222) did not indicate a high statistical significance.

References

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Appendix A

Librarians Say Information Literacy Is Important, They Don't Have the Tools to Teach It

- By **Joshua Bolkan**
- 01/05/17

According to a **new survey** from **ProQuest**, nearly all librarians (97 percent) say information literacy contributes to workforce success and more than four in five (83 percent) say it affects college graduation rates, and yet 44 percent said their library does not support information literacy as much as it should.

The survey polled more than 200 librarians from university, community college, high school and public libraries. Other key findings include:

- Only 21 percent of librarians said their users recognize information literacy's effect on lifelong success. Thirty-four percent said their users do not and 33 percent said they weren't sure;
- 91 percent of those surveyed said they rely on one-on-one in-person consultations to reinforce literacy skills;
- Classes on general research skills and classes on research skills for specific projects were the second most common way librarians in the survey said they reinforce information literacy, at 69 and 64 percent, respectively;
- Only one in four librarians surveyed said their library supports its users' information literacy needs as much as it should;
- 77 percent said they promote a specific information literacy platform to users;
- 60 percent of those surveyed told researchers their library's reference collection does not play a large role in information literacy instruction, with only 26 percent saying it does; and
- 42 percent of respondents said they have no formal tool to assess users' information literacy, while 29 percent said they offer informal assessment.

"While a number of respondents believe implementing or improving assessment tools could allow their libraries to better meet users' information literacy instruction needs, those surveyed already have a number of other ideas on how to achieve this aim," according to a **report on the survey results**. "For one, many librarians believe that better integrating information literacy within and across existing curricula would boost their users' information literacy skills. Similarly, many respondents feel that the answer lies in working more closely with faculty and other instructors — learning about their needs, educating them on the importance of information literacy and the resources the library offers, and encouraging them to include more research-based projects in their coursework."

"Overall, lack of budget and limited staffing were reported as some of the greatest obstacles for doing as much as they would like to drive development of this important skill set," said Kevin Stehr, ProQuest vice president of North American sales, in a prepared statement. "But I think this response summed it up best — 'We're doing the best we can, but we always aspire to do more.'"

Appendix B

Toward an Information Literate Society

Results from a 2016 ProQuest Survey

ProQuest

"We're doing the best we can, but we always aspire to do more,"

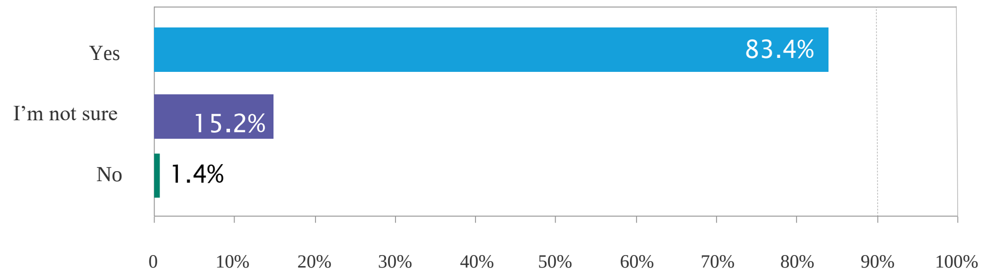
shares one librarian, discussing the information literacy instruction provided by the library to its users. While librarians seem to widely share this "do more" attitude regarding information literacy instruction, it's clear that teaching library users about information literacy and its importance is not always easy or successful. This survey, featuring insights from 217 librarians from university, community college, high school and public libraries in North America, explores:

- The perceived importance of information literacy among librarians and their users
- Current methods utilized by librarians to help their users gain information literacy skills
- Ways in which librarians feel they could improve their information literacy instruction

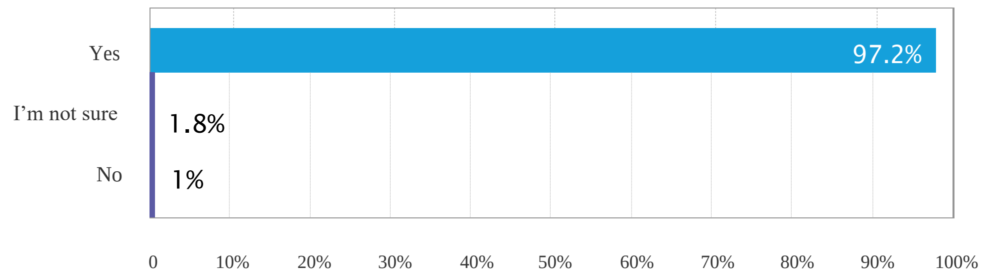
Information Literacy and Student Success

Librarians surveyed recognize that information literacy is important to the future successes of their users. *"I see students with low information literacy struggling to understand and complete assignments,"* shares one librarian. *"Students who possess [information literacy] skills approach these assignments with more confidence and creativity and achieve more success."* 83.4% of those surveyed believe that information literacy affects college graduation rates, and a tremendous 97.2% believe that information literacy contributes to success in the workforce. *"No matter which field you enter,"* explains one respondent, *"you have to be able to discern reliable versus unreliable sources to do your work [and] be able to evaluate content you come across in order to deem whether or not it's important."*

Do you believe that information literacy affects college graduation rates?

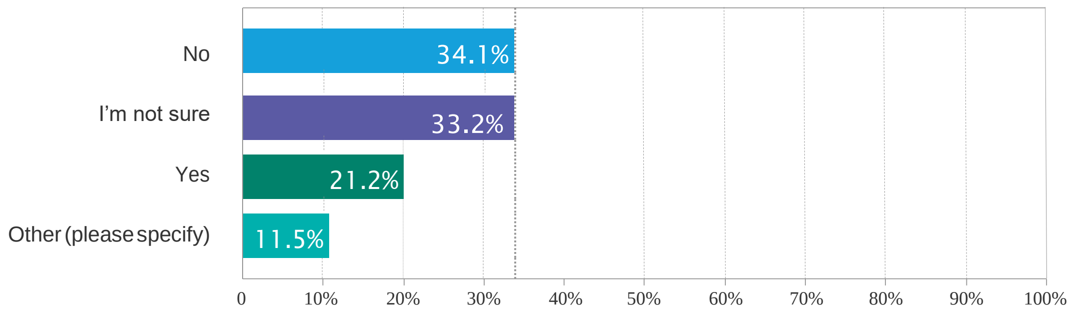


Do you believe that information literacy contributes to success in the workforce?

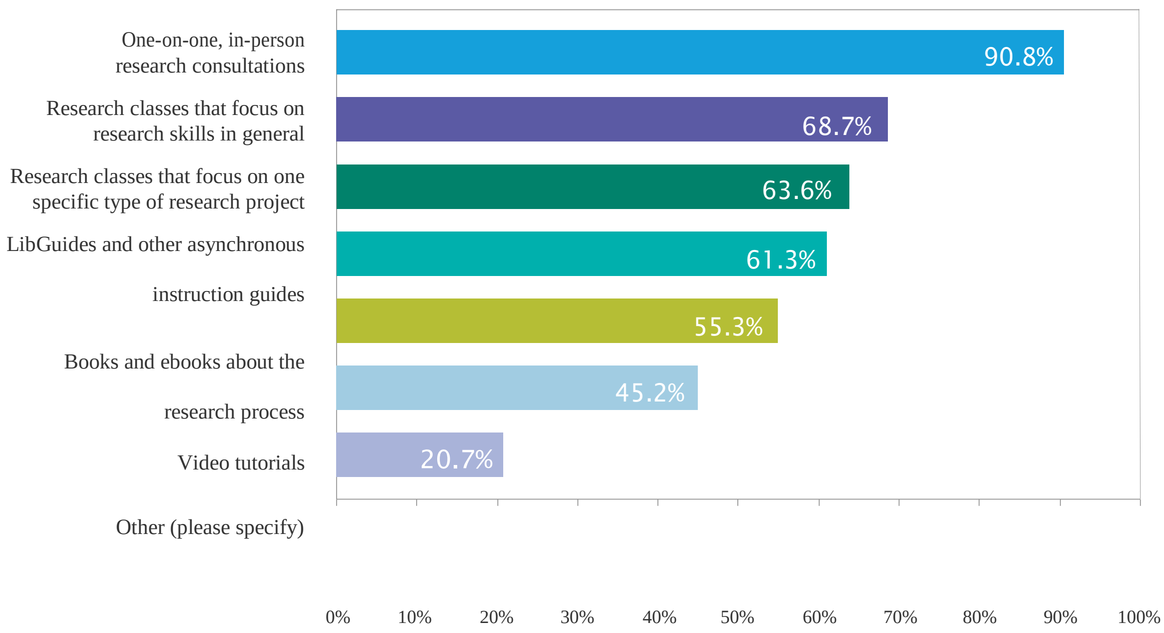


Yet these same librarians do not believe this recognition of the value of information literacy extends to their users — only 21.2% of librarians surveyed believe that their users recognize information literacy's effect on lifelong success. To combat this perceived lack of recognition among users that information literacy impacts lifelong success, librarians engage in a number of techniques to help their users gain or improve their existing information literacy skills. 90.8% of librarians surveyed rely on one-on-one, in-person research consultations to reinforce information literacy skills. Other methods and tools include research classes that focus on general research skills (68.7%) or a specific type of research (63.5%), LibGuides and other asynchronous instruction guides (61.3%), books and ebooks about the research process (55.3%), and video tutorials (45.2%).

In your opinion, do your users recognize information literacy's effect on lifelong success?

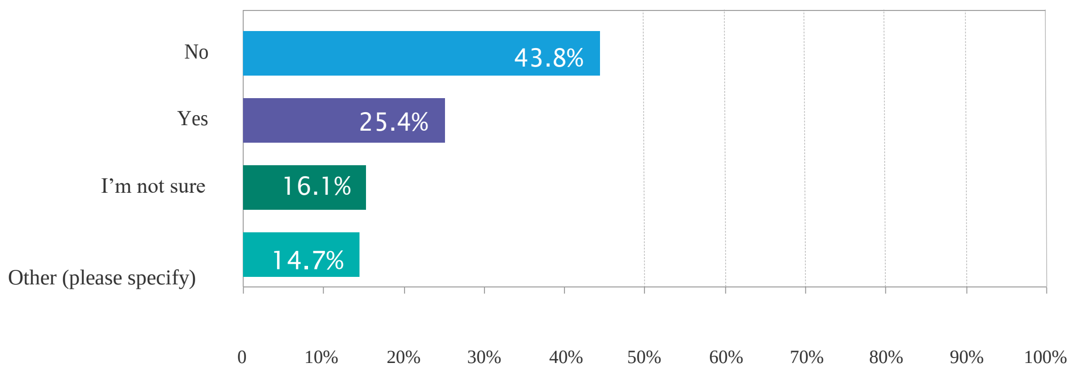


How does your library help users gain information literacy skills?
Select all that apply.

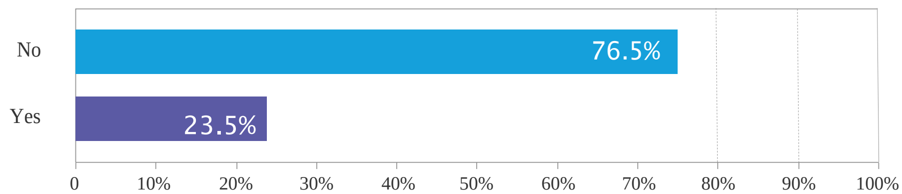


Despite these attempts to improve the information literacy of their users, only 25.4% of librarians surveyed feel that their library supports users' information literacy instruction needs as much as it should. 76.5% of the librarians surveyed work in libraries that do not offer a specific information literacy platform to their users, and only 26.3% feel that their library's reference collection plays a large role in supporting information literacy instruction. This is interesting in that authoritative content from the library has been seen as one way to drive students away from open web information that lacks credibility. The librarians surveyed seem to be moving away from this approach as a key way to teach students how to evaluate information, one of the core information literacy skills. *"Ideally, we'd be provided with additional time for genuine collaboration on research skills and projects with discipline specific teachers,"* said one librarian when asked about how he would like to augment his library's information literacy instruction.

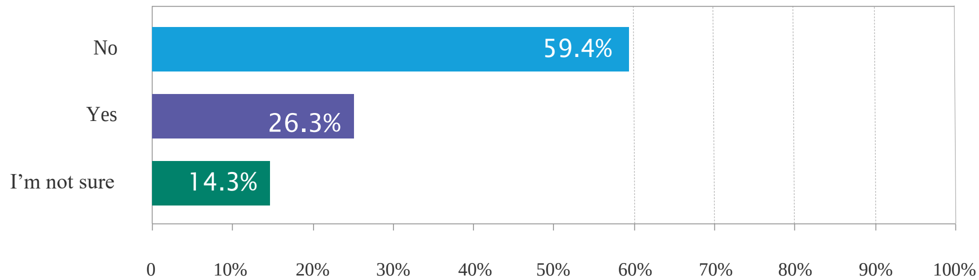
Do you feel that your library supports users' information literacy instruction needs as much as it should?



Do you offer a specific information literacy-promoting platform to your users?

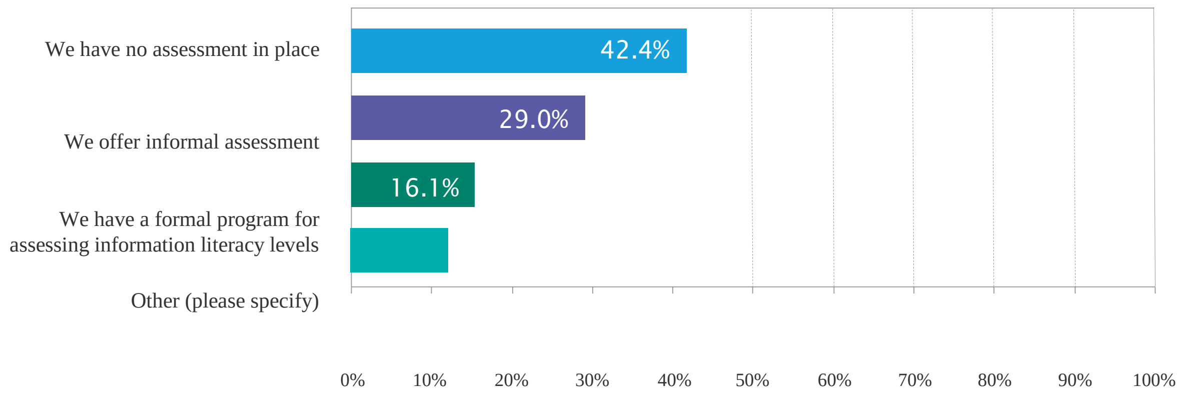


Do you feel that your library's reference collection plays a large role in supporting information literacy instruction?



Librarians' concerns over how to best support their users' information literacy needs are exacerbated by their inability to accurately assess their users' levels of information literacy; only 16.1% of librarians surveyed have a formal program for assessing information literacy levels, and 42.4% have no assessment in place. Discussing a need for more assessment and data, one librarian feels *"there are some needs that don't get met, because we don't know about them or don't understand them very well from a student perspective."*

How do you assess your users' levels of information literacy?



While a number of respondents believe implementing or improving assessment tools could allow their libraries to better meet users' information literacy instruction needs, those surveyed already have a number of other ideas on how to achieve this aim. For one, many librarians believe that by better integrating information literacy within and across existing curricula would boost their users' information literacy skills. Similarly, many respondents feel that the answer lies in working more closely with faculty and other instructors - learning about their needs, educating them on the importance of information literacy and the resources the library offers, and encouraging them to include more research-based projects in their coursework. *"We are badly in need of an integrated presence in the curriculum,"* explains one respondent. Another believes that *"partnering with faculty — and showing faculty the need for [information literacy] — is the number one thing we need to change. If faculty are on board, they will bring their students — we have evidence of this."* Yet another respondent feels the library needs to *"encourage faculty to create assignments that specifically address the need for information literacy skills."* Other ideas for how to better meet the information literacy instruction needs of library users include: developing an information literacy curriculum; adding or improving existing online tutorials and resources; integrating information literacy instruction into the library's strategic plan; increasing the number of librarians and library staff; increasing face to face instruction; and increasing user access to computers, E readers, tablets, and other electronic devices.

The results from this 2016 survey share insight into how individual libraries are making the case for information literacy at their institutions, but they also highlight the overarching approach that will help us move closer to becoming a more information literate society as a whole: integrating information literacy instruction beyond the library, a task that requires the support of faculty members, teachers and others that students and researchers of all levels interact with on a daily basis. A majority of librarians surveyed stated that their library's accrediting agency or governing body covers information literacy in their standards, making information literacy a key goal for librarians. But librarians can only do so much alone.

How ProQuest Supports Information Literacy Instruction

ProQuest's ebook subscriptions, specifically its Academic Complete, College Complete, Public Libraries Complete and Schools & Educators Complete as well as its Reference Ebooks Subscriptions, were developed specifically to drive the development of information literacy skills. These collections provide unlimited access to reliable, scholarly sources so authoritative content is as convenient to find and use as information openly available on the web.

Librarians need more than just quality resources to teach researchers how to find, evaluate and use authoritative information, though, as emphasized by the surprising finding that reference content is not a main part of their approach to teaching information literacy. That's why along with offering the largest and most diverse selection of digitized content — from journals to videos and newspapers to working papers — we offer Research Companion, our award-winning cloud-based information literacy solution for researchers and educators. Aligned both to ACRL Information Literacy and Common Core English Language Arts standards, Research Companion provides a framework and foundation for information literacy instruction.

Featuring more than 80 short videos that are organized into nine Learning Modules, Research Companion addresses questions like, *"How do I choose a topic?"* and *"How do I evaluate sources?"* And, various levels of "pre" and "post" assessment questions make the overall experience more interactive. Research Companion was built to help students do more effective scholarly research while allowing educators to measure learning and identify gaps in comprehension. Research Companion can be effortlessly incorporated into the researcher's workflow to get to answers and context quickly—and it provides librarians and educators the tools and resources to:

- Prepare high school and community college students for university-level research
- Help undergrad and graduate students produce better papers faster

Check out this video for a quick overview of the power of offering your researchers a research companion and contact your ProQuest representative to learn more about how ProQuest can help support your information literacy instruction.

Appendix C

Computers in the Schools

Interdisciplinary Journal of Practice, Theory, and Applied Research

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Programming with the KIBO Robotics Kit in Preschool Classrooms

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Programming with the KIBO Robotics Kit in Preschool Classrooms

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ABSTRACT

KIBO is a developmentally appropriate robotics kit for young children that is programmed using interlocking wooden blocks; no screens or keyboards are required. This study describes a pilot KIBO robotics curriculum at an urban public preschool in Rhode Island and presents data collected on children's knowledge of foundational programming concepts after completing the curriculum. The curriculum was designed to integrate music, literacy, and design with engineering and robotics. Children ($N = 64$) from seven preschool classrooms, ranging in age from 3 to 5, participated in the study. Findings indicated that children as young as age 3 could create syntactically correct programs for the KIBO robot, although older preschoolers (closer to age 5) performed better than younger preschoolers on a standardized programming task. Additionally, all students generally performed better on the programming tasks that required them to manipulate less programming instructions. Implications for designing developmentally appropriate curriculum and scaffolding for young children are addressed.

KEYWORDS
Early childhood education; preschool; programming; robotics

New technologies are increasingly influencing the ways young children are grow- ing, learning, and playing. Digital activities such as playing video games and using an iPad are growing in prevalence among young children under the age of 8. For example, a recent study by Common Sense Media (2013) found that two thirds of children ages 0 to 8 have access to a console video game player at home, and 35% have access to a handheld game player such as a Game Boy, PSP, or Nintendo DS. Additionally, there has been a fivefold increase in ownership of tablet devices such as iPads from 8% of all families in 2011 to 40% in 2013.

As technology has grown increasingly common in young children's home envi- ronments in recent years, educational technology in schools has also expanded. This has occurred in part due to federal education programs and private initiatives mak- ing computer science and technological literacy a priority for young children (Office of Educational Technology, 2010). Robotics and computer programming initiatives

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/wcis.

for young children have grown in popularity over the past 5 years as new products for young learners have emerged on the commercial market (i.e., KIBO, Bee-bot, Dot, and Dash).

Prior research has shown that children as young as age 4 can successfully build and program a simple robot (Bers, Ponte, Juelich, Viera, & Schenker, 2002; Cejka, Rogers, & Portsmore., 2006; Perlman, 1976; Sullivan & Bers, 2015; Sullivan, Kaza- koff, & Bers, 2013; Wyeth, 2008), but there is still very limited research on what children under age 4 can learn with robotics. Sullivan and Bers (2015) found that preschool students were able to successfully complete basic programming tasks upon completion of a Kids Invent With Imagination (KIWI) robotics curriculum. Similarly, Sullivan et al. (2013) found that with scaffolding, 5-year-old preschool children were able to design, build, and program a LEGO® WeDo robot. Both of these studies emphasized the importance of scaffolding and moving through the curriculum at a slower pace than when working with children in kindergarten through second grade. The present study builds on prior research with preschoolers by looking at what children as young as age 3 can learn about foundational program- ming concepts and skills when completing a developmentally appropriate curricu- lum that includes built-in scaffolding and review time. This article presents results from a pilot experience in a preschool robotics program at a public school in Rhode Island.

Literature review

Robotics in early education

From tablet devices to newly designed robotics kits, young children are exploring different types of technology while at school. While access to new technologies is growing, children's understanding of *how* and *why* these tools work the way they do is growing as a new area of research. Robotics and computer programming offer a way to playfully engage students with the process of *how* motors, sensors, and electronics work (much the way they work in automated doors, sinks, and digital toys) through hands-on building projects (Bers, 2008). Young children are naturally inquisitive about how things work and are willing to take risks to uncover solutions (Peel & Prinsloo, 2001). Robotics offers an environment for children to test their hypotheses, engage in problem solving, and make personally meaningful discoveries.

In recent years, there has been a range of new robotic kits on the market for young children. For example, Bee-Bot can be used to teach sequencing, estimation, and problem solving. Children program it by pushing on the directional buttons located on the robot's body (www.be-bot.us). More recently, the makers of Bee-Bot have cre- ated Blue-Bot, which functions similarly to the Bee-Bot but can also be programed from a tablet or computer; the program is sent to the robot through a Bluetooth connection (www.terrapinlogo.com/robots.html). Another example is the Dash and Dot robots, created by Wonder Workshop. Children program these robots through iPad and Android applications to navigate a route, as well as use lights and sensors.

Some of the applications target children of all ages, whereas others target children older than age 8 (www.makewonder.com). For the research presented in this study, we have chosen to use the KIBO robotics kit described in the next section.

Research with robotics in early childhood settings has shown that beginning in preschool, children can learn fundamental programming concepts of sequencing, logical ordering, cause-and-effect relationships, and engineering design skills (Bers, 2008; Fessakis, Gouli, & Mavroudi, 2013; Kazakoff & Bers, 2011; Kazakoff, Sullivan, & Bers, 2013). When children create programs for their robots, they are sequenc- ing commands for their robot to act out. The act of sequencing is foundational for early math, literacy, and planning (Zelazo, Carter, Reznick, & Frye, 1997). Addition- ally, educational robotics programs, when based in research, child development the- ory, and developmentally appropriate practices (National Association for the Edu- cation of Young Children [NAEYC] & Fred Rogers Center, 2012), can foster student learning of engineering such as design skills and methods (Druin & Hendler, 2000) while engaging in collaboration and other social skills necessary for school success (Clements, 1999; Lee, Sullivan, & Bers, 2013; Svensson, 2000).

The KIBO robotics kit

Although there are now many commercially available robotic kits that teach about programming, the majority described in the previous section are "pre-built" in the sense that children are not involved in any of the construction or design aspects of building a robot. For example, the Bee-Bot robot is designed to resemble a bright and colorful bumblebee, with all motors and design features ready to use, much like any children's toy. In contrast, this study utilized the KIBO robotics kit, which engages young children in both building and programming. This kit was devel- oped by the DevTech Research Group at Tufts University and commercialized by KinderLab Robotics. KIBO is designed for young children ages 4 to 7 to learn foun- dational engineering and programming content; however, this study examined the hypothesis that it may be developmentally appropriate to use with children as young as 3 years old. KIBO was chosen for this study because of the large and easy-to- manipulate parts, open-ended building and programming possibilities, and the kit's tangible programming language (Sullivan, Elkin, & Bers, 2015). Because KIBO is programmed by putting together wooden blocks, without a computer, tablet, or other form of "screen-time," curricula utilizing the KIBO kit is aligned with the American Academy of Pediatrics' (2003) recommendation that young children have a limited amount of screen time per day.

The KIBO kit contains easy-to-connect robotics materials including wheels, motors, light output, and a variety of sensors (see Figure 1). In addition to these electronic components, the KIBO kit also contains art platforms that can be used for children to decorate and personalize (Sullivan et al., 2015).

KIBO is programmed by using interlocking wooden programming blocks. These wooden blocks contain no embedded electronics or digital components, but each one has a unique barcode. A scanner embedded in the front of the KIBO robot allows users to scan the barcodes on the programming blocks and send a program to

Figure □. The KIBO robot and the blocks.

their robot instantaneously (Sullivan et al., 2015). Similar to other programming lan- guages, KIBO has specific syntax rules to follow (see Figures 2 and 3). For example, every program must start with a Begin block and finish with an End block. Addi- tionally, in order to create a functional repeat loop, one must use the Repeat block, a parameter (either a number or sensor), and the End Repeat block.

KIBO's developmental considerations

Young children's working memory changes drastically between the ages of 3 and 5 (Shonkoff, Duncan, Fisher, Magnuson, & Raver, 2011), enabling them to effectively learn new content. When children are entering preschool around age 3, most of them can organize themselves to complete tasks that involve following two steps, such as throwing away a napkin and putting away their lunchbox after snack time (Rhode Island Department of Education [RIDE], 2013; Shonkoff et al., 2011). By the time

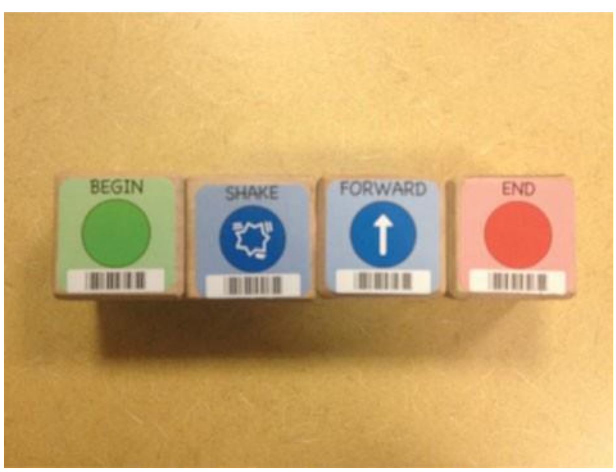

Figure □. Basic program starting with Begin block and finishing with End block.

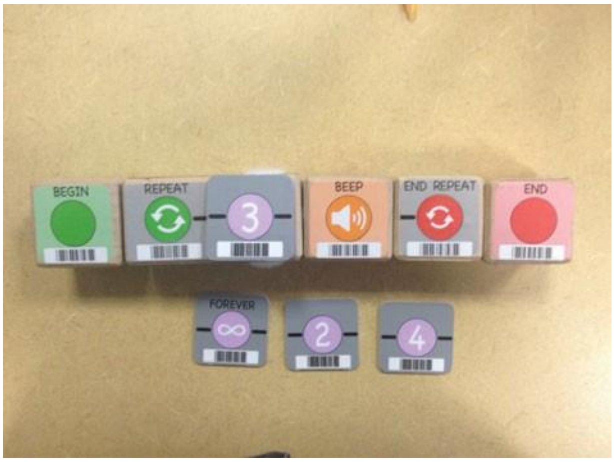

Figure □. Repeat loops program. *Note*. The program above shows a syntactically correct repeat loops program using the number □ parameter. This program will tell the robot to beep three times. Pictured below the program are choices of other number parameters that can be used for this type of program.

children are leaving preschool and entering kindergarten around age 5, children can follow multi-step instructions and retell familiar stories in the correct sequence (RIDE, 2013). Using the KIBO robot, children can strengthen their working mem- ory skills by learning to sequence increasingly complex programs and to master all of KIBO's syntax rules.

By building with the robotics manipulatives such as KIBO's motors, sensors, out- puts, and wooden programming blocks, children are able to develop fine motor skills and hand-eye coordination. Play that involves the manipulation of physi- cal objects with symbolic meaning (i.e., KIBO's programming blocks that symbol- ize robotic actions) lets children begin to explore more complex symbolic think- ing (Bers, 2008; Piaget, 1952). In addition to these technical manipulatives, chil- dren also exercise their fine motor skills through the addition of arts, crafts, and recyclable materials. Specifically, the two art platforms provide a space for explor- ing the engineering design process to build sturdy creations that are personally meaningful (Sullivan et al., 2015; see Figures 4 and 5). The following section describes the present research evaluating the use of KIBO robotics in a preschool context.

Robotics also engages young children in collaboration and teamwork (Lee et al., 2013). Preschool children are in the developmental process of learning social skills such as how to work with others; the design features of certain types of technology can promote social and prosocial development (Bers, 2012). Unlike many appli- cations and educational software designed for one child working independently, robotics activities lend themselves to more collaborative moments. For example, the KIBO robotics kit used in this study is designed so that small groups of children can work on one robot with each one taking on a very specific role: the programmer, the artist, or the engineer.

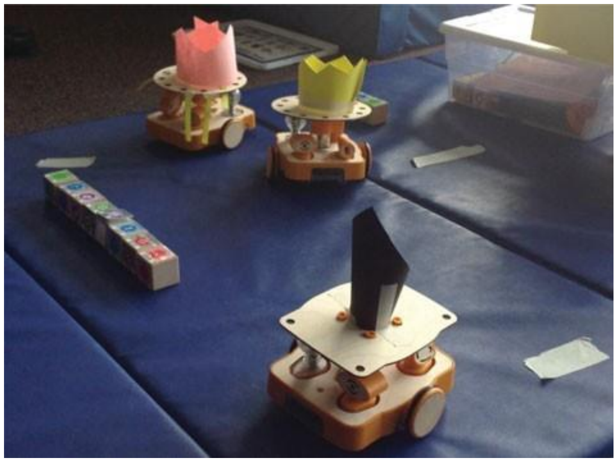

Figure . KIBO's static art platform for personalizing projects.

Method

Research overview

This study explores the following research questions:

1. What can young preschool children, ages 3 to 5, learn about foundational programming and robotics content through a short-term educational intervention?
2. What types of errors do young preschoolers make when programming with KIBO?
3. What kinds of programming concepts are easiest for young children to master? Which are more challenging?

To answer these questions, preschool students participated in a nine-hour introductory robotics and programming curriculum. Upon completion of the curriculum, students completed a KIBO programming task (called "Solve-It") to assess their programming knowledge.

Figure . The motorized turntable for personalizing projects.

Participants

Participants in this study were 64 predominantly low-income, Hispanic children drawn from seven classrooms in an urban public preschool in Rhode Island. They ranged in age from 3 to 5 years (mean age = 4.83 at the time of assessment). While students in all of the classes participated in the curriculum, they were not required to partake in the assessment portion of the study; all children were invited to com- plete the assessment, but if they did not want to, they could choose to do something else. Students who attend this school are 81% Hispanic, 8% Caucasian, 6% African American, 5% mixed race, and 1% Native American. Additionally, 91% of the stu- dents were eligible for subsidized lunch.

Procedure

Over the course of 3 months, seven preschool classrooms completed an introduc- tory robotics and programming curriculum taught by students from Tufts Univer- sity. These undergraduate and graduate students came from a variety of educational backgrounds ranging from the liberal arts to engineering. While some students had no previous experience teaching robotics, all students had experience working with children. Student volunteers were required to attend two trainings: one 8-hour train- ing before the start of the intervention, and one 4-hour training midway through the intervention in order to practice the curriculum and prepare for administering the assessments. Each volunteer practiced administering the assessment on other vol- unteers before administering the assessment on the children. The children's regular preschool teachers were in the classroom at all times to facilitate behavioral man- agement and assist with small group work. A larger goal for the robotics works at this site was to have classroom teachers learn by observing trained students so they would be able to implement their own robotics curriculum in the future without outside help.

Curriculum overview

The introductory robotics curriculum involved approximately nine hours of work over the course of 6 days. Each day's lesson was divided into two parts: 45 minutes was spent doing an activity with the KIBO robotics kit, and the other 45 minutes was spent doing robotics and engineering-related activities that did not require the use of the KIBO robotics kit. Half of the classes completed the robotics portion first while the other completed the non-robotics portion, and then they swapped (since kits were being shared between classrooms).

During non-robotics time, children spent a portion of the class participating in a full group activity, and then spent the remainder of time participating in an activity of their choice. According to the school's principal, Rhode Island requires preschool children to spend at least half of their school day engaged in self-directed activities. The KIBO curriculum was therefore designed to include multiple activity choices

Figure . KIBO BINGO.

related to engineering and programming. During the group activity time, children learned songs (such as one that teaches about the different parts of the KIBO robot) and listened to picture books being read aloud (reinforcing fundamental engineer- ing concepts like the engineering design process). During free-choice time, children could choose an activity related to KIBO. For example, one activity choice was KIBO BINGO (see Figure 6), which is played like the traditional BINGO game. The teacher showed a part of the robot (such as a wheel or a body), and students covered up that picture on their game board. The goal of this game was to teach children the dif- ferent parts of the robot. Another activity choice was KIBO Says (see Figure 7), an

Figure . Simon Says with programming commands.

Figure ▯. Small group work with robot.

adaptation of the Simon Says game, where children follow the directions on a large print-out version of the KIBO blocks if KIBO (the teacher) told them to do so. In addition to games, children could choose to create decorations for their robots or draw in their engineering design journals.

During robotics time, children were given a task to complete involving their robot. Each classroom had one robot for approximately three children; the student volunteers, as well as the classroom teachers, assisted the different groups. For exam- ple, during Session 2, children were asked to work in small groups to program their robots to dance the Hokey Pokey (see Figure 8). The Hokey Pokey involves children sequencing seven programming blocks in order to make the well-known song. This activity focuses on strengthening young children's working memory through trial and error and iterative programming (Shonkoff et al., 2011). It also works on their ability to understand sequence and order, which is a foundational early math and literacy component (Kazakoff & Bers, 2011). During Session 5, children worked in small groups and programmed their robots to travel along differently shaped paths using the Repeat and End Repeat blocks. The repeat loop required children to prac- tice sequencing, order, counting, and estimation to select the correct number param- eter that would make their robot travel the correct distance. See Table 1 for a break- down of the types of activities completed each day.

On the final day of the curriculum, each class was given a KIBO robot kit to build and program together. Prior to this session, children had learned about different dances from around the world, and as a class, they selected one dance that they wanted their robot to perform. During robotics time, each class created a dance program for their robot. For example, one class programmed their robot to dance the Hula, which resulted in a program with the robot repeating the motions of moving left and right. Another class wanted their robot to move like a Salsa dancer, so they included many Spin blocks in their program. During non-robotics time, students created decorations for the robot itself as well as a "stage" for the robot to dance on. At the end of the curriculum, students presented their dancing robots to special

Table □. Overview of the curriculum.

Session	Focus	Robotics activity	Non-Robotics activity
Session □	Introduction to engineering and robotics	Discussion about what is a robot, play a game to learn the difference between a robot, learn the "KIBO Robot Parts" song	Discussion about what is an engineer, learn the "Engineering Design Process" song, complete sturdy building activity with non-robotic materials
Session □	Introduction to what is a program	Introduction to KIBO's programming blocks, program the robot to dance the Hokey Pokey	Play Simon Says with KIBO commands, review the engineering design process
Session □	Introduction to sensing and sensors	Review parts of KIBO robot with the "KIBO Robot Parts" song, review the different blocks with KIBO Bingo, free exploration with the robot	Sing "Engineering Design Process" song, read a book about the five senses, go on a sensor walk
Session □	Sensing and introduction to repeats	Review what is a sensor, program a robot to dance to "If You are Happy and You Know it"	Talk about the meaning of the word "repeat," review KIBO's commands with KIBO Bingo
Session □	Repeat loops with numbers	Review sound sensor, program robot to travel along different maps using repeats	Learn about dances from around the world through watching different videos, create decorations for the robot as well as a stage area
Session □	Final projects	Create a dance for the KIBO robot based on a dance from around the world (as a whole class)	Create sturdy decorations for the robot and a stage area, plan the robot's dance

guests such as the principal and other administrators in order to celebrate the end of the unit.

Assessment

After curriculum implementation was complete, the Solve-It assessment was admin- istered to students to assess their programming knowledge. The assessment com- bines KIBO's programming language and playful stories to evaluate children's mas- tery of different programming concepts. Because children worked in small groups during the curricular activities, it was important to implement individual assess- ments to see what types of tasks children could solve on their own.

The Solve-It assessment was developed to target areas of foundational program- ming ability and basic sequencing skills. These tasks capture student mastery of programming concepts, from basic sequencing up through repeat loops. The assess- ment was verbally administered one-on-one to each student by one of the volunteers who taught the robotics curriculum. The assessment required children to listen to a series of stories being read aloud to them about a robot. Then, children attempted to create the robot's program using paper versions of the KIBO programming icons provided for them (see Figure 9 for a student example and Table 2 for the story prompts). Four Solve-It tasks were administered to address the following concepts: Easy Sequencing, Hard Sequencing, Easy "Wait for" Command, and Easy Repeat Loops with Number Parameters. Tasks were called easy or hard based on how many commands children needed to sequence (i.e., easy tasks had fewer blocks for chil- dren to sequence than hard tasks).

Table □. Solve-It story prompts and correct answers.

Solve-It number	Story prompt	Correct answer
Solve-It □ (Easy Sequencing)	"This story is about a robot that is a car. Have you ever heard a car honk its horn? First, I want my car robot to turn on. Next, I want the car robot to honk the horn—Beep! Beep!—to warn people that it's about to move. Then I want my car to drive straight ahead, and then stop. So in this story, my robot turns on, beeps, goes forward, and then stops. Can you make a program that matches this story?"	Begin, Beep, Forward, End
Solve-It □ (Hard Sequencing)	"This story is about a robot that drives into a puddle. I want you to make a program that lets my robot dry itself off after it accidentally moves into a puddle. First, my robot will turn on, and then it will move straight ahead—but OOPS! My robot is in a puddle! It's going to make a noise—Beep!— as if it is saying 'Oh no!' Then, I want the robot to shake itself dry—shake!—and finally, turn off! So my robot will turn on, go straight ahead, beep, shake, and then stop. Can you make a program that matches this story?"	Begin, Forward, Beep, Shake, End
Solve-It □ (Easy "Wait for" Command)	"This story is about a dancing robot. This robot is in a dance competition. The robot has stage fright though, so it is going to wait to start dancing until it hears a clap from the audience. Once it hears a clap, it will shake and keep shaking until the end of the song. Then it will stop. So, for this story, my robot will turn on, wait to hear a clap, then shake, and then stop. Can you make a program that matches this story?"	Begin, Wait for Clap, Shake, End
Solve-It □ (Easy Repeat)	"In this story, my robot is going to sleep. I want my robot to say goodnight to everyone in the house. It has a brother, a sister, and a mommy, so it will say goodnight to three people. First, I want my robot to turn on. Next, I want the robot to make a noise—Beep!—where it is telling us 'Goodnight!' I want the robot to say goodnight to three people, so it has to beep three times. Then, I want the robot to stop beeping, and last, to turn off." So my robot will turn on, repeat the beep sound three times, stop beeping, and then stop. Can you make a program that matches this story?"	Begin, Repeat (□), Beep, End Repeat, End

Note. Solve-It tasks are numbered based on overall difficulty of concept. For example, both the "easy" and "hard" sequencing tasks (tasks □ and □) are typically easier for children than the easiest "repeats" task (task □). Within each category, there may be easy and hard tasks (for example, an "easy sequencing" and a "hard sequencing" task). Both target the same conceptual understanding, but the more difficult task has more actions to sequence.

Each of the four Solve-It tasks described was scored on a 0–6 rubric based on how close the children's program came to being completely correct (a score of 6). The scoring rubric was developed and piloted by the DevTech Research Group (Strawhacker & Bers, 2015; Strawhacker, Sullivan, & Bers, 2013; Sullivan & Bers, 2015).

Each question received two sub-scores based on separate criteria, including placement of Begin and End blocks (worth up to 3 points) and relative order of action blocks (worth up to 3 points). The scoring rubric was developed after a pilot assessment was administered to identify incorrect answer patterns that could demonstrate developmental level rather than programming comprehension. Inter-scorer reliability tests during the development of the assessment showed precise agreement (two items; $K = 0.902$, $p < 0.001$; Strawhacker & Bers, 2015).

Figure . Sample Solve-It task.

Results

For all tasks on the Solve-It assessment, basic descriptive statistics were calculated. On average, the children in this study were highly successful at mastering basic pro- gramming concepts after completing the curriculum. After children's Solve-It data were examined for general trends and coded for the types of mistakes, the data were divided into two groups in order to compare programming performance between younger and older preschoolers. Detailed analysis is presented in the following sec- tions.

Solve-It errors

Solve-It tasks were analyzed to look at students' knowledge of various KIBO pro- gramming concepts and the types of errors students made. By looking at the types of mistakes, we can better understand how to create developmentally appropriate curricula that provide children the opportunity to master sequencing and other pro- gramming concepts.

Sixty-four (64) students elected to participate in the Solve-It tasks (if a student was asked to participate and he or she answered no, there was no force to complete the activity), but only 61 students completed all four tasks. Each Solve-It was scored on a scale from 0–6, with 3 points awarded for the placement of the Begin and End blocks, and another 3 points awarded for the relative order of the action blocks. For this analysis, overall scores as well as sub-scores were analyzed to look at the types of mistakes that students made on each of the Solve-Its.

Children made a variety of different types of mistakes on the Solve-Its—some of which were syntactical (i.e., the program had a logical programming error and would not work on a real robot) and some of which were story related (i.e., the pro- gram made syntactical sense but did not match the sequence of the story). Aside from Solve-It 4, most students were able to create syntactically correct programs,

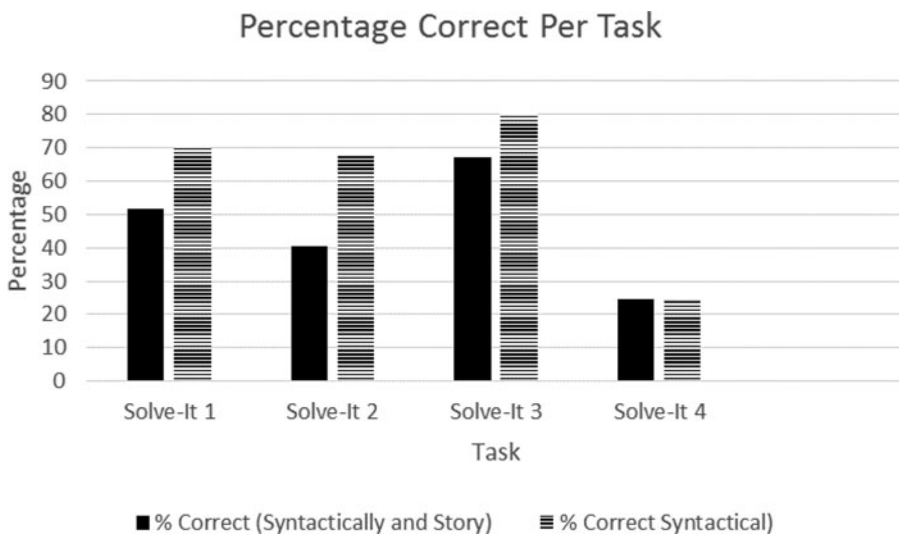

Figure 11. Percentage correct on each Solve-It task.

even if they did not match the story that they heard (See Figure 10). On three of the four Solve-Its, more than 65% of the children correctly placed Begin and End blocks.

For Solve-It 1 (Easy Sequencing), 70.4% of students made a syntactically correct program (with 51.6% of students creating a syntactically correct program that also matched the story). Interestingly, 14% of students sequenced the action instructions correctly but misplaced the Begin and/or End block. The average score, on a scale from 0–6, was 4.67 ($SD = 1.653$), with students most frequently scoring 6. The sec- ond most frequent score was 4 (26.6%), and only one student received a score of 0, which indicates that he or she not only misplaced the Begin and End blocks, but also did not order the action instructions correctly.

For Solve-It 2 (Hard Sequencing), a slightly lower percentage of students (67.8%) created a syntactically correct program, with 40.3% also making a program that matched the story. The average total score was 4.08 ($SD = 2.043$), with students most frequently scoring 6. Seven students (11.3%) received a score of 0.

Solve-It 3 (Easy "Wait for" Command) had the highest percentage (80.3%) of stu- dents who created a syntactically correct program, as well as the highest percentage (67.2%) of students whose programs also matched the story. The percentage of stu- dents who misplaced the Begin and/or End blocks was 13.1; also 13.1% of students swapped the Wait for Clap and Shake instructions. The average total score was 4.84 ($SD = 1.827$), with students most frequently scoring a perfect score of 6. Three stu- dents received a total score of 0.

The lowest scores were seen on Solve-It 4 (Easy Repeat). Only 24.6% of students created a functional program that also matched the story. The most frequent mis- take (16.4%) observed was an empty repeat loop, where no action block was placed between the Repeat and End Repeat blocks. Other mistakes included swapping the End and End Repeat blocks, as well as placing the incorrect action block inside the

Table 3. Performance on Solve-It programming tasks.

Solve-It number	Concept addressed	Mean score (out of a maximum of 6)
1	Easy sequencing	4.67 (*SD* = 1.653)
2	Hard sequencing	4.08 (*SD* = 2.043)
3	Easy "wait-for" command	4.84 (*SD* = 1.827)
4	Easy repeats with numbers	3.72 (*SD* = 1.845)

repeat loop. The average total score was 3.72 (SD = 1.845), with 3 being the most common score. Six students received a score of 0.

Overall, the preschool students were successful in their performance on the Solve-It tasks, particularly the sequencing tasks that did not involve repeat loops. Each Solve-It was scored on a scale from 0 to 6, and the average score for Solve-Its 1–3 was above 4 (See Table 3). On all Solve-Its, students scored on average higher on their Begin/End sub-score than their Sequence/Repeat sub-score. Of the four tasks, students performed best on Solve-Its 1 and 3, which required students to sequence four instructions. They performed worse on Solve-It 2 (Hard Sequencing), which required the sequencing of five instructions, and even lower on Solve-It 4 (Easy Repeat), which required the sequencing of seven instructions.

Solve-Its by age

A one-way independent samples t test was performed to determine if there were significant differences between older and younger children's mean scores on each of the Solve-It tasks. Group placement was determined by a median split (median = 4.91). For this analysis, we had 59 ($N = 59$) students because five students did not provide their birthdays on the consent forms; 29 students were placed in the "younger" group and 30 students were placed in the "older" group. On average, the older children performed better on all Solve-It tasks. Statistically significant differ- ences between the two groups were found on the easy ($t(57) = -2.030$, $p < .05$). Cohen's effect size value ($d = -0.54$) suggested a moderate level of practical signif- icance. Statistically significant differences between the two groups were also found on the hard sequencing tasks ($t(55) = -2.813$, $p < .05$). Further, Cohen's effect size value ($d = -0.76$) suggested a moderate to high practical significance. There were no significant differences found between the groups on the Repeat and "Wait for" command tasks (See Table 4) indicating that both groups demonstrated the same mastery of Repeats and "Wait for" programming concepts.

Table 4. Differences between younger and older preschoolers' Solve-It scores.

Solve-It Task	Mean younger	Mean older	t	df	p Value
Solve-It 1 (Easy Sequencing)	4.14 (*SD* = 1.827)	5.30 (*SD* = 1.291)	−2.83	57	p = .006*
Solve-It 2 (Hard Sequencing)	3.61 (*SD* = 2.299)	4.76 (*SD* = 1.504)	− 2.246	55	p = .029*
Solve-It 3 (Easy "Wait-for" Command)	4.56 (*SD* = 2.063)	5.14 V(*SD* = 1.432)	− 1.941	54	p = .058
Solve-It 4 (Easy Repeat Loops)	3.33 (*SD* = 1.961)	4.24 (*SD* = 1.527)	− 1.234	54	p = .222

* Significant p value less than .05.

Discussion

The results from this study suggest that the KIBO robot and some aspects of the KIBO programming language are appropriate for children as young as age 3, despite the fact that it was designed for children ages 4 and older. The introductory robotics curriculum used in this study focused on rudimentary programming skills for KIBO, including sequencing and an introduction to repeat loops. Preschool chil- dren in the study, ages 3 to 5, were able to successfully master sequencing a syn- tactically correct program. However, the more instructions the students were asked to sequence, the more difficult it was for them to correctly create a program. This is consistent with the findings of Sullivan and Bers (2015), who found that pre- kindergarten students were more successful on an easy-sequencing Solve-It task (ordering four blocks) than a hard-sequencing Solve-It task (ordering five blocks). This is also consistent with the literature showing that younger children do not have enough working memory to hold five instructions simultaneously in their minds until they are several years older (Shonkoff et al., 2011).

The students' success on sequencing shorter programs may be due to their work- ing memory and the capacity to remember all the parts of a longer story at a given time. Working memory is described as the ability to simultaneously hold and manip- ulate information internally over a short period of time (Shonkoff et al., 2011). Dur- ing the Solve-It tasks, students had to simultaneously process the story being told, remember the programming instructions they had learned, and connect the instruc- tions to the story. All of these elements in their mind may have been too heavy of a cognitive load for the young children in this study, even if the programming con- cepts were manageable.

Regardless of age, students in this study scored much lower on Solve-It 4. This suggests that programming repeat loops may be a challenging concept for very young children, either due to the number of blocks needed or their conceptual understanding of the repeat loop. The types of mistakes that students made on this Solve-It suggest that most children misunderstood the syntactical rules of creating repeat loops. Additionally, many students swapped the positions of the End and End Repeat blocks, suggesting that students had trouble distinguishing between the End block (which ends the whole program) and End Repeat block (which ends the repeat loop). Physically, both blocks include the word "end" and use the color red. However, when manipulating the blocks, the End and End Repeat blocks have different phys- ical features (such as the absence of a peg on the End block); these features were not present when using the paper version of the blocks for the Solve-It assessment. This may have added to the difficulty for students to fully differentiate between the blocks when they needed to be used in one program. Future work may want to include a block-identification task to better understand if these young preschoolers can iden- tify different blocks, and then using the Solve-It assessment to see if they can apply what they know about the blocks to create a syntactically correct program.

Given that less than a quarter of the children were able to create a functional program that included repeats, it may be worthwhile when introducing such young children to programming to focus on basic sequencing, or to provide more scaffolding when teaching repeat loops. Repeat loops involve more than just new blocks; they also introduce a new piece of KIBO syntax (i.e., creating a "parenthe- sis" with the Repeat and End Repeat block to separate a series of commands from the rest of the program). In addition to holding this new piece of syntax in their working memory, repeat loops also require children to estimate and mathematically reason with number parameters. This may be too much of a cognitive strain for children beginning to program. This connects with previous findings that preschool students spend more time than kindergarten through second-grade students on basic robotics concepts, and move through an introductory robotics curriculum at a slower pace (Sullivan & Bers, 2015; Sullivan et al. 2013).

Results also indicate that older preschoolers (around 5 years old) demonstrated a higher mean level of mastery on all programming concepts assessed than younger preschoolers (under 5 years). This may be due to a variety of factors including increased working memory, attention span, and ability to plan (Shonkoff et al., 2011). These results suggest that, even in a preschool setting, teachers should con- sider offering differentiated learning opportunities for students based on cognitive and social development. Additionally, when given more time, teachers may find that preschoolers, particularly the older students, may be able to master more program- ming concepts beyond those introduced in this study. Because KIBO programming concepts build on one another, children can easily continue to explore and mas- ter more complicated programming concepts including repeat loops with sensor parameters and conditional branching. This makes the kit ideal for preschool set- tings with a range of student abilities.

Limitations and recommendations for future research

The primary limitation of this study was the availability of robotic materials at the school. In order to keep the ratio of three children to one robot, robotics kits needed to be shared between classrooms. As a result, of the 9 hours in which students partic- ipated in the robotics curriculum, only half the time was spent with the robot itself. While the non-robotics time was a great opportunity for students to play games and read stories reinforcing what they learned during robotics time, students did not have a lot of time to engage in hands-on programming. Given that the assessment measured programming ability, students may have done better if they had received more practice with the curriculum.

Another limitation of this study correlates with the scheduling and logistics of working with students of all ages. Due to the schedules of both the preschoolers and the student volunteers from Tufts University, the six sessions were spread out with lengthy gaps between each one. Each lesson built off of the previous sessions, so students were asked to recall information that they had been taught a while ago. If implemented again, a longer intervention with more consistent timing may be helpful.

Furthermore, the way in which the Solve-It assessments were administered may have hindered student performance. The curriculum allowed time for students to create programs for their robot using tangible blocks, scan the program onto the robot, and then see the robot move. In this way, students were able to directly check if the program they had created made the robot move like they had intended it to. Additionally, the curriculum was designed to be open-ended, so children could choose whichever instructions they wanted for their robot to act out. Conversely, on the Solve-It assessment, students were given a specific story that they needed to recreate using paper representations of the blocks. Students did not have the opportunity to see the robot act out the program and decide whether they needed to change any instructions. Future studies may want to develop an assessment that gives students the opportunity to use the tangible blocks and check their robot's pro- gram for each story.

Conclusion

Robotics offers preschool children and teachers a playful new way to learn founda- tional engineering and programming concepts. This study demonstrated that it is possible to teach preschool children as young as 3 years of age fundamental pro- gramming concepts such as sequencing and repeat loops. As results from this study show, with proper scaffolding and time to explore engineering concepts through robotic and non-robotic activities, students as young as 3 can successfully build and program a KIBO robot.

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