Horizons for Homeless Children

CAL-KIBO-PreK Pilot Program Research Findings Report

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September 16, 2022

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Project Overview

Over the past several decades, significant research focus has been placed on designing coding and robotics tools for young children as well as researching and exploring their use in early childhood learning settings. One such tool is KIBO, developed by Dr. Marina Umaschi Bers and the DevTech Research Group at Boston College, previously at Tufts University. KIBO is a screen-free robotics kit that engages children in foundational programming and robotics concepts while encouraging creative expression and collaboration (see Figure 1). Current work at DevTech is exploring pedagogical theories of early childhood computer science and developing innovative curricula and professional learning resources to help teachers implement coding and robotics in the early childhood classroom. Emerging from this ongoing work are the Coding As Another Language (CAL) curricula which teach coding and computational thinking alongside language and literacy skills. The CAL-KIBO curriculum for PreK (CAL-KIBO-PreK) presents KIBO activities alongside storybooks, games, and songs. Along the way, the curriculum also promotes additional key areas such as social emotional learning and approaches to learning.

Figure 1. *KIBO Robotics Kit*

Between October 2021 and June 2022, the DevTech Research Group has partnered with Horizons for Homeless Children in Boston, MA to implement the CAL-KIBO-PreK curriculum

in its preschool classroom. From their mission statement, Horizons for Homeless Children works to "improve the lives of young homeless children in Massachusetts and help their families succeed by providing high-quality early education, opportunities for play, and comprehensive family support services." Horizons for Homeless Children operates six preschool classrooms. Three of these preschool classrooms are general preschool classrooms serving children between the ages of 3 and 4. The other three classrooms are part of the Boston Public Schools Universal PreK (UPK) program and serve children between the ages of four and five.

As part of the research collaboration with the DevTech Research Group, Horizons for Homeless Children administrators and teachers attended a professional development training led by members of the DevTech team, where they engaged in play-based activities with KIBO and discussions surrounding the CAL approach and integration of coding in early childhood education. Teachers subsequently implemented the CAL-KIBO-PreK curriculum in their classrooms.

This pilot program had two primary research goals, one of which focused on student outcomes and the second of which focused on teacher outcomes. To understand these goals, multiple forms of data were collected from students and teachers at various points of the training and curricular intervention. In this report these goals are operationalized into the following research questions:

1. What is the impact of the CAL-KIBO-PreK training and curriculum on teachers' coding knowledge and their attitudes and experiences teaching coding?
2. What is the impact of the CAL-KIBO-PreK curriculum on students' coding knowledge and their academic/developmental competencies?

The following sections of the report describe the research design, the CAL-KIBO-PreK curriculum, and preliminary outcomes for each research question. Future presentations and journal articles will present these findings in more detail.

Research Design

The CAL-KIBO at Horizons for Homeless Children project was conducted over the 2021-2022 school year, with preliminary meetings in Spring 2021 between the DevTech and Horizons for Homeless Children teams. The professional development training was conducted in October 2021. Teachers subsequently implemented the curriculum between January and July 2022.

Research Protocol

Multiple forms of data were collected from students and teachers over the course of this pilot study. The timeline of the study procedure is included below in Figure 2.

Both before and after the professional development training, all teachers completed surveys and a KIBO language coding assessment. Teachers completed interviews with members of the DevTech research team after the professional development training and at the conclusion of the research project. Teachers also completed final surveys at the conclusion of the project.

The BPS UPK classrooms taught the 30 lesson CAL curriculum in the winter and spring of 2022. During curriculum implementation, teachers kept lesson logs of the time spent teaching and preparing each lesson, as well as any modifications made. Final student projects were documented and scored using the KIBO project rubric. Teachers completed additional surveys midway through the curriculum. Before and after curriculum implementation, children were assessed by Tufts University researchers on their coding and computational thinking knowledge.

Researchers visited the school and completed assessments in a quiet corner of the classroom. Assessments lasted between ten and twenty minutes.

Children in the general preschool classrooms were assessed in the fall and spring, aligning with assessment times for the UPK classrooms. Some KIBO lessons occurred in these classrooms, which were documented with lesson logs.

All study procedures were approved by the Tufts Institutional Review Board (IRB) under Protocol #1810044. Findings in this report are presented only from students and teachers who consented to research participation using our IRB-approved consent forms.

Figure 2. *General Study Procedure for CAL-KIBO at Horizons for Homeless Children Project*

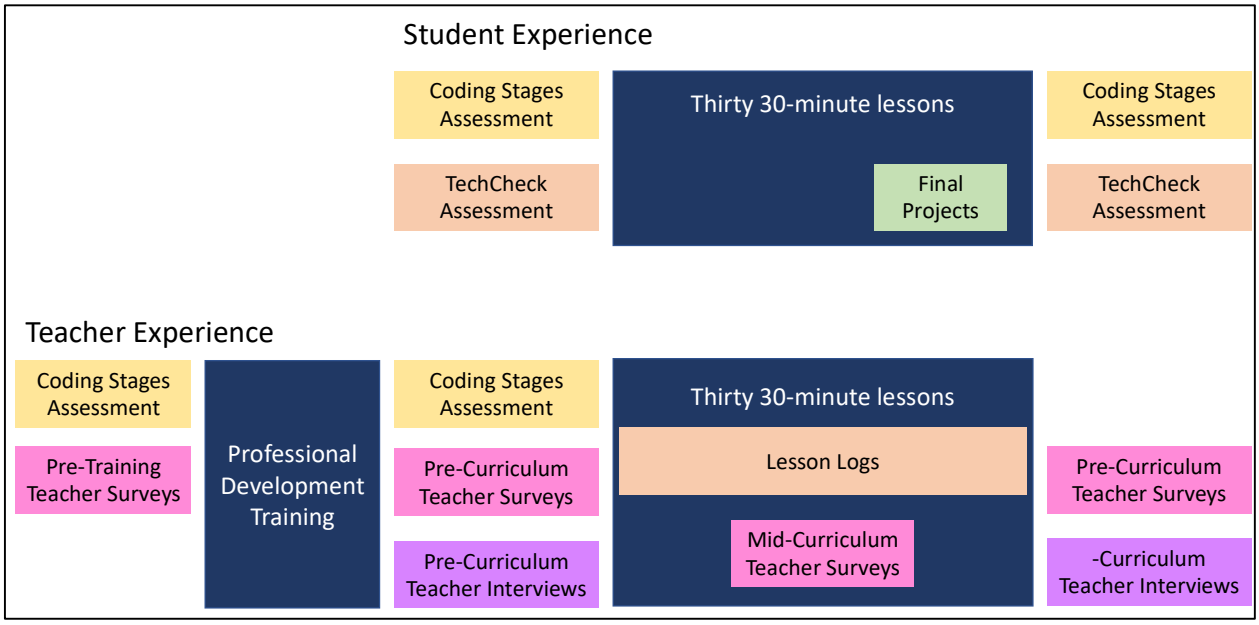


Table 1 presents the various measures in greater detail, including a brief description of the research instrument, details regarding the duration and type of administration, and links to the instruments. Some of the assessment instruments (e.g., Coding Stages Assessment) are not available for public use and are thus not provided in this report.

Table 1. *Study Measures for CAL-KIBO at Horizons for Homeless Children Project*

Measure	Description	Administration and Scoring	Link
Coding Stages Assessment (CSA)	• Prompt-based questionnaire used to assess KIBO knowledge (Strawhacker et al., 2022) • Items based on Bers' (2019) conceptualization of Coding Stages: *Emergent, Coding and Decoding, Fluent, New Knowledge,* and *Purposefulness*	• Individual, in-person • Designed for children and adults • Weighted score ranges from 0-30 • 10-60 minutes to administer	
TechCheck	• Standardized assessment used to assess computational thinking knowledge in young children (Relkin et al., 2020) • Multiple choice, with three answer choices per question	• Individual • Designed for children in Pre-K through 2nd grade • 15 questions with a total score ranging from 0-15 • 10-20 minutes to administer	
Final Project	• Documentation of students' final KIBO projects • Rubric used to assess the programming concepts and design elements exhibited in the project (Govind & Bers, 2021)	• Individual or group of students, depending on how final project was implemented • Score ranges from 0-50 • 10-15 minutes to score project using rubric	Rubric
Teaching Strategies GOLD	• Standardized child observation tool designed to measure on-going development and learning progress of children 0-5 years (Lambert et al., 2015) • Probes various domains, including social–emotional, physical, language, cognitive, literacy, mathematics, and English language acquisition	• Scores reported by classroom teacher three times a year • 38 objectives across 10 areas of development and learning	Details
Interviews	• Semi-structured format • Asked questions related to their experiences with CAL-KIBO-PreK curriculum and their perceptions of student and teacher outcomes	• Individual • Recorded (Zoom) or live with detailed notes • 30-45 minutes	Protocol
Lesson Logs	• Brief reflection form used to measure implementation status of lesson activities	• Individual or one per classroom • Administered virtually via Qualtrics • Completed at the end of each lesson • 5 minutes	Qualtrics Form

Surveys	• Asked teachers about efficacy and challenges implementing the CAL-KIBO-PreK curriculum, experiences with KIBO and the CAL-KIBO PreK curriculum, and usefulness of resources	• Individual • Administered virtually via Qualtrics • 10-15 minutes	Pre-Training Post-Training Mid-Curriculum Post-Curriculum

Participants

Eighty-six total children enrolled in the study. As mentioned above, three of the classrooms were general preschool classrooms, while three classrooms were part of the Boston Public Schools Universal Prekindergarten program. UPK classrooms completed the curriculum while general preschool classrooms completed either some KIBO lessons or no KIBO programming at all.

Over the course of the research project, 11 children disenrolled from the program while other children transitioned from the general preschool classroom to the UPK classrooms. The research design consisted of two assessment periods, one in the fall and one in the spring. Children who began in preschool or UPK classrooms after the study began were enrolled in the study and completed assessments upon enrollment. Post-assessments were only completed for children in UPK classrooms and children in the general preschool classrooms who enrolled in the fall. Forty-nine children completed post-assessments – 40 in UPK classrooms and 9 in general preschool classrooms.

Twenty-six total teachers took part in the project over the course of the study, with two to three teachers teaching in each classroom. Some teachers left the site or were hired over the course of the project, and not all classrooms completed the curricula, so not all teachers completed all research protocols over the course of the project. Teachers had a mean classroom experience of 11.67 years (*SD= 7.18*), but only three (14.3%) teachers had prior experience

teaching computer science or robotics in some form and none of the teachers had prior experience teaching KIBO robotics.

CAL-KIBO-PreK Curriculum

The Coding as Another Language (CAL) framework was developed by Dr. Marina Umaschi Bers and the DevTech Research Group as an approach to early childhood computer science as a literacy of the 21st century. The framework proposes that coding and computer science offer a language and literacy for children to connect with others, express themselves, and develop new ways of thinking about themselves and the world around them.

The Coding as Another Language KIBO curriculum for PreK (CAL-KIBO-PreK) is a research-based curriculum for preschool students developed on this framework. The curriculum teaches coding and robotics alongside literacy skills such as story comprehension, storytelling, and sequencing, both through books and through creative expression with the KIBO robot. The curriculum is comprised of 30 half-hour lessons and aligned to the Head Start Learning Outcomes Framework. Lessons consist of games, songs, movement activities, books including as *Robots, Robots, Everywhere*, *Click, Clack, Moo: Cows That Type*, *The Very Hungry Caterpillar*, and *Pete the Cat: Robo-Pete*, and coding activities with the KIBO-15 robotics kit. Figure 3 shows a few pictures of the CAL-KIBO-PreK curriculum in action at Horizons for Homeless Children.

Figure 3. *Photos from UPK Classrooms Implementing CAL-KIBO-PreK Curriculum*

Professional Development

In October 2021, a four-hour professional development training was provided by the DevTech team to preschool and UPK teachers at Horizons for Homeless Children. Due to the COVID-19 pandemic, the professional development was conducted in a hybrid format, with teachers working in their teaching teams while DevTech team members presented over Zoom. The first part of the training covered the basics of the KIBO programming language. Teachers then were introduced to the Coding as Another Language Pedagogy and its four foundational metaphors: coding as a playground, coding as another language, coding as a bridge, and coding as a palette of virtues. Finally, teachers explored the CAL-KIBO PreK curriculum, including create their own KIBO robotics project using arts and crafts materials. Figure 4 shows photographs from the CAL professional development training at Horizons for Homeless Children.

Figure 4. *Photos from Horizons for Homeless Children Professional Development Trainings*

Findings

Findings are organized around our two groups of research participants: teachers and students. The first set of findings describe the impact of the training on teachers' coding knowledge and attitudes towards teaching coding. This set of findings also describes strengths and challenges of the CAL-KIBO curriculum and project implementation at Horizons for Homeless through illustrative quotes by teachers. The second set of findings illustrate the impact of the CAL-KIBO-PreK curriculum on students' coding knowledge (as measured by the Coding Stages Assessment for KIBO, or CSA) and on students' academic/developmental competencies (as described through illustrative quotes by teachers).

Teacher Outcomes

Impact of Professional Development. As described in Table 1, CSA scores range from 0-30, which are mapped onto a hierarchy of "coding stages" (Bers, 2020): Emergent, Coding and Decoding, Fluent, New Knowledge, and Purposefulness. There is a Pre-Coding designation for individuals who have not yet reached the Emergent stage of coding knowledge.

Figure 5 shows that teachers demonstrated an increase in coding knowledge following the Coding as Another Language professional development training. The mean pre-training CSA

score ($N = 20$) for teachers was 13.0 points, and the mean post-training CSA score ($N = 15$) was 17.4 points. This difference between pre-training and post-training scores was statistically significant, $p = 0.02$.

Figure 5. *Teachers' Measured Coding Knowledge Pre- and Post-Training*

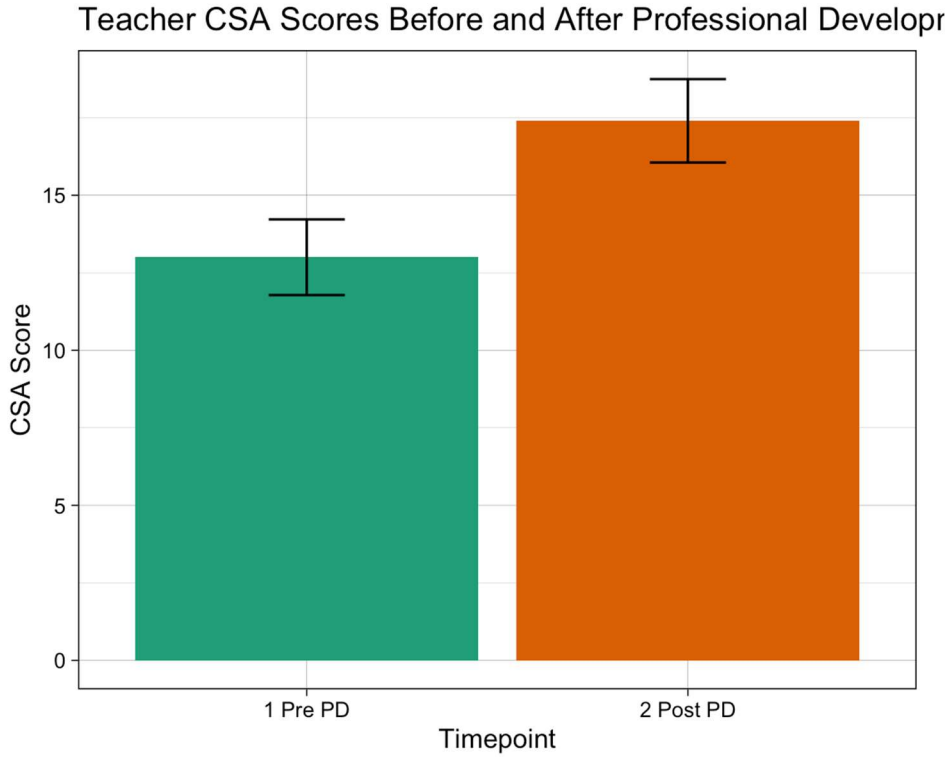


Figure 6 shows that more teachers were at higher coding stages following the Coding as Another Language professional development training. Most teachers were at the *Coding and Decoding* stage prior to the professional development training. Four teachers were in the *Pre-Coding* stage, three teachers were in the *Emergent* stage, and no teachers were at the *Fluency* stage. After the professional development training, only one teacher was in each of the *Pre-Coding* and *Emergent* stages, and four teachers reached the *Fluency* stage.

Figure 6. *Distribution of Teachers' Coding Stages Pre- and Post- Professional Development*

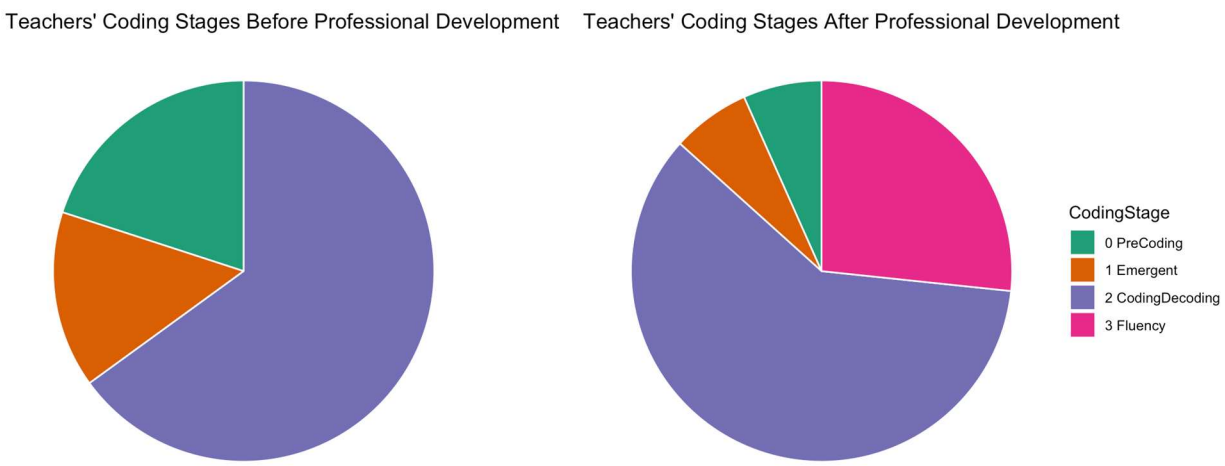
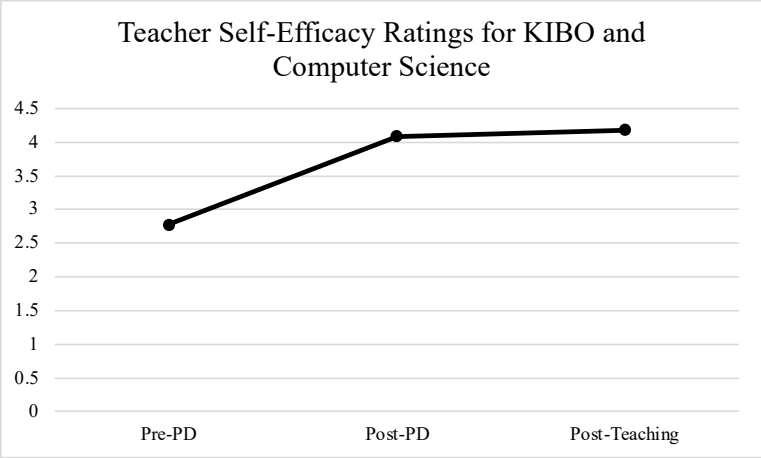


Figure 7 shows teachers' ratings of self-efficacy and confidence before and after the professional development, and after teaching the Coding as Another Language curriculum. The professional development led to an increase in confidence and self-efficacy for teaching computer science and robotics for the teachers. Teachers rated their self-efficacy between zero and five for items including ability to teach KIBO, ability to explain basic programming concepts, ability to help students debug programs, and ability to integrate coding into existing classroom curricula. Prior to attending the professional development, teachers' mean self-rated efficacy for KIBO and computer science was 2.78 out of 5, and after the professional development, mean self-rated efficacy for KIBO and computer science was 4.08 out of 5. There was not significant growth in self-efficacy over the course of curriculum implementation, but that might have been due to teachers' high self-efficacy scores creating a potential ceiling effect following the professional development training.

Figure 7. *Teachers' Self-Rated Efficacy for Teaching KIBO and Computer Science Topics*



Student Outcomes

Thirty-five students completed the CAL curriculum and pre- and post-curriculum testing on the Coding Stages Assessment of coding language knowledge and the TechCheck assessment of computational thinking. Data for these 35 students are reported below.

Coding Knowledge. Figure 8 shows children's coding knowledge as measured by the Coding Stages Assessment (CSA) before and after completing the CAL curriculum. The mean pre-curriculum CSA score was 3.57 (SD = 2.94), and the mean post-curriculum CSA score (N = 23) was 8.17 (SD = 5.16). A paired samples t-test indicated that students significantly improved in their coding knowledge, $t(53.98) = -4.58$, $p < .0001$.

Figure 8. *Children's Coding Knowledge Pre and Post Curriculum*

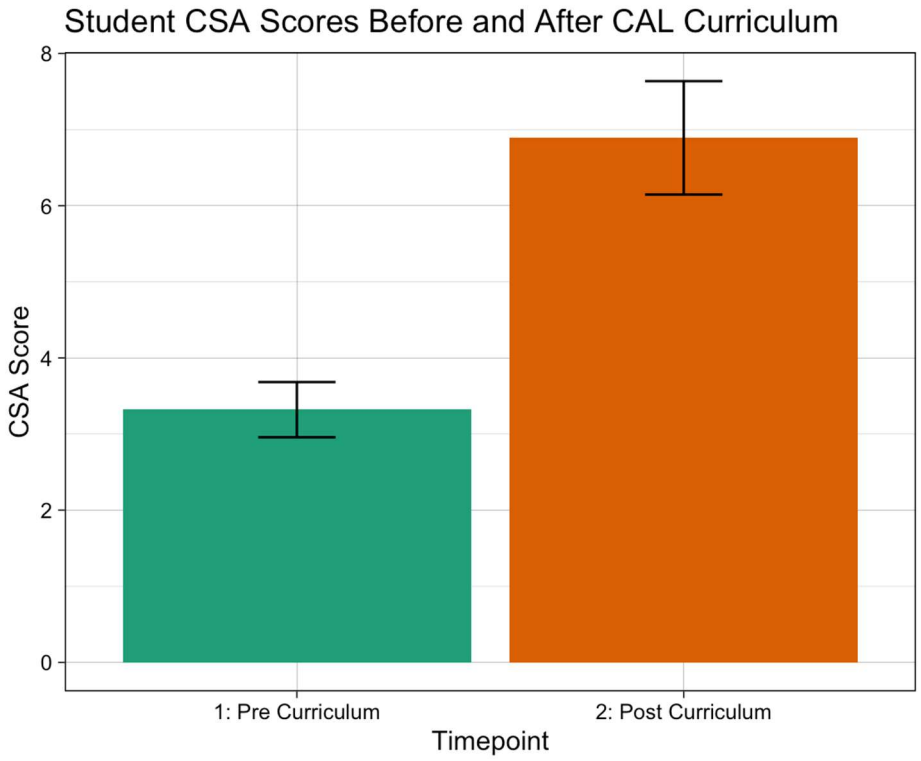
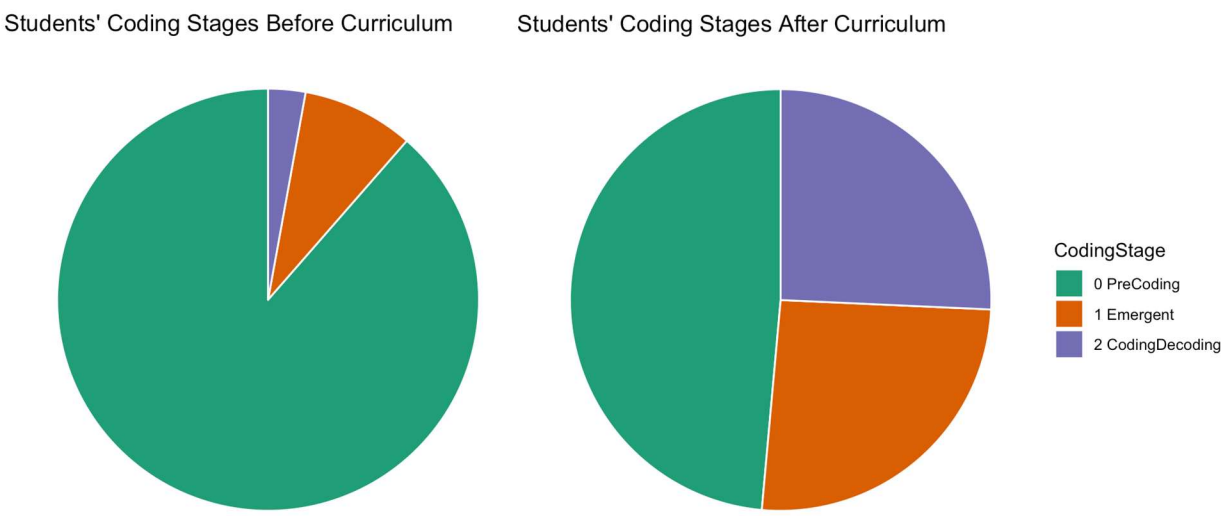


Figure 9 shows that more children were at higher coding stages after the CAL curriculum than before the curriculum. Before the CAL curriculum, 31 students were in the *Pre-Coding* stage of coding knowledge, three children were in the *Emergent* stage, and one child was in the *Coding and Decoding* stage. After participating in the curriculum, 17 of the 35 students stayed in the *Pre-Coding* stage, but 18 students improved one or two stages, with nine students moving to the *Emergent* stage and nine students moving to the *Coding and Decoding* stage.

Figure 9. *Distribution of Coding Stages Pre- and Post- Curriculum*



Computational Thinking. Computational thinking knowledge was assessed using the TechCheck-PreK assessment of computational thinking. As mentioned above in Table 1, the assessment consists of 15 multiple choice questions and is scored between 0 and 15. The mean pre-curriculum TechCheck score was 7.60 (SD = 3.04) and the mean post-curriculum TechCheck score was 7.68 (SD = 2.95). A paired samples *t*-test did not suggest significant differences in computational thinking knowledge between pre and post curriculum assessments, $p = 0.96$. This suggests that the curriculum may not target the computational thinking skills assessed by the TechCheck assessment.

Teacher interviews suggest children's growth in developmentally appropriate computational thinking skills, such as algorithms and debugging. One teacher described children's understanding of algorithms in their morning routine: "even with following directions, we will talk about step two, step [three], and they were correlated with KIBO. Like KIBO, we have to begin, and then we do this, and then we finished. So…like our morning routines when they walk in – so they walk in, they go to the cubby, they wash their hands, they sit for breakfast, then the ending is we sitting for circle."

Academic and Developmental Competencies. We also wanted to examine if the CAL-KIBO curriculum affected student development in other academic or developmental domains targeted by the curriculum, such as literacy, approaches to learning, and social-emotional development.

Teachers described how KIBO affected children's literacy engagement. Two teachers described children identifying KIBO as starting with the same letter as a child in the class. Another teacher described how the working with the KIBO curriculum affected children's writing practices: "They slow them down with the scanning to take their time. So now they slow down to do things rather than rushing and running right in…even with them writing their names. We use the 'O is Oops, let's try again' to let them know it's okay if you mess up… they really grasp it and they're trying it."

Excitingly, teachers described how working with KIBO fostered new collaboration skills among children who generally worked alone, or among pairs of children who did not normally work together. One teacher described "children who would not generally work with peers [and] would rather work solo, but with KIBO, they began to really express that they wanted to work with peers, and they were solving problems in the midst of that which is something that they normally didn't do." Another teacher described how two students that "don't gravitate towards each other…were working together and actually taking turns and listening to each other when they were trying to create their own programs and put KIBO together. They weren't snatching, they weren't saying 'I want to do that' or anything. They literally gave themselves jobs and were working through it, so I thought that was really cool."

Additionally, teachers described students making connections to KIBO during other parts of the day. Teachers described their students bringing up KIBO programs while standing and

walking in line, making comments such as “we need to walk forward like KIBO” and “we can’t walk forever like KIBO.” A teacher also described her excitement when she realized that the children were talking about KIBO with their parents. “The kids were noticing barcodes in stores and on the crosswalk and telling their parents that. So, the parents would come like, ‘Oh, they were telling me about this, and this, and that.’ And so, knowing that they're taking it in to the point where they feel good about it, to talk to their parents about it.”

Program Successes and Challenges

Successes. Teachers reported many successes from and strengths of the curriculum. Although many teachers described initial hesitancy to adding something new and unfamiliar to their program, teachers expressed how the CAL-KIBO curriculum fit nicely within the overall Horizons for Homeless Children curricula. One teacher said, “I was skeptical at first again about like where we got to fit this in, but it fits and it works, and it really coincides with our curriculum and the things that we're trying to teach the kids here right.” Teachers discussed different ways KIBO fit in the existing UPK curriculum. One teacher described how the discussions of language in the KIBO curriculum aligned with existing classroom discussions of the multiple languages spoken in the classroom. Another teacher mentioned the ways KIBO had been integrated into classroom lessons and spaces, for example “in dramatic play, I think we did a cash register or a store… they like would put something on KIBO and do the program where it will go to the left and go to the right, and the kids would use it to serve the customers.”

Teachers specifically liked the inclusive curriculum, and the option to create teachers used printed copies of the curriculum books in addition to the curriculum website. One teacher explained “I think all the teachers had it printed it out, we had binders in our classroom to

reference things, and if we needed something from the online curriculum, we were able to go there just print it out and get what we need… absolutely, we had everything that people needed."

Challenges. Teachers' reported challenges in implementing the CAL-KIBO curriculum took two forms. Challenges around staffing, classroom turnover, as well as relating to children's development, created difficulty implementing the CAL-KIBO curriculum in the general preschool classrooms. In the UPK classrooms, teachers' reported challenges converged around two key issues: language limitations and access to KIBOs.

As reported above, the general classrooms did not teach the CAL-KIBO curriculum due to challenges related to changes in staffing and children's turnover during the time of program implementation. During the time of the curriculum implementation, the general preschool classrooms were missing teachers, had teachers out on medical leave, or had new hires transitioning in during the KIBO curriculum program. Also, during this time, as mentioned above, many children in these classrooms transitioned to UPK classrooms, so students who had begun working on the curriculum with their teacher were not able to complete the curriculum. For these reasons, no general preschool classroom completed the curriculum, although some completed some KIBO lessons. With these lessons, the other challenge described by teachers was the developmental appropriateness of the curriculum for children as young as 2.9 years old. One teacher noted that "they just don't understand the concept or have the focus to really even try to understand the concept but they like messing around with it and seeing how things move, even if the teachers do it for them." This challenge was expected, as neither curriculum and the KIBO robotics set were developed for children three years old or younger. However, teachers still found benefit of introducing KIBO in the younger classrooms. One teacher explained how "one of the things that we're doing in this the younger preschool classroom is taking out a group of

children that can focus and having them do it… so that some of the children are getting that hands-on experience with little disruption… every lesson they enjoyed that individual, you know the smaller group size, and being able to put the hands on it and explore it."

As mentioned above, in the UPK classrooms, teachers' reported challenges converged around three key issues: language limitations, access to KIBOs, and staffing. The majority of teachers identified language limitations as a challenge in implementing the KIBO curriculum. Although the teachers taught in multilingual classrooms, and each classroom had at least one teacher who taught both in English and Spanish, the curriculum was only offered in English. One non-Spanish-speaking teacher said "if I'm not Spanish-speaking, and we have children in the classroom who need to learn -- how would we be able to implement it? So maybe having it in Spanish, or some things in Spanish…even if it's just the songs, that would be great." A Spanish-speaking teacher said "trying to translate everything into [Spanish], that was kind of rough… I think some words in English and Spanish are… hard to translate."

However, teachers were able to adapt their instructional practices to accommodate the needs of Spanish speaking students, including Spanish-speaking teachers translated the materials and instructions themselves, on the spot. One of the classrooms sorted students into smaller groups for working and described sorting the students by language in order to provide Spanish-language support to the Spanish-speaking students, with one small group receiving KIBO time in translated Spanish and one group receiving KIBO time in English. One teacher said, "once we split the groups into the Spanish speaking groups – we still did some whole group activities with them, but in a split whole group – it work[ed] so much better."

Another primary challenge reported by teachers was that at times, classrooms had limited access to KIBOs. There were six KIBO sets available to share among the six classrooms, but in

practice, the UPK rooms each wanted to use at least two KIBO sets per lesson. One teacher referenced the Spanish and English groups to explain the need for two KIBOs, explaining “we try to always have two KIBOs because I told you, it was easier to split the groups, but it wasn't always available.” Teachers described difficulty on days where they had difficulty accessing multiple KIBO kits, with one teacher saying “I would lose kids’ interest more, because I didn't have the two split [groups] and so on. Whenever we did have at least two [KIBO kits], it was fine.” However, another classroom took a different approach. Having first tried running small groups one after the other, the teachers ultimately “had to figure out how to make it a whole group activity, and if you did any work that everybody participated.”

Conclusions, Implications, and Future Work

Overall, our findings suggested that although the students and teachers in the preschool classrooms did not spend much time with KIBO, the students and teachers in the UPK program had a generally positive experience with KIBO and the CAL-KIBO-PreK curriculum. Both students and teachers had positive learning outcomes. From the professional development, teachers demonstrated increased coding knowledge as well as an increased ability to and confidence in their ability to teach programming and robotics concepts in the classroom.

Students gained increased knowledge of robotics and programming concepts, as seen both through coding language assessments and demonstrative behaviors described by their teachers. Although there was not a significant increase in computational thinking as seen by the TechCheck assessment, children did demonstrate knowledge of computational thinking skills such as sequencing and debugging. Additionally, teachers described student growth in associated developmental domains such as social emotional learning, literacy, and approaches to learning. This project highlights the opportunities that can arise from research-practice collaborations. In

our future work, we will continue to explore student and teacher outcomes from this program, as well as make revisions to the curriculum based on findings from this research.

References

Bers, M. U. (2020). *Coding as a playground: Programming and computational thinking in the early childhood classroom*. Routledge.

Govind, M., & Bers, M. U. (2021). Assessing Robotics Skills in Early Childhood: Development and Testing of a Tool for Evaluating Children's Projects. *Journal of Research in STEM Education*, *7*(1), 47–68.

Lambert, R. G., Kim, D.-H., & Burts, D. C. (2015). The measurement properties of the Teaching Strategies GOLD® assessment system. *Early Childhood Research Quarterly*, *33*, 49–63. https://doi.org/10.1016/j.ecresq.2015.05.004

Relkin, E., de Ruiter, L., & Bers, M. U. (2020). TechCheck: Development and Validation of an Unplugged Assessment of Computational Thinking in Early Childhood Education. *Journal of Science Education and Technology*, *29*(4), 482–498. https://doi.org/10.1007/s10956-020-09831-x

Strawhacker, A., Relkin, E., & Bers, M. U. (2022). *Designing an Adaptive Assessment for Preschool Children's Robotics Knowledge*. 23.

Acknowledgements

We wish to thank Amanda Martinez, Jayd Rodrigues, and Sheila O'Neil for their efforts in making this research collaboration possible, the teachers and students who participated in this research, and the DevTech Research Group.