Nurturing Computational Thinking in an Israeli Kindergarten with the CAL-KIBO Robotics Curriculum

Avia Ben-Ari
Faculty of Education in Science and Technology
Technion – Israel Institute of Technology
Haifa, Israel
avia.ben@campus.technion.ac.il

Tess Gavrielle Levinson
Lynch School of Education and Human Development
Boston College, Massachusetts, USA
tess.levinson@bc.edu

Marina Umaschi Bers
Lynch School of Education and Human Development
Boston College, Massachusetts, USA
marina.bers@bc.edu

Rinat B. Rosenberg-Kima
Faculty of Education in Science and Technology
Technion – Israel Institute of Technology
Haifa, Israel
rinatros@technion.ac.il

Abstract

Coding, robotics, and computational thinking have been recognized as leading skills that should be taught at early ages. In this case study, we examined whether engaging with the *Coding as Another Language* curriculum using the screen-free KIBO-15 robotics kit could promote children's computational thinking and coding skills. We further accounted for the necessary curricular adaptations in an international setting. Twenty-eight children (age M =5.94; SD =0.52) and two teachers were recruited from an Israeli kindergarten. Students' outcomes showed significant growth in coding knowledge over the course of the curriculum, with no gender effect. Teachers' accounts suggested developmental, pedagogical, and cultural considerations for future international curriculum implementation. Findings from this work have implications for future researchers implementing STEM-related curricula internationally.

1. Introduction

While coding, robotics, and computational thinking have been recognized as leading skills that should be taught early (Wing, 2006; Zviel-Girshin et al., 2020), a few challenges characterize the implementation of programs aimed at developing computational thinking skills and coding at early ages. First, kindergarten children are yet to reach the fluency and literacy needed to comprehend common coding languages. Second, many parents and educators object to the use of screens by young children, as it has been negatively associated with physical and cognitive abilities development (Domingues-Montanari, 2017). Third, there exists an initial gap in professional training, as most kindergarten and elementary teachers lack the knowledge and self-efficacy to teach STEM-related subjects (Yadav et al., 2016).

In the current case study, we examined the implementation of a coding learning program based on the Coding as Another Language (CAL; Bers, 2019) pedagogy, using the off-screen KIBO-15 Robotics kit in an Israeli kindergarten. We examined whether engaging with this program could promote children's computational thinking and coding skills and accounted for the necessary adaptations needed for the implementation of the CAL-KIBO curriculum as an American program in an international setting. The implementation consisted of a teachers' professional development session and a seven-month-long curriculum completion.

2. Theoretical Framework

The case study presented in this paper followed two principles of how coding, computational thinking, and robotics can be taught in the early childhood classroom in a developmentally appropriate way: 1) *Coding as Another Language*, and 2) *Coding as a Playground*.

2.1 Coding as Another Language

Papert (1987) had already suggested that learning to code highly resembles learning a new language. Bers (2019) introduced the pedagogical approach *Coding as Another Language* (CAL), presenting coding as a novel form of the traditional ability to read and write, emphasizing the parallel qualities shared by learning to code and learning to write. Earlier on, Resnick and Siegel (2015) claimed that coding is as creative and important as writing, and Norman (2017) highlighted the three core criteria both abilities share, namely meaningfulness, productivity, and displacement. Bers (2019) further suggests that natural and coding languages are equally powerful, as both may be used to create something that has not previously existed. Accordingly, her pedagogy renders coding as a relevant tool for the creative expression of ideas and thoughts.

2.2 Coding as a Playground

The *Coding as a Playground* framework considers coding as an engaging playground (Bers, 2018). This framework is specifically relevant for early childhood CS, as the *playground* is the natural domain where various developmental needs are met. Without detracting from their natural eagerness to have fun and discover the world around them, playgrounds enable children to develop their personal, cognitive, social, motor, and moral skills altogether. It is within the playground reign that children develop their imagination, problem-solving, and planning skills. Based on this approach, Bers directs early-age CS practices towards the developmentally appropriate environments within which the coding language is to be acquired.

Stemming from these two frameworks, the CAL-KIBO Kindergarten (CAL-KIBO-K) curriculum described in this paper was developed (Bers, 2019). Aimed at the acquisition of coding as another language, the curriculum enables kids to gradually move from basic to more linguistically complex coding structures while consolidating the direct relation between coding and a natural language. The curriculum is based on natural and intuitive child-like activities aligned with children's developmental needs, emphasizing self-expression and creativity using games, songs, movement, and crafting.

3. Method

3.1. Participants

One kindergarten classroom from Northern Israel, including 28 children ages five and six (17 boys and 11 girls, age M =5.94; SD =0.52), a primary teacher, and an assistant were recruited to participate in the study. It should be noted that in Israel kindergarten is part of the preschool system and not the elementary school system. The participants consented to engage in a 24-session programming curriculum over the period of seven months utilizing the KIBO robotics kit.

3.2 Materials

3.2.1 CAL KIBO Curriculum

The CAL-KIBO-K curriculum is an integrated curriculum designed in Massachusetts, USA, for coding, robotics, computational thinking, and literacy based on the *Coding as Another Language* pedagogy (Bers, 2019). The curriculum consists of 45-minute long 24 sessions. Lessons consist of a variety of activity types, including songs, games, scaffolded instruction, expressive exploration, read-aloud story time, literacy activities, and group sharing. The curriculum is designed for the KIBO-15 robotics kit and is aligned to American educational standards such as *Common Core*[1].

All original curricular student-and-teacher-facing materials, including songs and games, were translated into Hebrew by the research team. Additionally, the original non-fiction story accompanying the curriculum "*Hidden Figures*" was replaced by the story *"My First Hero: Marie Curie"*, maintaining the curricular guidelines for book selection. Lastly, while all visual materials were translated, the Kibo-15 blocks remained in their original form, such that children created left-to-right codes using blocks presenting English words and appropriate icons.

3.2.2 KIBO-15 robotics kit

KIBO is a screen-free robot that can be programmed through scanning command blocks (see Figure 1). The KIBO-15 kit contains the KIBO robot with a drawable faceplate,

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[1] The translated version as it was used in the study is freely accessible on the CAL website, alongside all other CAL-KIBO curricula (https://sites.tufts.edu/codingasanotherlanguage/curricula/kindergarten-kibo/).

wheels, motors, and scannable cards for creating KIBO programs. Also included are KIBO's light bulb, sound sensor, and an art platform for added creativity and imaginative play.

3.3 Measures

We used the Coding Stages Assessment (CSA) scale, as well as qualitative data, including teachers' interviews and feedback as described below.

3.3.1 Coding Stages Assessment (CSA)

The Coding Stages Assessment (CSA) (de Ruiter & Bers, 2021) was used before and after curriculum implementation with students. Bers' model of *Coding Stages* proposes that children learn to code in developmental stages, similar to learning to read (Bers, 2019). Accordingly, the five stages are *Emergent*, *Coding and Decoding*, *New Knowledge*, *Fluency*, and *Purposefulness*. The CSA consists of six prompts for each stage, enabling participants to proceed to the next stage if they answer at least five prompts correctly.

3.2.2 Teachers' Feedback and Interviews

Teachers' feedback about curricular activities, perceived students' reactions to them, and necessary curricular changes were recorded throughout the teaching course. Upon program completion, an in-depth interview was held with the primary teacher. The formal summative interviews were recorded and transcribed.

3.4 Procedure

The staff participated in a single in-person training session on the KIBO robotics kit and its curriculum. Teachers were authorized to modify the lesson plans should cultural or other considerations urge them to, as long as they recorded the adaptations and informed the researchers (i.e., omitting a nursery rhyme, combining two consecutive lessons into one, etc.). Regardless of the changes made, all sessions maintained the original lesson structure.

The primary teacher and her assistant taught the curriculum in small groups of up to seven kids per session. Thus, one lesson was repeatedly taught throughout the week to all groups. The coding skills of all participating students were assessed before and after the program.

4. Results

4.1 Children's Outcomes

Children showed statistically significant improvement between pre-tests (M = 2.68 mean, SD = 1.98) and post-test (M = 15.08, SD = 3.76) results, $F(1,23)=219.59$, $p<.0001$. Engaging with the KIBO Robot curriculum did promote computational thinking and coding skills in the examined age group (see Figure 2). No significant effect was found for gender, $F(1, 23)=2.713$, $p=.113$.

Regarding coding stages, most children were at *Pre-Coding* stage before the beginning of the curriculum, with only two children at the first *Emergent* coding stage. At the end of the curriculum, while few children reached only the first *Emergent* coding stage, most children reached the second *Coding-Decoding* coding stage and were proficient in programming using motion, sound, and light blocks, proving hardware knowledge as they could debug and explain the different Kibo-15 parts' functionality (i.e., wheels, light sensor). Four kids reached the third *Fluency* coding stage and could use the repeat loops and parameters fluently (see Figure 3).

4.2 Teachers' Feedback

With the iterative design process, we welcomed feedback from teachers along the way. The feedback, based on informal conversations as well as on in-depth interviews, was divided into three main themes: developmental, cultural, and pedagogical considerations. On the developmental level, teachers found some of the materials to not align with the kids' cognitive abilities. As kindergarten is part of the preschool system in Israel, children are not expected to read and write in kindergarten. Thus, most natural writing activities had to be modified or scaffolded. Similarly, teachers noted that there were specific materials whose lexical level exceeded the children's objective level and were claimed to include "words that are meaningless to the kids" (e.g., the *Design Process Song*). Similarly, the local non-fiction book accompanying the curriculum required rephrasing of the content by the teachers while putting more emphasis on the images. Culturally, the nursery songs incorporated along the lessons (some based on unfamiliar melodies) were defined as "rather unnatural" and were replaced by alternative local routines. Lastly, pedagogical notions referred to the time dedicated to some of the activities. While there were materials that felt "needlessly repetitive" (e.g., the repetitive reading of the book throughout a few lessons), teachers believed more time should have been given to "free exploration opportunities". Teachers further reported that children seemed to enjoy the scanning and crafting activities. Specifically, the primary teacher emphasized how crafting enabled each child "to own and invent their creations."

5. Discussion

This case study aimed to examine whether engaging with the CAL-KIBO-K curriculum using the KIBO-15 Robotics Kit could promote computational thinking and coding skills in children while defining the adaptations needed for such implementation in an international setting. We found that learning to code with the CAL-KIBO curriculum significantly improved children's computational skills and coding abilities. Interestingly, only four kids reached the *Fluency* coding stage and could use the repeat loops and parameters fluently. It could be that when required to engage in more complex *fluency* curricular tasks, children naturally preferred to invest in 'certain-success' experiences, such as the repetitive scanning of a given block or crafting. Interestingly, while we were not interested in gender differences, we were encouraged to see they were not significant, contradicting previous findings showing gender gaps in computational thinking skills already in sixth grade (Ardito et al., 2020) and in middle and high school years (Master et al., 2016). This finding supports the implementation of STEM-related subjects in kindergarten, a stage in which gender paving and cultural biases have not yet consolidated.

A few cultural and developmental considerations should be considered when planning to implement the CAL- KIBO curriculum in international settings. We would suggest dedicating designated time already in the professional development training to welcome teachers to thoroughly consider and comment on the lesson plans, giving full legitimacy to critical thinking and necessary adaptations. Doing so ahead of time could make teachers "own" the curriculum, thus increasing their motivation for its full potential and successful completion. In terms of language localization, it appears that the terms appearing in English on the KIBO programming blocks did not affect the Hebrew-speaking learners' outcomes. We would further suggest that such acquisition may be beneficial for the future learning of left-to-right languages.

In summary, the fact that the CAL-KIBO curriculum combines crafting activities and coding without depending on screens makes it particularly appropriate for young children who are yet to develop literacy skills. Furthermore, these features make it accessible for kindergarten and preschool teachers, empowering them to take a significant role in preparing children for the 21st-century needed technological skills.

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Figure 1. The KIBO-15 robotics kit

Figure 2. Children's Coding Knowledge pre- and post-curriculum

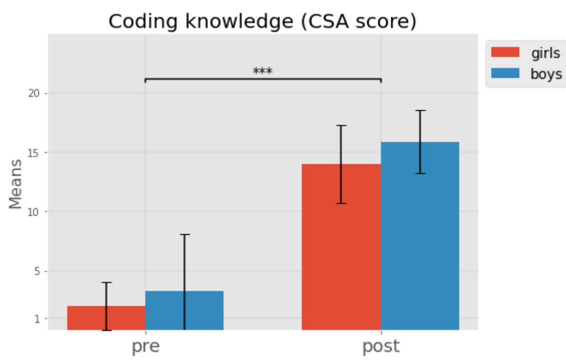

Figure 3. Children's coding stages' distribution pre- and post- curriculum