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Coding as Another Language: An International Comparative Study of Learning Computer Science and Computational Thinking in Kindergarten

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Abstract: This symposium brings together researchers and practitioners from four regions in three countries who localized, adapted, implemented, and evaluated a 24-lesson kindergarten curriculum called Coding as Another Language (CAL). CAL uses ScratchJr and unplugged activities, to promote computer science learning and computational thinking development. Given the growing need for evidence-based curricula that allow the integration of computer science and computational thinking into early childhood, this symposium brings together educational researchers and practitioners who worked with CAL in kindergarten classrooms to share their experiences. This symposium presents comparative experiences, across languages and continents, which involved adaptation of curricular materials and assessment instruments, language localization, training research partners, conducting professional development for teachers, mixed-methods data collection with children and teachers, and analysis of results. Lessons learned about working in cross-cultural settings, integrating computer science in the early childhood classroom, and different conceptions of literacy, across different countries will be shared.

Description

This symposium brings together researchers and practitioners in four locations: two regions of the United States (one on the East Coast and one on the West Coast), Argentina, and Israel. The researchers and practitioners worked to localize, adapt, implement, and evaluate a 24-lesson kindergarten curriculum called Coding as Another Language (CAL). CAL uses the ScratchJr free programming language, along with unplugged activities, to promote the learning of computer science and the development of computational thinking.

The pedagogical foundation of CAL involves the understanding of coding as a literacy, that is, putting powerful ideas of computer science in conversation with those taught in language arts. Since kindergarten is a schooling period in which children are starting to be exposed to symbolic systems of representation, CAL introduces the teaching of an artificial language (i.e., programming blocks of ScratchJr) at the same time as instruction about the children's natural languages (in this case, English, Spanish and Hebrew).

The Coding as Another Language (CAL) approach (Bers, 2019, Bers et al., 2022) views the learning of computer science as a new literacy for the 21st century that supports young learners in developing new ways of thinking and expressing themselves. The CAL approach is not about teaching children how to code so they become software developers. It is about children developing character strengths, problem-solving strategies, and collaborative attitudes, along with technical skills and computational thinking (CT), to become future global citizens who can think and act in new ways. Based on this pedagogical approach, the DevTech team, directed by Marina Bers, has developed the K-2 CAL curriculum units using the free ScratchJr introductory programming language.

CAL was designed using principles of three theoretical frameworks: Curriculum Research Framework (CRF), which proposes different phases of work in the creation of research-based curriculum (Clements, 2007); Constructionism, which presents a computationally-rich project-based methodology based on identifying

powerful ideas from a learning domain (Papert, 1980); and Positive Technological Development, which intentionally integrates socio-emotional and ethical dimensions into curricular experiences (Bers et al., 2012). The CAL curriculum introduces powerful ideas from computer science, in conversation with literacy, in playful, structured, and developmentally appropriate ways. The curriculum consists of 24 lessons, designed for a total of 18 hours. Through unplugged games, storytelling, movement, singing, and coding, students learn computer science and develop problem solving and computational thinking in the context of creating their own projects using the ScratchJr coding app. In addition, to strengthen the literacy connection, students explore two books, a non-fiction book exploring a historical figure in STEM and a fiction book with a narrative story and a social-emotional component, to write creative, fun programs on ScratchJr. In the kindergarten curriculum, the two books are *A Computer Called Katherine* and *Knuffle Bunny,* which are both available in Spanish as *Una computadora llamada Katherine* and *El conejito knuffle*. Alternative books were selected for the Hebrew curriculum, as is described in Paper 3.

CAL has been used over the last few years by thousands of children and hundreds of teachers all over the world and has been translated and localized from English into Spanish and Hebrew. Given the growing need for evidence-based curricula that allow the integration of computer science and computational thinking into early childhood, this symposium brings together educational researchers and practitioners from three different countries who worked with CAL in kindergarten classrooms to share their experiences.

This symposium presents comparative experiences, across languages and continents, which involved adaptation of curricular materials and assessment instruments, language localization, training research partners, conducting professional development for teachers, mixed-methods data collection with children and teachers, and analysis of results. Lessons learned about working in cross-cultural settings, integrating computer science in the early childhood classroom, and different conceptions of literacy, across different countries will be shared.

Each of the papers in the symposium addresses four interrelated issues:

1. Researcher-practitioner collaboration to implement CAL and study the impacts of CAL in kindergarten programs.
2. Localization of CAL to achieve feasibility of implementation and evaluation.
3. Learning outcomes in terms of coding, CT, and literacy for students participating in CAL.
4. Teachers' experiences regarding the construct of "coding as a literacy."

As new curricula and experiences are developed, implemented, and evaluated, it is important to understand the factors that make this feasible, sustainable, and scalable internationally. Furthermore, while coding is a universal language, when integrated into classrooms across the world that have different educational practices regarding the teaching of alphabetical and computational literacy, lessons can be learned about culturally responsive instruction.

This symposium will help move the field forward by contributing to the emerging understanding of how to integrate coding and CT in diverse early childhood settings and exploring implications for both research and practice across the world.

The papers in this symposium address each of these issues by presenting the experiences in four different locations: 1) On the East Coast of the United States in a large urban district in Massachusetts and several districts in Rhode Island; 2) On the West Coast of the United States in a large district in California; 3) In Argentina in two large districts in Mendoza and Corrientes; and 4) In Israel in a small school in Haifa.

Symposium structure

The session chair will introduce the symposium theme and goals, as well as the CAL curriculum and ScratchJr programming language and the methodological approach used in the comparative study (15 minutes). Then, four papers, each describing one of the studies: US, East Coast, US: West Coast, Argentina and Israel will be presented in the order listed in the proposal (10 minutes each). After this, the chair will comment on general trends and discuss converging themes and implications (10 minutes). The session will conclude with a moderated discussion between the presenters, coordinated by the chair) and open Q&A with the audience, focusing on implications for research and practice (10 minutes).

Methodology

All papers presented in this symposium involved the following components:

- Conducting professional development(PD) about the ScratchJr coding app, and the CAL curriculum and pedagogy.
- Providing ongoing support to teachers implementing the CAL in kindergarten classrooms

- Examining impact on teacher's attitudes and knowledge and students' computational thinking and coding skills
- Understanding teacher and student experiences regarding coding and literacy
- Trained research assistants administered student computational thinking (Tech Check) and coding (CSA) assessments over Zoom before and after the CAL curriculum was implemented.
- Teacher surveys, lesson logs, focus groups, and end-of-year interviews were used.

Paper 1: Coding as Another Language on the East Coast of the United States

On the East Coast of the United States, we conducted a randomized control trial of the Coding as Another Language (CAL) ScratchJr curriculum in kindergarten, first, and second grade classrooms in two New England states. The curriculum was initially designed for this setting, so it was not adapted to be localized for this implementation. This paper will primarily focus on the kindergarten implementation.

Schools were randomly assigned to either the "treatment" condition or a "control" condition. For the treatment condition, the CAL curriculum was introduced in 18 total kindergarten classrooms from three public school districts in one state (Site 1) and five schools from a large urban public school district in a different state (Site 2). These nine schools were randomly assigned to implement the CAL curriculum. Twenty-seven teachers from these nine "treatment" schools received a 4-hour, virtual professional development. The professional development covered ScratchJr, a block-based programming language that enables young children (ages 5 and up) to create their own interactive stories and games, the CAL pedagogy, the CAL curriculum, and the research study protocol. Participating teachers then taught the CAL curriculum, completed surveys and lesson logs, and participated in focus groups.

Nine additional schools participated as "control" schools in this randomized control trial. In these schools, teachers completed "business as usual," meaning they taught their traditional existing curriculum without including the CAL-ScratchJr curriculum or making modification. Therefore, these teachers did not receive ScratchJr and CAL curriculum training and did not implement the curriculum. In these control schools, 10 Kindergarten classrooms with 166 students participated in the same one-on-one virtual coding games assessments with a trained research assistant where student coding skills and computational thinking (CT) were assessed at two points in time, similar to the times the students in the treatment group were assessed.

Two-hundred forty-seven kindergarten students (158 from Site 1 and 116 from Site 2) were assessed on coding knowledge and computational thinking (CT) using the Coding Stages assessment (CSA) and TechCheck assessment before and after completing the curriculum (Ruiter and Bers, 2021, Relkin et al., 2020). Students who received the CAL curriculum had a mean pre-curriculum coding score of 1.87 (SD= 1.23) and a post-curriculum coding score of 7.75 (SD= 3.23). The intervention group showed significantly higher growth of coding performance (β = 4.14, Hedge's g = 0.39) than the control group, who grew from a mean coding score of 2.31 (SD=1.47) to 3.99 (SD= 2.05).

The intervention group also grew on the assessment of computational thinking, with a pre-curriculum TechCheck score of 7.042 (SD= 2.32) and a post-curriculum TechCheck score of 8.53 (SD= 2.43). However, this increase in students' computational thinking scores across time was not significantly different from the control group, who had a pre-curriculum TechCheck score of 7.11 (SD=2.42) and a post-curriculum TechCheck score of 7.96 (SD= 2.36).

Teachers' self-reported efficacy (confidence that they could teach various aspects of the coding curriculum to their students) from both Site 1 and 2 increased significantly after the PD training ($t(42)$ = 7.48, $p < 0.001$), $t(31)$ = 6.97, $p < 0.001$). Self-efficacy was reported on Likert scale from 1 to 5 and grew from a mean of 2.8 (SD = 1.14) to 3.98 (SD = 0.73). These results include all K-2 teachers who participated in the PD training, not just kindergarten classroom teachers, as the PD and study included both classroom teachers and enrichment and support teachers who taught the curriculum in multiple grades.

Additionally, qualitative data from these teachers who taught and supported kindergarten classrooms provide opportunities to explore many differences in these samples including collaboration, support, and teacher role. While some teachers are the sole participating teacher at their school, others have participating colleagues to collaborate with. Also at Site 1, designated Tech Leaders at each school provide ongoing support to teachers. In addition, classroom teachers may have flexibility regarding when and how often to implement, while enrichment teachers may have limited scheduled times. These conditions along with teacher reports of support and curricular modifications are examined as well as their impact on outcome measures.

Teachers shared that their students, "asked to do it [the CAL curriculum and ScratchJr] every day. If we couldn't do it, they were disappointed." One teacher mentioned, "watching the kids get up to help other kids naturally and organically without being told someone needs help… that's a highlight when you see kids taking over the responsibility in the room themselves."

Yet another teacher emphasized, "Post-Covid, it was just what we needed. It was interaction, it was dynamic, give and take." She also added, "And I had five students where English was not their second language, and loved watching how they all did with this."

In terms of integrating the CAL curriculum into their existing curriculum, one teacher mentioned, "We were learning about different ecosystems... and they [ScratchJr app] happen to have the jungle and the ocean, and so kids were able to explore with those backgrounds and add the animals that belong there."

When asked if they would recommend the CAL curriculum to other teachers, one teacher said, "I've recommended it a million times. We are actually going to be training all of the K-2 teachers in our district; that's going to be my role…They know I've been talking about perseverance, and grit, and applied skills, and those soft skills… cooperative learning, collaboration, and so they know… that this is going to be a really exciting time for them.

Our findings suggest that the CAL curriculum was both a successful program for improving coding knowledge on the East Coast of the United States and was enjoyable to classroom and support teachers. This second feature is promising for future use of the program, as an enjoyable program is more likely to be implemented in the future and remain part of the school's program. As mentioned above, the curriculum was not adapted to be localized for this implementation. However, that does not mean that the curriculum may not have been adapted for local cultural contexts, as individual teachers may have localized the curriculum to meet the cultural contexts of their classroom. In future research, we will examine individual classroom differences in teachers' experiences and implementation practices of the curriculum, as well as student responses to the curriculum.

Paper 2: Coding as Another Language on the West Coast of the United States

As evidence-based curricula scale, it is crucial to account for local contexts to co-design instructional materials that are appropriate for diverse and often marginalized communities. This paper investigates teacher implementation of the Coding as Another Language (CAL) curriculum for California's culturally and linguistically diverse learners.

Our study draws from the Jacob & Warschauer (2018) model of computational literacy, grounded in sociocultural theory, including the work of Barton and Hamilton (1998); DiSessa (2000); and Gee (2000). The Jacob & Warschauer (2018) model takes an asset-based approach to understanding how teachers can leverage students' literacy skills to develop their computational thinking skills and vice versa. This paper builds on this work to consider the cultural and linguistic factors contributing to the development of computational literacies for diverse learners. As a result, this new culturally responsive model explores how teachers can mobilize the rich traditions and cultural practices present in marginalized communities.

This Design-based Implementation Research (DBIR) pilot study followed three teachers as they implemented the CAL curriculum in their culturally and linguistically diverse classrooms. The participating district in California has among the highest percentages in the US of Latinx students (93%), low-income learners (89.7%), and students designated as English learners (62.7% in the elementary grades). Therefore, we focused on culturally responsive instructional adaptations and strategies teachers used to develop computational literacies for Latinx and multilingual students.

Data sources included field notes on co-design meetings with teachers who engaged in reflection cycles, in which we collected their feedback and reflections to improve the intervention. The field notes focused on instructional strategies and their relationship to student engagement, coding activities, and language use. Co-design teachers were also formally interviewed at the end of the year to better understand their instructional goals and practices and to collect feedback for improving the curriculum and PD.

Teachers suggested several adaptations to the curriculum that would better meet the needs of their Latinx and multilingual students, including 1) integrating culturally responsive materials, such as storybooks depicting Latinx computer scientists, into the curriculum; 2) providing additional language support; 3) balancing guided instruction with exploration; and 4) increasing multimodal and digital resources. We will use these and other findings to revise the curriculum to meet the needs of the district's diverse learners.

Considering that Latinx and multilingual students have unequal access to technology and CS learning (Irwin, 2021), it behooves researchers to focus more attention on culturally responsive CS interventions that promote equitable participation for these students. Implementing culturally responsive instruction that accommodates local contexts of diverse communities leads to increased teacher uptake of evidence-based curricular interventions such as CAL and better supports both scaling efforts and overall sustainability.

Paper 3: Coding as Another Language in Haifa, Israel

In this case study, we implemented the CAL-ScratchJr-K curriculum in a Hebrew-speaking kindergarten classroom in Northern Israel. The implementation included a professional development (PD) training for teachers and curricular implementation over the course of seven months. We were interested in teachers' self-efficacy and objective ability to implement coding in their classes while using the CAL-ScratchJr-K curriculum. Furthermore, we were interested in accounting for the adaptations needed to implement the CAL-ScratchJr-K curriculum as a program developed in alignment with American pedagogical standards and culture, which are very different from the ones in Israel.

Kindergartens in Israel are part of the preschool education system as opposed to the American elementary school system. As such, kindergarten programs in Israel differ greatly from their American equivalents in terms of literacy instruction, which officially starts in the first grade. Thus, the children we worked with were not yet exposed to formal reading and writing. Nevertheless, informally, students were immersed in a culture in which the Hebrew language is written from right-to-left, as opposed to left-to-right. The ScratchJr coding language is assembled left-to-right, which might create a mismatch in directionality between coding and natural language in Israeli children. We were interested in whether this would interfere with children's development of coding skills.

The CAL-ScratchJr Kindergarten curriculum was implemented in a Hebrew-speaking kindergarten classroom for a period of seven months. Two teachers and 26 children (14 boys, age mean=6, sd=0.33) participated in this project. All student and teacher-facing materials were translated to Hebrew, and necessary cultural adaptations were implemented. For example, instead of using the book *Hidden Figures,* teachers taught the book of *My First Hero: Marie Currie* to better integrate the coding curriculum with their broader science unit.

Teachers' coding stages assessments (CSA) and their self-efficacy surveys were collected before and after PD completion. Teachers also completed a mid-curriculum survey. Furthermore, teachers reported all adjustments made to the curriculum. Students' pre-CSA (coding) and TechCheck (computational thinking) assessments were collected at the beginning of the curriculum and again at the end. In addition, 26 ScratchJr projects created by each child were scored using the ScratchJr project rubric. Teachers' summative in-depth semi-instructed interviews were also conducted at the end of the curriculum.

Children's average CSA stage was *Pre-Coding* at baseline, with an average TechCheck score of 7.56 (SD=1.7). At post, children's average CSA stage was *Emergent*, with an average TechCheck score of 8.23 (SD=1.86). Both teachers scored higher on their CSA stage following the PD training, moving from the *Emergent* stage to the stages of *Fluency* and *New Knowledge*. Likewise, their self-efficacy to teach basic coding principles improved following PD completion. In terms of cultural adaptations to the curriculum, age-related cognitive abilities and cultural considerations urged the omission of all charts and tables as well as of most nursery songs, and required further scaffolding in literacy activities. Interestingly, teachers reported that the platform's inherent English aspects did not hinder learning.

Results suggest that the CAL-ScratchJr-K curriculum may support teachers' perceived self-efficacy and objective ability to implement coding in their classes, contributing not only to the teaching of coding at early ages but also to the empowerment of early childhood teachers and children *within* the educational system. This conclusion is depicted in the following account, given by the primary teacher who taught ScratchJr in her classroom: "I've always thought that computers were a 'boys' thing' [and] I used to have a serious computer phobia (…), and today I do everything on my own! Suddenly, I've come to realize that I am a programmer, a technician, that I *solve* problems! I really went through an empowering process. I felt valuable. My [coding] knowledge gave me strength." Furthermore, despite pedagogical and linguistic differences, the translation of the curriculum and its cultural adjustments do not seem to require the adaptation of the ScratchJr coding platform itself.

Paper 4: Coding as Another Language in Argentina

According to data provided by the World Bank, the rate of learning poverty, an indicator that combines the concepts of schooling and learning at the end of primary education, based on reading literacy and school enrollment indicators generated in the reporting process of Sustainable Development Goal 4- showed in the 2018 Development Report, that in low and middle-income countries more than half of children cannot read and understand simple text at the age of 10 years (World Bank, 2017). On average, learning poverty in Argentina is 53.9%.

This project was designed to address learning poverty in two provinces in Argentina, Mendoza and Corrientes, by focusing on the development of new literacies (coding and computational thinking) in conversation with traditional alphabetical literacy. Additionally, the pilot project was designed to learn lessons that could later be replicated to other provinces in the country and in Latin America. The CAL-Argentina study in kindergarten reached 39 teachers across the provinces of Corrientes and Mendoza. Assessment and data collection was done

both virtually and in-person depending on Wi-Fi-dependency and other resources available at each site. All instruments, training, consents, and study materials were translated and localized into Spanish. Spanish versions of the curriculum books were identified at this time. In the classroom while teaching, teachers made further decisions regarding localization, including adapting songs, games, and lesson activities to fit their classroom and curriculum. These decisions were documented in teachers' lesson logs and further recorded during focus groups and will be analyzed in future papers.

Like in the United States, schools were randomly assigned to a treatment condition (receiving the CAL curriculum) or a control curriculum (with instruction as normal). Seventeen schools, with 62 teachers and 529 students participated in the study, with 284 students receiving the CAL intervention and 245 students in the control condition. Both student and teacher data were collected to parallel data collected in the CAL-ScratchJr studies in the United States. Student data included the Coding Stages Assessment of coding knowledge and the TechCheck assessment of computational thinking collected before and after the curriculum and ScratchJr projects collected at three time points during the curriculum. Teacher data included the CSA and TechCheck assessments before and after training, surveys at four timepoints, and focus groups before, during, and after curricular implementation. 223 kindergarten students participated in the study.

In the kindergarten sample, the mean coding stage for a child at baseline was in the Pre-Coding stage with a CSA score of 3.32 (SD = 2.55). There was a significant interaction effect of condition and timepoint on coding knowledge, $F(1, 435) = 100.25$, $p < 0.0001$. Students who received the curricula scored higher on the post-curriculum coding stages assessment (M = 9.90, SD = 4.07) than students in the control condition (M = 4.70, SD = 1.97).

Overall, kindergarten children had a mean TechCheck score of 7.37 (SD = 2.14) at baseline, with a mean score of 8.40 (SD = 2.66) for children in the control group and a mean score of 7.79 (SD= 2.47) for children in the treatment group. This difference was statistically significant. Unlike in the United States contexts described above, there was a statistically significant interaction of condition and timepoint on computational thinking, with the treatment group (M = 10.42, SD = 2.23) surpassing the control group (M = 9.56, SD = 1.73) on post-curriculum TechCheck scores, $F(1, 435) = 11.69$, $p < 0.001$.

These results, and the differences between the Argentinian and United States findings, suggest that in adapting an early childhood curriculum across international settings, collaborators should consider that expected developmental trajectory across the school curricula differ across different countries. Curricula and resources for kindergarten programs, both generally and specifically for technology, vary across countries. Additionally, when discussing kindergarten programming, we should consider that language and literacy programs for kindergarten students differ across languages and countries. The available resources may also affect the implementation of the CAL curriculum, as different schools may have different environmental features such as movable tables, flexible seating, or available crafting materials. Further research should examine how these factors play a role in the effectiveness of the CAL program implementation across countries. We should also consider variations in the existing computational thinking and computer science curricula experienced by the children in control conditions in various countries, as what is considered developmentally normative for the control group may in fact be a feature of a country's existing curriculum. Moving forward, this variation in development should be accounted for as we continue to develop coding language and computational literacy curricula and programs for children in early childhood in a variety of national, cultural, and linguistic contexts.

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