Inclusive science education in the early years

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 872104 (http://www.communities-for-sciences.eu/ https://www.ioise.org/)

Children's Library Collection
Collection Directors: Vicenç Arnaiz and Cristina Elorza
Series: Teaching experimental science

Edition ©: Editorial GRAÓ,
IRIF, S.L. C/ Hurtado, 29. 08022 Barcelona. www.grao.com

1st edition: April 2024
ISBN: 978-84-19788-96-2

Design: Maria Tortajada

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Implementing the powerful ideas of computer science through culturally relevant pedagogy in the early classroom[1]

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This chapter has two goals; first, it provides a perspective on the importance of inclusive early science, STEAM, and the impact of twenty-first century learning skills, while also highlighting the positive influence research-practice partnerships can have in early childhood learning spaces, homes, and communities. Second, this chapter follows the experiences of three early childhood educators in public pre-kindergarten classrooms in the Southeastern United States. The stories shared here describe teachers actively implementing STEAM robotics curriculum with preschoolers, connecting with families, and co-constructing curriculum through hands-on community-engaged research. The shared experiences are direct examples of how culturally relevant, inclusive early

science builds a bridge between home and school, the importance of learning science through play, and the observed discoveries of the young children as they build a sense of belonging to computer science.

Introduction

The position of an early childhood educator (ECE) is complex and multifaceted. As the caretaker, educator, family liaison, community builder, and curriculum and developmental specialist within their classroom spaces, ECE are responsible for creating inclusive, anti-bias, anti-racist, anti-sexist, anti-ableist spaces for children to thrive. And yet, especially in early science education and practices, ECE are at a severe disadvantage. As part of a crumbling system of education and care in the United States that is currently undergoing continued systemic failure, ECE have little access to sustainable professional development specifically focused on early science, earth sciences, STEAM (e.g., science, technology, engineering, art, and mathematics), and other critical knowledge that children need in order to problem solve in their complex world.

To create inclusive early science in early childhood (EC) learning spaces, ECE teachers have to push back consistently and consciously against the cultural and systematic norms of the EC capitalist, curriculum driven landscape. Inclusive science opportunities include provocations for children to gain scientific knowledge and a sense of belonging to science. Learning spaces and practices should be designed with the understanding that children are competent learners at all ages, capable of growing as change makers who need support to develop social and emotional regulatory processes and patterns that lead to problem solving, critical thinking, and executive, higher-order thinking. By providing opportunities for the real-life application of 21st century skills (i.e., information and communication skills, thinking and problem-solving skills, and interpersonal and self-directional skills; Sahin, 2009), children develop the ability to be successful social beings in a complex, ever-changing world.

Part of an ECE responsibility is to provide access to scientific knowledge and opportunities for experimentation. Although there has been an increase in the STEAM curriculum, there is still a lack of shared knowledge and identity among ECE as competent science teachers.

Historically, science education has overlooked ECEs as learners who often lack science classes in their professional development or higher education requirements. In the US, there has been a historical dismissal of ways of knowing in early care and education, and also in science education, within Black, Indigenous, People of Color (BIPOC) communities. More specifically, the scientific accomplishments and knowledge of women have been ignored and credited to others (Edwards et al., 2021). This has led to the misconception that science education and STEAM fields are not inclusive to everyone. Nevertheless, children are scientists at their very core, discovering their world through play, exploration, experimentation, and questioning. Therefore, ECE have the responsibility of fostering scientific discovery in children and challenging contemporary, cultural norms to create inclusive early science spaces that are culturally relevant, community oriented, and focused on 21st century skills. These spaces are intended to support children in developing critical consciousness and problem solving.

Research-practice partnerships (RPPs) are an extended form of community-engaged research and collaboration. They often include stakeholders from universities or research institutions, the community, and specific populations of individuals within a community. They work together to co-construct knowledge and understanding in a effort to address persistent issues (Blair & Haneda, 2021; Coburn, Penuel & Geil, 2013; Henrick et al., 2017). One type of RPP is Culturally Relevant Robotics a Family and Teacher Partnership (CRRAFT), which incorporates inclusive early learning practices through computer science (CS) and culturally relevant robotics (CRR). It provides intersectional opportunities for ECE to be leaders who engage with children and families. This partnership contributes to breaking down systemic barriers in EC education practices. Through intentional relationship-building and navigation of cultural capital, teachers support stakeholders in navigating early science. This is achieved by creating inclusive learning connections for children and families to promote a sense of belonging in science and CRR (Harper, Caudle & Quinn, 2023; Harper, Stumbo & Kim, 2021).

Hope, a CRRAFT teacher shared:

> *I have gained so much confidence not only in teaching but in sharing those teaching experiences with other people. You know, in the beginning I felt like I maybe didn't have enough background knowledge to teach STEM education and I was very hesitant…I have been able to come a long way and progress my teaching and my students, and not only that, but their families and the community as well.*

Hope goes on to share working in partnership brings significant benefits when engaging in research that directly impacts her classroom. This collaboration fosters joy, collective problem solving, and co-construction of meaning. It also gives teachers the space and support needed to implement inclusive science practices in their classroom environments. Inclusive science practices offer the children who may not typically have access to CRR and STEAM education from a very young age a range of opportunities to engage in science materials and experiences. These activities help children gain confidence in their abilities and identities as scientists.

The work of Marina Bers, *Coding is a Playground* (2019), describes the seven powerful ideas of computer science (CS) as a framework for bridging the gap in early science, computational thinking (CT), and everyday experiences for children. The seven powerful ideas of CS (i.e., algorithms, the design process, modularity, control structures, hardware/software, debugging, and representation) are all ways for children to develop CT skills or the ability to deal with complex problems and cultivate executive, higher-order thinking. Each of the powerful ideas is relatable to a child's everyday experiences in the early classroom, at home, and in their community. Through interactive and inclusive STEAM opportunities that are presented as play provocations, children seamlessly integrate CS concepts and skills into their daily lives and environments. For example, children use sequences in everyday routines, such as handwashing, to gain experience using both linear and non-linear problem solving flexibly within their environment. This teaches them to understand that order is important in some situations, but not in others. Incorporating the powerful ideas and CS language expands children's knowledge and their ability to learn CT skills, social emotional regulation, and problem solving at their own pace through play. The importance of inclusive science education lies in its integration of the core tenets of STEAM and more specifically, CS and CT. It empowers today's children to grow into the adults of tomorrow with the knowledge, sense of belonging, and ability to use their foundational CS and CT skills taught in EC.

CT extends beyond STEAM work and allows children to engage, explore, and incorporate the critical thinking and complex skills they need to solve real world, everyday problems. By providing opportunities for CT and CS-related development, ECE are incorporating inclusive early science practices that break down systemic barriers to STEAM education. In this work, ECEs pave the way for future opportunities, enabling children to enter STEAM-related fields or career paths, already equipped with the necessary 21st century skills. Further, inclusive early science provides culturally relevant and responsive approaches to learning while working alongside families and individual children to build relationships and community (Harper, Caudle & Quinn, 2023). Lastly, inclusive science bridges the gap between school and home while emphasizing the funds of knowledge and values that children and families contribute to early learning spaces. In turn, these spaces dismantle systemic and structural barriers to STEAM learning, ultimately creating an inclusive environment for everyone in STEAM education and exploration (González, Moll & Amanti, 2005; Harper, Caudle & Quinn, 2023).

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School experiences

Stacy, Wendy and Wanda are lead teachers in state funded pre-kindergarten preschool classrooms that serve three-to five-year-old children in the Southeastern United States. All have been part of the CRRAFT for two or more years as of July 2023. Stacy and Wendy have their master's degrees and Wanda has her education doctorate (Ed.D), and they have all been in the EC classroom for ten or more years. Stacy, Wendy, and Wanda are intentional in their work and implement inclusive science opportunities that are open-ended, rooted in CS and CT, and anti-bias, -racist, -sexist, and -ableist. They are leaders in the field of early care and education who, over time, have gained confidence and a sense of belonging in STEAM themselves. As a result, they are able to effectively foster 21st century learning skills to encourage a sense of building in early science, within the classroom community, and in STEAM.

Stacy's classroom is warm, with pictures of the children on the walls, small groups buzzing and a KIBO robot zooming forward, forward, back, left, spinning, clapping, stopping as children grin and giggle with delight. They have worked together to scan the blocks needed to code the KIBO robot and are watching as the robot moves, pushing against their toes. According to Stacy, their teacher, the children had been actively forging connections to the powerful ideas of CS (Bers, 2019) through the use of algorithms. Algorithms are defined as the steps needed to complete a task, build a sequence, or solve a problem (Bers, 2019). Stacy noted that the children actively worked together intentionally and happily while putting together the sequence of codes on wooden blocks. They asked questions and self-corrected to scan the blocks used to code the KIBO robot and build a sequence or pattern of movement. Reflecting on the small group activity, Stacy noted that one child made a significant connection between classroom activities and CS skills and their world outside the classroom. The child shared that scanning the blocks of the KIBO robot is like scanning the barcodes on groceries at the store. The child recognised the meaningful connections between barcodes and how technology uses algorithms to understand information. Stacy explained how the language of CS and CT skills, taught in the classroom, also appears in children's daily lives. Stacy also shared that one child noticed that KIBO has a light that flashes green and red. The child went on to compare the blinking red and green lights to the traffic lights they see on their way home from school. The child also noted the associated action (i.e., red, stop and green, go) for both the traffic lights and the Kibo robot.

By connecting home and school activities, children are building real-life skills and gaining an understanding of sequencing. They include CS language and contextual knowledge in their observations and problem-solving abilities, specifically debugging. This approach helps the children to develop a sense of belonging in STEAM and early science. Stacy provided stimulation for the children in her classroom to encourage them to engage with low and no-tech robots. The aim is to forge connections beyond the school environment, demonstrating a sense of belonging, both in the classroom and in science. Through this kind of observation and connection, together with the rapport built among peers and teachers, children can engage with the early STEAM work and come to see themselves as scientists at both home and school.

On CRRAFT days, Wendy reads culturally relevant, STEAM-related children's books to the three- and four-year-old children sitting around her on a colorful carpet. During this time, Wendy makes connections to CS concepts, points out how the characters solve their problems, and asks open ended questions that enable the children to make connections. Wendy uses literature and early literacy practices to build an inclusive environment and supports the children as they make the connections with classroom CS activities. Wendy works alongside university researchers to choose the literature that is part of the co-constructed CRRAFT curriculum. Specific books are mixed into the four phases of CRRAFT, each phase incorporating different components of the powerful ideas of CS proposed by Bers (2019). Phases are meaningfully built, co-constructed, based in CCR, and follow the pace and structure of the classroom environment. The chosen books are inclusive, culturally relevant, and reflect the children, the teachers and the communities served by CRRAFT. According to Crisp et al. (2016), children look for images of themselves, reflections of their community, and those they love in the pages of books, as this enables them to make sense of their lives, environment, and experiences. Wendy and the university researchers want to make sure the children have the opportunity to see themselves on the pages as, consequently, both the children and teachers would be able to build a sense of belonging in CS.

Many of the books chosen in CRRAFT have characters that identify as BIPOC children, families, and communities, showcasing the resilience of many great scientists such as Dr. Ellen Ochoa. Others offered stories based on problem solving (i.e., *Jabari Tries*), social emotional regulation (i.e., *Computer Decoder: Dorothy Vaughan, Computer Scientist*) and trying new activities that reflect the powerful ideas of CS (i.e., *Gabi's If/Then Garden*). Wendy explained that this work supported her sense of belonging in CS and solidified her understanding of teachers as leaders. Using children's books to guide conversation and the integration of CS concepts, Wendy supported the children in her classroom as they gained pivotal 21st century skills for subsequent learning. Through literature, children are being exposed to CS language, and develop a sense of belonging as they see themselves on the pages. This also gives them the opportunity to think of themselves as computer scientists and creative problem solvers who, similar to the scientists they read about, address the needs of the world they are growing up in.

In the first phase of the CRRAFT project children who often have very little knowledge or awareness of CS or robots are asked what a robot is? Where are robots? What can they do? What do they look like? They are then given loose, recyclable materials to create a robot that has a job to do. In the fall of 2022, Wanda's class explored these questions and used the design process to introduce children to the steps of design in relation to the powerful ideas of CS (Bers, 2019). Children noted that robots can help humans solve problems, and they explained that their robot was going to work to solve the environmental crisis (i.e., cleaning up ocean trash). The design process allows children to view themselves in their work and connects their learning in the classroom to their environment, community, and the problems they will have to solve together as adults.

Wanda used inclusive science practices by giving each child the space to think in-depth and talk about environmental justice, the on-going environmental crisis. This gave the children more experience in honing their 21st century learning skills by strengthening their sense of belonging to science and demonstrating that everyone plays a part in taking care of our planet. The activity intended to cultivate a critical consciousness by incorporating real world skills and using problem solving. Consequently, the children engaged with environmental and social justice, and demonstrated how they perceived themselves in a wider context with others.

To conclude, inclusive early science education enables children to see themselves as scientists in their own environment and various settings. It affords them plenty of opportunities to explore, build community and make change. In year two of the project, the opportunities to increase children's understanding of CT and CS are ongoing. The results reflect the responsive relationships that are built within the classroom environment, the confidence of the teachers, the importance of empowering EC educators as leaders, and the effective integration of lived experiences through the collaborative construction of knowledge.

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1. This work is being supported with funding from the National Science Foundation CSforALL (Award #2031394).

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