21CSLA Project Brief

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Early Learning with LEGO Robotics

Executive Summary

As Science, Technology, Engineering, Mathematics (STEM) learning technologies become more ubiquitous in society, the need to understand how teachers design and implement curriculum and pedagogy to facilitate their students' development of computational thinking needed in STEM subjects is crucial. More research is needed in collaboration with teachers to see which strategies are effective in making STEM subjects accessible to early learners. We focus on teachers' use of LEGO robotics as one aspect of STEM technology that has the potential to expand the development of computational thinking and engineering mindsets.

We observed, documented, interviewed, and analyzed two teachers' design and implementation of both pedagogy and curriculum in the context of a LEGO robotics after-school program. Research indicates that STEM disciplinary practices support social-emotional learning (SEL); skills like social awareness and responsible decision-making bolster fundamental engineering processes. Reflecting on STEM instruction during noticing interviews revealed the importance of SEL, productive struggle, and extensive knowledge of children as catalysts for access to and success with STEM. Attending to teachers' individual approaches to time—how they reflect on the past to inform the present and the future—deepened our understanding of how SEL was facilitated in the classroom.

The innovations of these two teachers advance our knowledge and understanding of how educators sequence the scope of their work and address relevant challenges that emerge from implementing learning with LEGO robotics technology. Our research advocates for a multifaceted approach that blends project- and play-based, individual and collaborative learning to stimulate deep STEM engagement in early childhood. Professional learning should address SEL fundamentals, teacher noticing, and time perspective in early childhood STEM learning contexts.

Background

STEM in early learning contexts is a developing area of research that suggests our youngest students (i.e., 4-, 5-, and 6-year-olds) can benefit from learning activities rooted in STEM (Ching & Hsu, 2024; Sullivan & Bers, 2016; Sullivan et al., 2013; Tippett & Milford, 2017). Robotics instruction, which draws on technology and engineering, supports strategies including collaborative learning and project-based learning (Ching & Hsu, 2024). Furthermore, children who participate in robotics units experience increases in aspects of computational thinking which include sequencing, conditionals, loops, debugging, and algorithmic thinking (Ching & Hsu, 2024; Kazakoff et al., 2013).

Not only are young learners able to cultivate basic robotics and programming skills, but their teachers can integrate that learning into foundational literacy and mathematics concepts (Sullivan & Bers, 2016; Sullivan et al., 2013). Indeed, robotics can inspire significant student engagement that is fundamental to deep learning. Through a pedagogy of play, young students can develop skills of collaboration, communication, critical thinking, creative innovation, and confidence all while deepening STEM learning (LEGO Education, 2022). Furthermore, research indicates that STEM and SEL can have a symbiotic relationship: STEM disciplinary practices can support students' social-emotional and interpersonal relationships while SEL fundamentals, like social awareness and responsible decision-making, can support core science and engineering practices and processes (Murphy, 2023; Su & Guo, 2023).

Equity and access issues provide both constraints and opportunities for research and practice. Often, robotics kits and curriculum are resources reserved for affluent schools and districts, skewing access along lines of race and class (Wallace & Poulopoulos, 2022). Furthermore, robotics activities can be reserved for older students, high-achieving students, "well-behaved" students, and/or students who qualify for enrichment programs, rather than being used broadly at the classroom, grade, school, or district level (LEGO Education, 2022). Positioning robotics as a reward yields additional equity issues as sometimes the students who would benefit most from these learning experiences are excluded from such opportunities (LEGO Education, 2022).

21CSLA (21st Century California School Leadership Academy) uses a research–practice approach that includes: (1) co-constructed research goals focused on learning to lead for equity, (2) practitioner input, and (3) reciprocal benefit. 21CSLA operates in alignment with the University of California's public mission of teaching, research, and public service and supports "the University's active involvement in public-school partnerships and professional development institutes [that] help strengthen the expertise of teachers and the academic achievement of students in communities throughout California" (University of California Office of the President, n.d., ″public service″ section). 21CSLA research-practice collaborations investigate how educational leaders learn to lead for equity in TK–12 education by examining professional context, leadership capacities, and equity in schools (21CSLA, n.d.).

Overview of the Study

Informed by 21CSLA's research-practice approach, this study aims to deepen leaders' understanding of how the pedagogy of play, in the context of a LEGO robotics program, can support the STEM learning of young students. At a 21CSLA Universal Transitional Kindergarten (UTK) professional learning offering, Dr. Mahiri connected with a UC Berkeley Principal Leadership Institute alumna who described a unique LEGO robotics curriculum being implemented in the after-school program of a local high-needs school district. Through multiple visits and discussions with practitioners, district leaders, and LEGO representatives, a research-practice partnership was formed between two teachers and 21CSLA researchers.

In this study, we explore pedagogy and content, how two educators sequenced the scope of their work, and how they addressed relevant challenges that emerged from STEM learning with young children. By situating the study at a Title 1 school and focusing on the youngest learners at that school (i.e., 4-, 5-, and 6-year-olds) we attempt to shed light on possible equity and access issues and opportunities in the context of a LEGO robotics after-school program.[1] Practitioner input was essential to highlighting the need to consider issues of SEL as research goals were articulated and refined and reciprocity was established.

This brief provides an overview of three smaller studies within our larger study. All three studies draw on data collected from the 2023–2024 academic year: classroom observations, semi-structured and/or noticing interviews, field notes, content logs, and curricular materials. As shown in Table 1, eight students were in transitional kindergarten (TK) and 3 students were in kindergarten (11 students total); students ranged in age from 4 to 5 years old. The beginning of the free after-school program was rooted in students developing SEL skills and abilities.

1. STEM and Social-Emotional Learning

This qualitative study explored how STEM learning and SEL were enabled in the LEGO robotics program. Participating teachers, Mrs. Vega and Ms. Ryan,[2] implemented project- and play-based pedagogies that used LEGO materials to guide the students in designing and building objects and structures as well as programming and coding robotic devices.

All students developed foundational science and math skills that were focused on in the lesson plans of a LEGO kit that the teachers used to guide students to design and build objects and structures. Further, students developed technology, engineering, and computational skills and mindsets through the teachers' use of lesson plans in a second LEGO kit to guide students to program and build robots. Finally, through the teachers' extensive focus on SEL in conjunction with STEM learning in project- and play-based pedagogies, the students embodied and demonstrated the abilities and skills reflected in the five Collaborative for Academic, Social, and Emotional Learning (CASEL) pillars: self-awareness, self-management, responsible decision-making, relationship skills, and social awareness (CASEL, n.d.). Mrs. Vega captured the importance of SEL in the overall STEM learning process:

I noticed that it's important for them to ground themselves…to share how they're feeling, what they're dealing with…getting the wiggles out.… It's how they understand the feelings within themselves, and, you know, what they are working with, with friends.… It's also giving them vocabulary around feelings.… It's a transition to get them ready.… It gives them something to pull from in our everyday life together in the classroom.… I validate how they feel, and it helps me better navigate what their needs are through the day or through the lesson.

[1] Title 1 schools receive supplemental federal financial assistance to support students from low-income families.

[2] All names are pseudonyms.

Additionally, the following quote from Ms. Ryan reflected how the students were developing relationship skills as well as engineering mindsets and skillsets:

When we first worked with the ramp, we had trouble because there's a design flaw. [Students] figured out how to work around it. They figured out how to put plates from the STEM kit under every joint in the train kit to make the tracks more stable for running the trains on them. It's not like common knowledge. [There's] not really any instructions out there. So that's really their design, their engineering…to figure it out.

2. Teacher Noticing and STEM Access

This qualitative study used noticing interviews to support teachers to narrate their awareness of pedagogical moves and make visible the ways that equity considerations were incorporated into STEM instruction with 4-, 5-, and 6-year-olds in the after-school program. We analyzed teachers' responses to *critical events*—moments that supported teachers to connect their pedagogical theories and classroom practices—and considered how specific features of those events revealed teachers' approaches to equitable STEM instruction.

Table 1

Demographic Characteristics of Study Participants

Participant	Race/Ethnicity	Gender	Age	Grade
Teacher of record	Latine American	Female	46	
Teaching assistant	Fijian American	Female	45	
Student 1	African American	Female	4	TK
Student 2	African American	Male	4	TK
Student 3	African American	Male	4	TK
Student 4	Latine American	Female	4	TK
Student 5	Latine American	Female	4	TK
Student 6	Latine American	Male	4	TK
Student 7	Pacific Islander American	Male	4	TK
Student 8	Biracial (White and Filipino American)	Male	4	TK
Student 9	White	Male	5	K
Student 10	Latine American	Female	5	K
Student 11	Latine American	Female	5	K

Our findings suggested that, in the context of STEM instruction with young children, critical events that are *routine*, *benign*, *intimate*, and *dense* supported teachers' reflection and analysis of their instruction and revealed the importance of SEL, productive struggle, and extensive knowledge of children as catalysts for access to and success with STEM. Routine moments, which are defined as typical and ordinary events that occur with regularity (van Es et al., 2025), provided a window into SEL as teachers articulated their thoughtful approaches to assessing and attending to students' needs so that they could adapt instruction accordingly. Benign moments—nonjudgmental and nonadversarial—shed light on the ways in which Mrs. Vega and Ms. Ryan supported students to be appropriately challenged by an activity or concept by offering complementary support that bolstered engagement, perseverance, and learning. Intimate moments, those interactions that embody the detailed knowledge and awareness that teachers have of their students, communities, and school contexts, revealed the ways in which Mrs. Vega and Ms. Ryan used their deep familiarity with individual students and the after-school group to shape interactions and instruction that supported student learning. Dense moments—interactions that are examples of multidimensional awareness and practice—provided a window into equity and access issues, including child language development and children's identities, and how teachers responded in equity-oriented ways. Overall, these moments supported teachers in narrating their classroom noticing and instruction to reveal equitable approaches to STEM instruction with early learners.

During a noticing interview, researchers shared a critical event that was categorized as intimate. In the video segment, students are building with LEGOs in various formations: some independently, others in pairs, a small group sitting close to Mrs. Vega. Mrs. Vega checks in with Ms. Ryan and together they decide, in the moment, to extend students' time to free build.

After Mrs. Vega reviewed the clip, the interviewer asked about her decision-making in that moment. Mrs. Vega explained:

[The children] said, "Aww!" both times the timer went off. And we're looking around, they're actively building, why would we destroy this? They're working, they're happy. They're excited, they're learning. They're producing. So that's why we [decided] let's just keep going. Because we read the cues of the children, they needed it.

In a different noticing interview, researchers shared a critical event that was categorized as benign. During the segment, Ms. Ryan explained the shape of a crucial piece that students would need to find for this particular build. She formed the Y shape with her arms and wiggled her fingers to engage students' attention, but she did not do the build herself.

After Ms. Ryan reviewed the clip, the interviewer asked what she noticed about this interaction. Ms. Ryan reflected on how she scaffolds instruction to support students:

I constantly have to be reminded of [letting children struggle] by Mrs. Vega. With [this group], I kind of want to see them fall before I help them. I'm used to correcting right away, but they're not going to learn well that way. And that translates to the switch of the train. I could easily do the first demonstration, teach them everything first, and let them just mirror it, instead of having them fail at it first and then prompting them to try again. Instead of correcting them in the moment, we're trying to [notice], "Oh that didn't go as expected. I need to make an adjustment."

3. Multidimensional Time Perspective and SEL

Research has pointed to the utility of examining psychological factors among early childhood educators in understanding psychosocial development as well as SEL in young children. Time perspective, which refers to feelings and thoughts about time, may be an important psychological factor to promote positive outcomes in children, adolescents, and adults, especially when it is approached multidimensionally. However, this construct has yet to be examined among teachers in relation to SEL. This qualitative study explored time perspective with Mrs. Vega and Ms. Ryan. Interviews were conducted with these teachers to understand their perceptions and approaches to time and to identify ways it was used to facilitate SEL during STEM learning. The teachers' time perspectives were analyzed in terms of how they were integrated within and integral to their SEL practices.

Results indicated that the teachers' individual approaches to time played a critical role in shaping their STEM pedagogical strategies, particularly in their implementation of SEL. These findings further refine the roles that time perspectives of teachers play in facilitating SEL for early learners.

Ms. Ryan: I think I live in the present a lot. A lot of the past can be painful. So, it's just easier, I would say, to stay in the present and then look to the future.… [Teachers' approach to time] may be very important. Everyone learns at a different pace and style. Not everyone will get it the first time or the second time, but you never want them to just associate this with the negative, especially if it's something hard like math. Math is usually hard, so we say, "Let's make it fun. Let's do something else." So, you want them to get it, but you have to tailor it to every single student in a way. Some of the past is important when you're teaching, so it can't be the same as in your personal life. It's important to say, "Oh, this is the past, let's try not to trigger these emotions."

Mrs. Vega: I need to know what I did, to what I'm doing right now, to where I'm going. And also, where I messed up, right? To fix here, so that I could fix there.… It's like they all work together. It's not one or the other, because even when we talk about the painful parts of history, I think it's crucial to remember those moments not to glorify them, but to learn from them. I believe it's important to understand how our past, present, and future are connected. To move forward, we need to reflect on where we've been, what we're doing now, and where we're headed. Acknowledging past mistakes is key to making better choices today and building a stronger future.

Conclusion and Implications

1. STEM and Social-Emotional Learning

These findings are significant for informing the current movement in California and other states about viable pedagogical approaches and tools to stimulate and guide STEM learning at the TK and kindergarten levels, particularly as it can be facilitated through SEL. This study documented the blending of multiple kinds of learning: SEL and STEM, project- and play-based, individual and collaborative, teacher-guided and student-selected. This multifaceted approach supported students' developing computational thinking and deeper learning needed to design and code robotic devices. Policymakers might consider the kinds of perspectives and resources needed to implement similar programs. This research can support teacher training and development in UTK and STEM contexts.

2. Teacher Noticing and STEM Access

This study adds significant insights for early childhood education in STEM contexts to prior research on teacher noticing. It is important that educators embed SEL, plan for productive struggle, and prioritize cultivating relationships with children,

families, and communities as they respond to issues of equity and access in schooling. Noticing interviews are a useful tool for teachers developing their awareness of equity issues and how they can disrupt practices that marginalize students. These findings have implications for teachers and educational leaders with regards to fostering equitable STEM instruction, particularly for early learners.

3. Multidimensional Time Perspective and SEL

These findings further refine the roles that teachers' feelings and thoughts about time play in facilitating SEL for early learners. Teachers with adaptive approaches to time may be more successful in modeling and cultivating SEL competencies with their students. Implications include incorporating insights from educators' time perspectives into teacher training programs and professional learning focused on SEL.

Overall, this research–practice collaboration shed new light on how teacher leaders learn to lead for equity by examining their professional context and equity issues in early childhood education. Practitioner input supported the co-construction of research goals that ultimately led to reciprocal benefits, including centering and highlighting innovative practice, informing future 21CSLA UTK learning offerings, and generating research to guide policymakers.

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21CSLA
Leading for Equity

21CSLA Equity Statement

Leaders for equity transform education to improve access, opportunity, and inclusion for students and adults, especially those who are systemically marginalized and historically underserved, so that they can thrive.

About 21CSLA

21CSLA (21st Century California School Leadership Academy) is dedicated to the professional learning and support of California's educational leaders—teacher, site, and district—to create more equitable learning environments that improve success for underserved students. A key member of California's Statewide System of Support, 21CSLA is headquartered at UC Berkeley School of Education and works in partnership with UCLA School of Education and Information Studies, California Subject Matter Project, and seven 21CSLA regional academies throughout the state.

The 21CSLA initiative provides high-quality, equity-centered professional learning for educational leaders of schools and districts in California. Programs are provided at no cost to participants and include leadership coaching, communities of practice, and localized professional learning to improve outcomes for historically marginalized students.

Bridging Research and Practice

21CSLA seeks to bridge the gap between research and practice in education for educational leaders. We coordinate and facilitate Research–Practice Partnerships among California educational leaders and educational researchers by creating connections and providing research support. The briefs compile and present current research in a concise format, including reflection questions to help leaders adapt and adopt the information into their own practice. 21CSLA regularly produces Research–Practice Webinars in which scholars and practitioners engage in conversations about timely issues. We also curate a variety of resources for educational leaders to learn about current and important topics in education (e.g., webinar video recordings and highlights, briefs, podcasts). For more information, visit 21cslacenter.berkeley.edu/research.

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