Abstract
This study developed a teacher professional learning program centered on computational thinking (CT). Arts and inquiry approaches framed CT as expressive meaning making. Participants included preK-to-2nd grade teachers (n=27) in public schools in Texas. The program began with a two-week summer CT institute and included classroom observations and teacher meetups during the school year. Data collection was mixed methods, including fieldnotes, interviews, participant-made artifacts, and a Likert scale survey on CT attitudes and dispositions (Rich et al., 2020). Findings show the learning program had an effect on teachers' CT learning and implementation and suggest participants found their learning transformative. In this paper we argue arts and inquiry approaches can be effective for early elementary teacher professional learning even in STEM domains considered non-expressive. We call for further research on arts and inquiry approaches in teacher education beyond early elementary.

Keywords: teacher education; computational thinking; art; literacy

We undertook this study of elementary teachers' CT learning to think about broadening educational opportunities for all learners. Computer science and CT is a component of equitable 21st century education (Kafai & Proctor, 2022; Yadav & Berthelsen, 2021), but not sufficiently addressed by teacher education or in-service professional learning research (Delyser, at al., 2018; Ottenbreit-Leftwich et al., 2021). After noticing mechanistic operationalizations of computer science education in the literature, where the identity-building capacity of expressive story- and art-making was downplayed or ignored, or where teachers were given a pre-baked curriculum and simply told to deploy it, we wondered about the potential of arts and inquiry approaches to foster teachers' sustainable generative learning in a domain normally considered esoteric and perhaps not even pertinent in early childhood education.

Researchers from the learning sciences have recently weighed in on the overlooked advantages of arts and inquiry learning in STEM domains (Halverson & Sawyer, 2022), and computer science educators

have long considered CT an expressive practice (Resnick, 2006, 2017; Papert,1980), but we know of no other teacher education studies that position teacher CT learning as generative and expressive.

Halverson, E., & Sawyer, K. (2022). Learning in and through the arts. *Journal of the Learning Sciences*, *31*(1), 1-13. https://doi.org/10.1080/10508406.2022.2029127
Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books.
Resnick, M. (2006). Computer as paintbrush: Technology, play, and the creative society. In D. Singer, R. Golikoff, & K. Hirsh-Pasek (Eds.), *Play = Learning: How play motivates and enhances children's cognitive and social-emotional growth* (pp. 192-206). Oxford University Press.
Resnick, M. (2017). *Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play*. MIT Press.

Citation

Justice, S. & Assaf, L.C. (2023, October 19-21). *Make it move!: Arts & inquiry approaches to computational thinking in teacher profession learning* [Conference presentation]. Arts Education Research Institute 2023, Tucson, AZ, United States.
https://www.aerinstitute.org/2023-symposium-information

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https://epk2.wp.txstate.edu/

Computational thinking (CT) with PreK-2nd grade teachers.

4-year exploratory study (2020-2024) in Central Texas.

CT as expressive community meaning making.

Participants

Two cohorts of teachers (n=27); average 12.5 yrs in the profession; all were novices with CT—seldom if ever had done coding in their classrooms.

District Profile

Urban; 8K enrollment; 72% Hispanic; 20% White; 70% free lunch; 10% ELL.

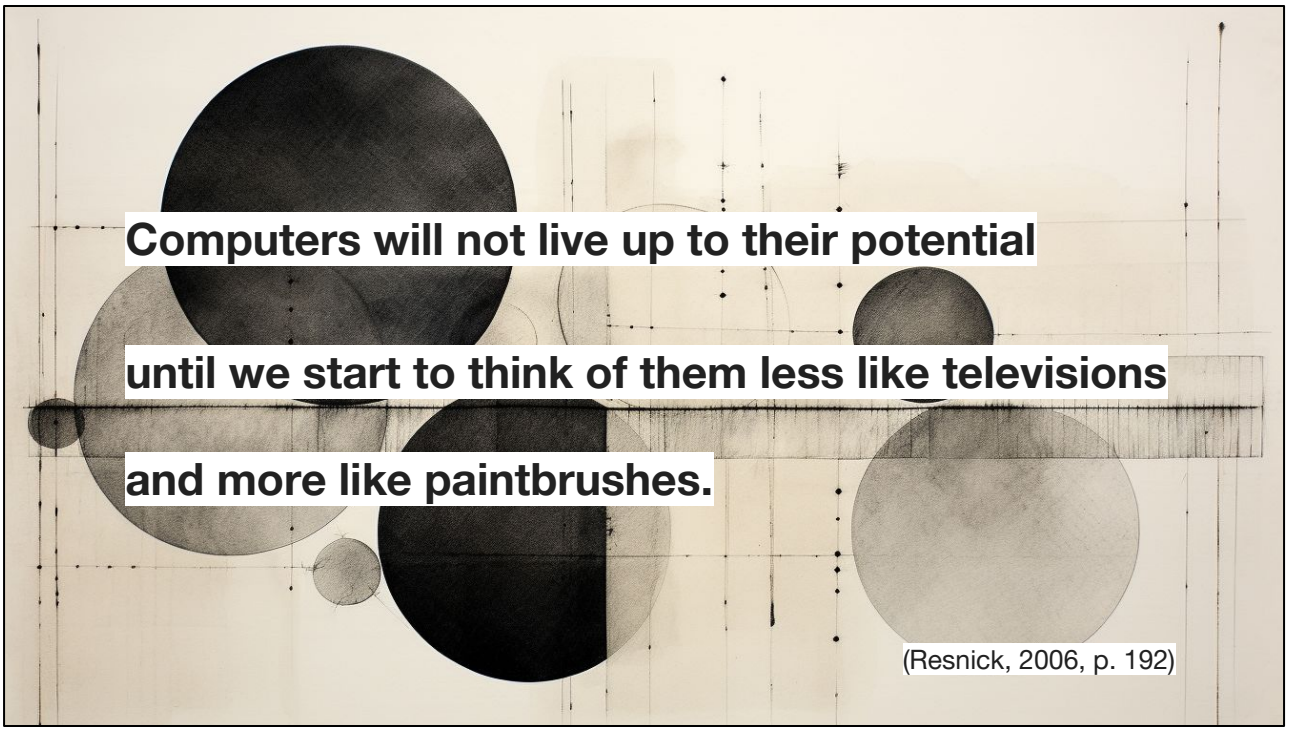
Positionality

We are teacher educators from complementary fields, art (Justice) and literacy (Assaf), who share a commitment to culturally relevant education.

This paper describes a 3-year study exploring the integration of computational thinking (CT) in early elementary classrooms.
Goals included the development of a CT professional learning program that framed CT as a meaningful teaching practice.

The program had three components: a summer arts and inquiry CT institute; classroom observations and meetups during the school year; and a learning conference.

This presentation focuses on and describes findings related to the summer CT institute.



"We need to start seeing computers not only as information machines but also as a new medium for creative design and expression." Resnick 2006

In this study we think of CT as a human way of thinking with computers, where thinking routines and practices shape and are shaped by working expressively with computational machines and programming symbol systems, e.g., by making stories, games, and art.

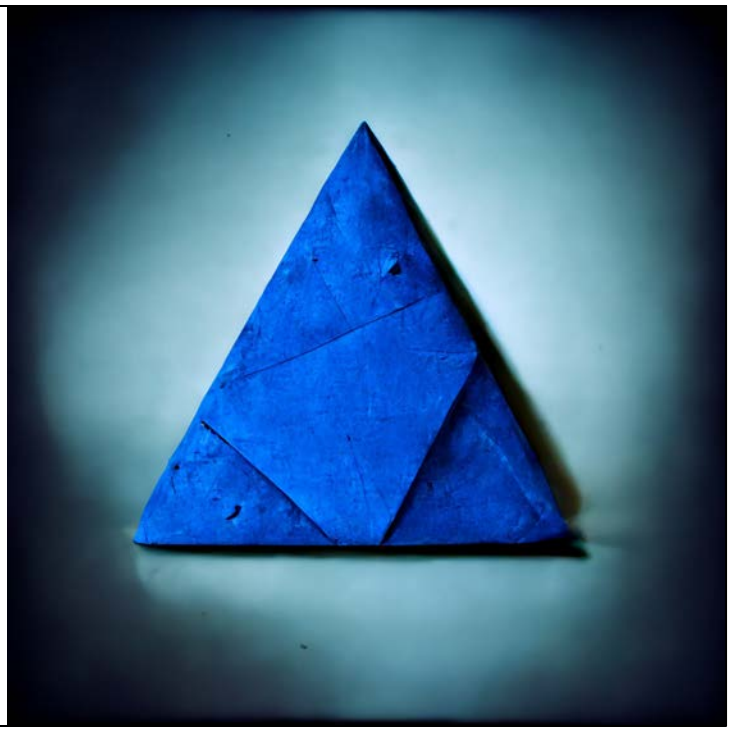
Recently, Kafai and Procter (2022), framed CT as a content-less practice relevant across the K-12 spectrum and emphasized the need to understand computation as a set of literacies that build interdependent individual and social identities.

Kafai, Y. B., & Proctor, C. (2022). A revaluation of computational thinking in K–12 education: Moving toward computational literacies. Educational Researcher, 51(2), 146-151. https://doi.org/10.3102/0013189x211057904
Resnick, M. (2006). Computer as paintbrush: Technology, play, and the creative society. In D. Singer, R. Golikoff, & K. Hirsh-Pasek (Eds.), Play = Learning: How play motivates and enhances children's cognitive and social-emotional growth (pp. 192-206). Oxford University Press.

Learning Perspectives

Generative Change

Material Inquiry



The study's professional learning program was anchored in generative change theory (Assaf et al., 2016; Ball, 2009, 2020; Brito & Ball, 2020), and implemented with a material inquiry approach (Cabral & Justice, 2013, 2019; Justice et al., 2019). Learning was described as a process of mediation (Vygotsky, 1978) that changes relationships between people and tools in cultural settings (Hawley, 2022; Taber, 2020).

Generative Change

Learning can be described as *generative* when teachers design and then re-design their teaching practice as an assemblage of professional and personal knowledge, and knowledge gained from students. This teaching-learning-teaching cycle becomes recursively generative and interdependent on teachers, students, and the relationships between them. (Ball, 2009, 2020; Brito & Ball, 2020).

Material Inquiry

Sociomaterialism emphasizes the way tools and materials contribute unintended and unpredictable effects to relational learning processes. Material inquiry approaches consider material agency as a more-than-cultural pedagogical design principle. (Cabral & Justice, 2013, 2019; Justice et al., 2019)

Assaf, L.C., Ralfe, L., & Steinbach, B. (2016). South African teachers learning to become writers and writing teachers: A study of generative learning. *Teaching and Teacher Education, 56*, 173-184.

Ball, A. F. (2009). Toward a theory of generative change in culturally and linguistically complex classrooms. *American Educational Research Journal*, *46*(1), 45-72. https://doi.org/10.3102/0002831208323277

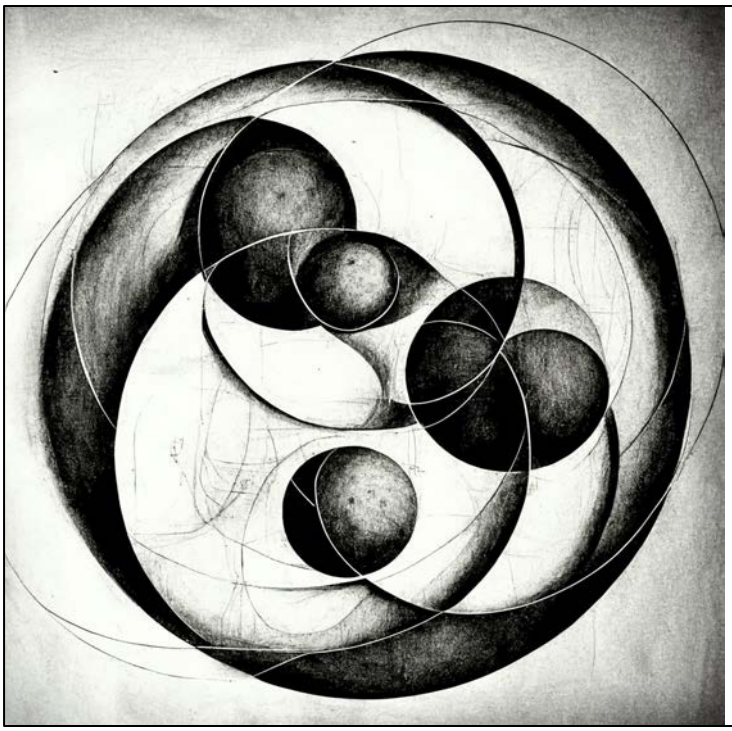
Ball, A. F. (2020). Theories of generative change in teacher education. In J. Lampert (Ed.), *The Oxford Encyclopedia of Global Perspectives on Teacher Education*. Oxford University Press. https://doi.org/10.1093/acrefore/9780190264093.013.471

Brito, E., & Ball, A. F. (2020). Realizing the theory of generative change using a freirean lens: Situating the zone of generativity within a liberatory framework. *Action in Teacher Education*, *42*(1), 19-30. https://doi.org/10.1080/01626620.2019.1702598

Cabral, M., & Justice, S. (2013). *Material learning: Digital 3D with young children*. In *FabLearn 13: Digital Fabrication in Education, Stanford University, October 2013*. Palo Alto, CA. https://www.academia.edu/11925338/Material_Learning_Digital_3D_with_Young_Children

Cabral, M., & Justice, S. (2019). Material inquiry: Digital materials, people, and the relationships between them. In E. Garber, L. Hochtritt, & M. Sharma (Eds.), *Makers, crafters, educators: Working for cultural change* (pp. 28-32). Routledge.

Justice, S., Cabral, M., & Gugliotta, K. (2019). The crayon doesn't do that: Early childhood and advanced technology. In R. L. Garner (Ed.), *Exploring digital technologies for art-based special education* (pp. 122-131). Routledge.



Methodology

Mixed Methods

Ethnographic

Active Learning

We did not tell teachers what to do but asked them to reflect on their learning and connect CT to student learning.

Mixed Methods: all teachers participated in a two-week computational making and inquiry workshop; classroom observations, interviews; plus meetups; and a survey of dispositions and beliefs given 3 times

Ethnographic: year long, researchers spending time inside the world of the participants

Active Learning:
Learners' engaged response drives the curriculum. A hallmark of expressive teaching and learning in expressive domains, eg the arts and writing

In contrast to research that gives teachers scripted CT activities, we did not tell teachers what to do but asked them to reflect on their learning and look for CT opportunities that connected with students.

Findings

Learning

Implementation

Mediators

Learning

- Programming computers and robots; acquired frameworks contextualizing CT.
- Survey responses pre- and post-institute, paired t-test (n=23) suggest teachers' self-efficacy for learning and teaching CT, and in the value of doing so, strengthened significantly ($p<.001$), with medium to very strong effect sizes.
- A collaborative inquiry-based view of teaching, where students become classroom experts.

Implementation

- Every teacher who completed the program (n=27) implemented CT activities.
- Teachers innovated and adapted materials and activities from the institute in response to students' learning.

Mediators

What moved learning from raw action or concept to embodied purposeful action that seeded and then guided implementation? Enactivist perspective on knowing and doing. Like learning to ride a bicycle the training wheels and the steady hand of a parent might be framed as mediators. Or on a sailboat, the sail but also the crew and the many diverse other aspects of the sailboat as a tool and the ocean and wind as materials might be considered as mediators, or as a system of mediators.

- *Noticing and Naming.* Teachers noticed and named CT concepts (Bers, 2021), amplifying their understanding of CT.
- *Learner and Teacher identities.* Teachers connected learning identities to teaching identities, catalyzing new teaching and learning practices.
- *Awareness of Students' CT Thinking Experiences.* Teachers recognized student CT learning and characterized it as sparking the highest engagement they had ever seen.
- *Leveraging Literacy.* Teachers embedded CT in English Language Arts and Reading (ELAR) to

- extend and expand district-mandated curriculum.
- *Pedagogical Practices from the Summer CT Institute*. Teachers adapted teaching practices and learning activities from the institute for use in their classrooms.

Unpacking Teacher Learning

It goes back to what I learned this summer. Let them take ownership of what they want to learn…it's hard to let go sometimes, as teachers.
(Annie, Kindergarten)

I desperately want to grow with [inquiry teaching], because … I don't want to ruin their learning. Whenever you find something on your own and you learn how to do it, that's intrinsically woven into the fabric of your being.
(Bridget, Kindergarten)

After doing the institute and realizing I don't have to know everything to get started, and I could learn along with the kids, that was a huge mind-change. As a teacher you feel like you have to know everything. You can't show weakness.
(Karen, elementary specialist)

Teachers told us their teaching changed after the summer institute, and that those changes were transforming their relationships with students.

The emergence of this last domain, i.e., learning about teaching, or pedagogical knowledge (Shulman, 1986), surprised us. We expected participants to learn some programming, but we were unprepared for teachers learning about teaching, especially with such experienced teachers (12.5 years in the profession, on average).

Unpacking Teacher Learning

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In these quotes we hear teachers wrestling with inquiry learning, a practice they believed was benefiting their students at the same time as it was disrupting their identities as teachers.

Recognizing that changing practices changed identities is consistent with generative theories of teacher professional development

But in this context, what mediated transformative learning about teaching—after all, this study focused narrowly on CT.

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Boisterous chatter fills hallways and meeting spaces as small of groups of teachers huddle together with computers and robots, small motors, blinking LEDs, and children's books, mapping and re-mapping historical, personal, family stories, surrounded by murals depicting heroes, cultural mythologies, pianos, and children's art, while wandering into and out of galleries flowing over with historical photographs, flags, newspaper clippings, papel cortado, portraits of the founders, wedding dresses, and handmade santos pressed from painted tin. ***The Summer Institute at Centro Hispano Cultural***

The Summer CT Institute
The institute was a two-week professional development workshop following material inquiry approaches. The curriculum was based on art education frameworks (e.g., Hafeli, 2015; Pacini-Ketchabaw et al., 2017) focused on "purposeful play" (Hafeli, 2015, p. 20) to spark expressive, meaningful engagement with computational tools and materials that were unfamiliar if not utterly brand new to the participants.

Daily schedules during the institute included greet the day circles followed by hands-on making activities, both computational and non-computational, oral and written reflection, reading and video discussion circles, and small group project work.

Features
- CT as a meaning making practice, contextualized in early childhood learning (Bers, 2021).
- Hands-on storymaking (Compton & Thompson, 2018; Buganza et al., 2023).
- Programming with screen-based (ScratchJr.) and screen-free tools (KIBO, Makey Makey).
- Low-floor & high-ceiling challenges: "Make the cat move!" "Make KIBO dance!"
- Individual and grade-level reflections on CT extensions of current teaching.

Expressive Meaning Making
Aspects of the Institute might sound familiar to choice-based art teachers (Douglas & Jaquith, 2018), and to literacy teachers with robustly multimodal reading and writing practices (Kuby & Rucker, 2016).

These depictions of inquiry teaching align with inquiry design principles from formal to informal learning, from early childhood through adult, though features vary depending on the learners: very young children (Wohlwend et al., 2019); K-12 students (Martinez & Stager, 2019; Resnick, 2017), college students (Goldberg & Somerville, 2014), and adults in the workplace (Watkins et al., 2018).

Commonalities include hands-on activities, exploratory play, divergent outcomes, authentic meaning, process over product, and critical reflection. Each of these features was designed into the summer CT institute.

Douglas, K. M., & Jaquith, D. B. (2018). *Engaging learners through artmaking: Choice-based art education in the classroom (TAB)* (2 ed.). Teachers College Press.
Goldberg, D. E., & Somerville, M. (2014). *A whole new engineer: The coming revolution in engineering education*. Threejoy Associates, Inc.
Kuby, C. R., & Rucker, T. G. (2016). *Go Be a Writer!: Expanding the Curricular Boundaries of Literacy Learning with Children*. Teachers College Press.
Martinez, S. L., & Stager, G. S. (2013). *Invent To Learn: Making, Tinkering, and Engineering in the Classroom*. Constructing Modern Knowledge Press.
Resnick, M. (2017). *Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play*. MIT Press.
Watkins, K. E., Marsick, V. J., Wofford, M. G., & Ellinger, A. D. (2018). The Evolving Marsick and Watkins (1990) Theory of Informal and Incidental Learning. *New Directions for Adult & Continuing Education*, *2018*(159), 21-36. https://doi.org/10.1002/ace.20285
Wohlwend, K. E., Keune, A., & Peppler, K. A. (2019). “We need it loud!”: Preschool making from mediated and materialist perspectives. In J. Osgood & M. Sakr (Eds.), *Postdevelopmental Approaches to Childhood Art* (pp. 177-189). Bloomsbury Publishing.

Note: the text description on the previous slide was copied into ChatGPT-4 to produce an prompt to generate the image above in DALLE-2.

Bers, M. U. (2021). *Coding as a playground: Programming and computational thinking in the early childhood classroom* (2nd ed.). Routledge.
Buganza, T., Bellis, P., Magnanini, S., Press, J., Shani, A. B., Trabucchi, D., Verganti, R., & Zasa, F. P. (2023). *Storymaking and organizational transformation: How the co-creation of narratives engages people for innovation and transformation.* Routledge.
Compton, M. K., & Thompson, R. C. (2018). *StoryMaking : The Maker Movement Approach to Literacy for Early Learners*. Redleaf Press.
Hafeli, M. (2105). *Exploring studio materials: teaching creative art making to children*. Oxford University Press.
Pacini-Ketchabaw, V., Kind, S., & Kocher, L. L. M. (2017). *Encounters with materials in early childhood education*. Routledge.

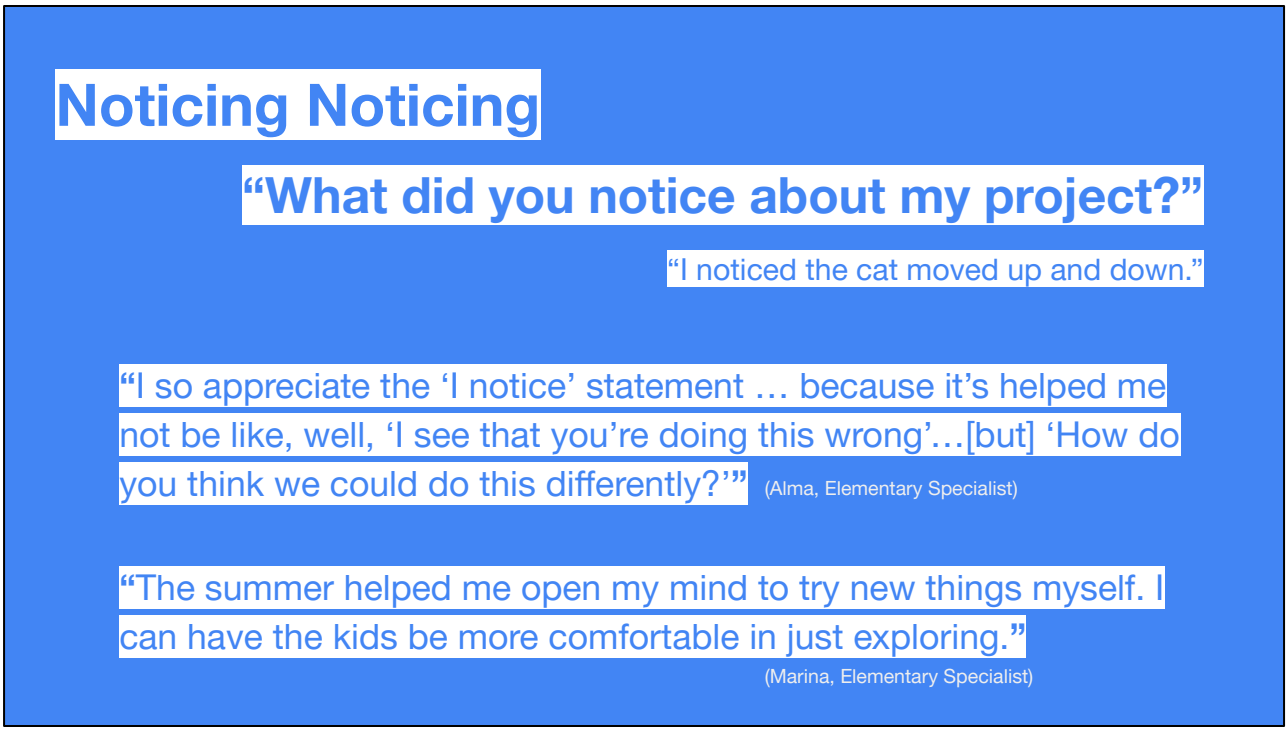
The activities listed here have been developed as learning engagements from a Material Inquiry approach.

Activity prompts often include movement, making something move. The notion of expanded media art that I want to invoke is deeply entangled with agency ie the capacity for making one's own trajectory in the world. This involves moving oneself, or someone else, but also recognition of the terrain, or the world. Sometimes it also includes the desire to make or remake the world as well.

None of these activities are brand new ideas, strictly speaking. Art machines have been a thing since Guy Tingley. Computational materials like microbits that can control a simple hobby motor open new potentials of movement, no doubt, but the underlying principles of mark making and agency remain core to the experience.

In the institute teachers worked with each other to figure out how to work with various new tools and materials on offer in basic terms and then deployed the knowledge and skills gained (together) to play purposefully in response to the prompt given, i.e.,

What's your favorite letter in your name? How did you get to Centro today? Who do you want to say 'thank you' to?



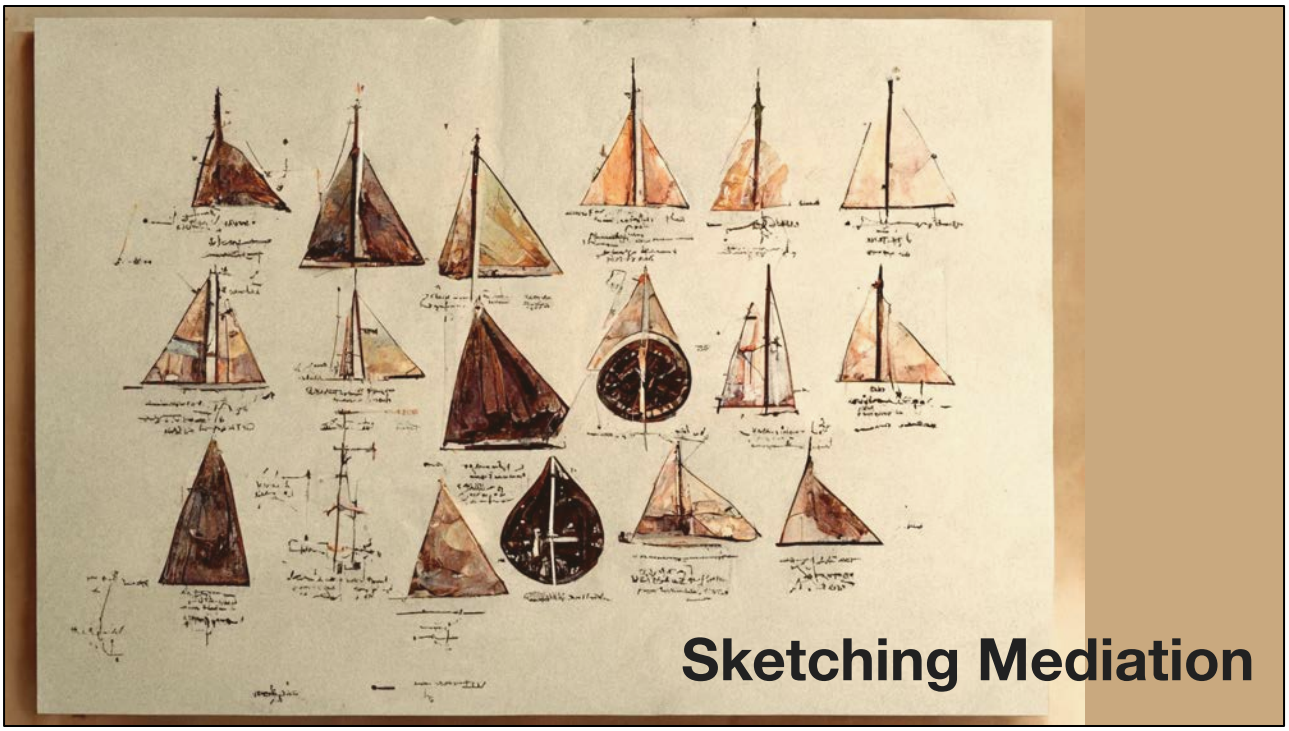
Noticing Noticing

Throughout the institute we noticed enthusiasm for a dialogic routine we named the ‘noticing practice’. With precedents in mathematics teacher education (Mason, 2002; Jacobs et al., 2020), but tailored for learner engagement during material inquiry workshops (Justice, 2017, 2019, 2020b), the noticing practice begins with sharing work-in-process without self-derogatory preambles (i.e., by not saying, “I’m not good at this,” or “I didn’t have time to finish.”). After sharing, learners ask, “What did you notice about my project?” Classmates or colleagues raise their hands and are noticed by the presenter. Non-judgmental responses might include “I noticed the cat moved up and down” or “I noticed the music was loud,” but cannot include “I liked it!” or “That was awesome!” Often the dialog evolves into a rhythmic call and response of noticing and sharing among the learners, without the need for teacher intervention.

“What did you notice about my project?”
No self-derogatory preamble; non-evaluative responses.
Rhythmic call and response, noticing and sharing among learners, minimal teacher intervention.

Participants adopted noticing in their teaching. Alma, an elementary specialist, said it sparked her students’ and her own enthusiasm for learning new skills, saying, “I’m so appreciative of the ‘I notice’ statement … because that’s helped me not be like, well, ‘I see that you’re doing this wrong’…[but] ‘How do you think we could do this differently?’” And at the beginning of the school year, Marina, another elementary specialist, introduced her students to paper circuits with copper tape and LEDs. When asked how she had scaffolded circuitry skills in the first week of school she shrugged it off: “The summer helped me open my mind to try new things myself. I can have the kids be more comfortable in just exploring.”

Justice, S. (2017a). Material learning in action: Building an arts-based research community. *Art Education*, *70*(3), 39-48.
Justice, S. (2017b). Prompting for a serendipity mindset with simple digital tools. *NAEA News*, *59*(2), 18. https://doi.org/10.1080/01606395.2017.1296278
Justice, S. (2019). Interface: The transformative potential of computational making. *NAEA News*, *61*(5), 20. https://doi.org/10.1080/01606395.2019.1657759
Justice, S. (2020a). Designing the social interface: More than social, more than material. In A. Knochel, C. Liao, & R. Patton (Eds.), *Critical digital making in art education*. Peter Lang, Inc.
Justice, S. (2020b). Joyful toys: A journey in expanded media arts learning. *NAEA News*, *62*(4), 19. https://doi.org/10.1080/01606395.2020.1778962



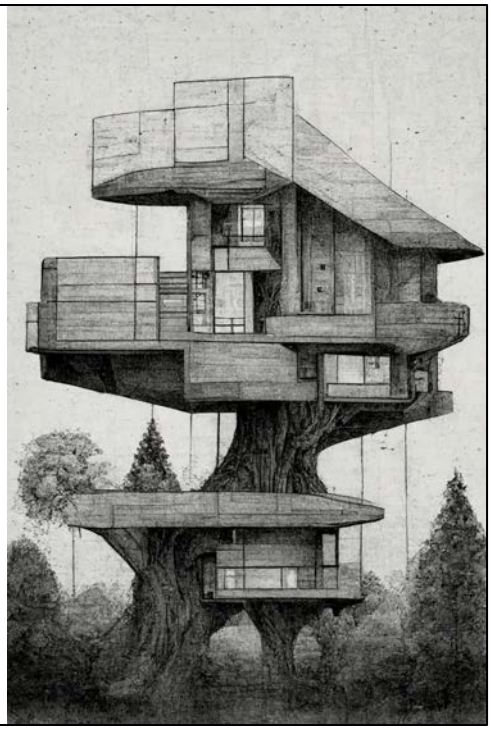
What mediated teachers' CT learning and implementation?

How did the structure and flow of the institute mediate teachers' interdependent learning (individual and communal) and spark the enactment of classroom learning during the school year?

As a mediation process, maybe the emphasis on shared community learning invited participants to relax expectations about their deficits (*I can't program a computer!*) and hold a little loosely to teacher expertise (*We can figure it out together!*). Which nurtured a *feeling* of knowing in a domain that once felt esoteric or off limits. This transgression, routinized by the noticing practice, sparked an appetite for purposeful play with the unfamiliar computational tools and materials on offer, and confidence that they could indeed engage in expressive meaning making with those tools. Which positioned emergent capacities as intertwined with early childhood learning possibilities. Which produced a comradery of not-knowing together. Which catalyzed a brave space where making mistakes, feeling confused, and celebrating hard fun became normative, just something we do together. Perhaps this saturated and invigorating learning space invited teachers to forge new connections between what they learned and how they taught, fusing teacher identities to learning identities and igniting a desire for inquiry learning in their own classrooms. Later, during the school year, teachers noticed students' engagement, which kicked off a recursive amplification cycle, where students' learning amplified teachers' learning, which amplified students' learning, and so on.

This sketch of teachers' generative learning mediated by the summer institute's diverse arts and inquiry teaching practices is speculative and incomplete. It cannot adequately describe the messy social, cultural, and material complexities that accompany vigorous interdependent learning (Marsick et al., 2017). But neither does it contradict the findings of transformative learning discussed above. As such we would argue that recursive generativity as catalyzed by the material inquiry approach appears plausible as a mediator of transformative learning in this context.

What Comes Next



What Comes Next

Findings suggest the arts and inquiry program we developed influenced participants' CT learning and implementation. Surprisingly, teachers said their participation catalyzed transformations in practice that went beyond simply understanding and teaching with CT, provoking critical re-evaluations of teaching and learning identities and strengthening student learning engagement.

Would the approach we took with the summer institute catalyze teaching and learning transformations in later grades, or in other STEM domains not considered expressive?

Constraints on innovation in teacher education, rather than dismissing arts and inquiry approaches entirely, might reflect high stakes testing practices that determine how content is taught—explicitly and directly—and stubborn developmental hierarchies that frame expressive learning as childish, or position expertise as human-centered mastery. From our perspective, though aiming to ensure all students are prepared to meet national and state expectations is a laudable goal, these developmental, direct mastery approaches do not appear to be working very well.

By this light, our study responds to Peppler and Wohlwend's (2018) call for hybrid approaches to make "art fields more culturally valued" (p. 97), and supports Halverson and Sawyer's (2022) assertion that "the arts can transform STEM teaching" (p. 1). Shoring up these speculations requires further research on the mediators that connect teacher learning and student learning, and on the efficacy of arts and inquiry approaches across the K-12 spectrum and beyond computer science.

Delyser, L. A., Goode, J., Guzdial, M., Kafai, Y. B., & Yadav, A. (2018). *Priming the computer science teacher pump: Integrating computer science education into schools of education*. CSforAll. https://www.csfored.org/report2018

Halverson, E., & Sawyer, K. (2022). Learning in and through the arts. *Journal of the Learning Sciences*, *31*(1), 1-13. https://doi.org/10.1080/10508406.2022.2029127
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Peppler, K., & Wohlwend, K. (2018). Theorizing the nexus of STEAM practice. *Arts Education Policy Review*, *119*(2), 88-99. https://doi.org/10.1080/10632913.2017.1316331
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Make it Move!

Arts & Inquiry Approaches to Computational Thinking in Teacher Professional Learning

Art Education Research Institute
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Tucson AZ
Oct. 19-21, 2023

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https://www.aerinstitute.org/2023-symposium-information

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