What Does Computer Science and Maker Education Look Like in 2030?

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Abstract: Making and computer science are fast becoming a part of the educational experience of youth growing up today. At the outset of a new decade, it is important to take pause to think critically about where we are and where we want to go. In order to realize our desired vision for the future of computer science and Maker education, the seeds must be planted today. The goal of this symposium is to bring together computer science and Maker education researchers to lay out a vision for where we hope to see these fields go over the course of the next decade. Each presenter in this session will share work currently underway and discuss how it helps set us on a path towards realizing these visions. In doing so, we seek to set an aspirational agenda and position the Learning Sciences at the forefront of defining the future of computer science and Maker education.

Overview

As the role of technology grows, it is increasingly important for today's youth to understand the digital landscape that surrounds them and to be prepared to meaningfully participate in our computational world. From pre-kindergarten through undergraduate education and across diverse learning contexts, there are opportunities to engage learners with the big ideas of computer science and making. The goal of this symposium is to bring together researchers to explore different ideas for what we hope computer science and Maker education will look like at the decade's end and begin to build connections between projects currently underway and the endpoints we seek to achieve. In combining making and computer science we recognize the similarities between the two disciplines while also identifying distinct opportunities and ideas unique to each.

This symposium emerged out of a two-0day workshop on computer science and Maker education. As part of this workshop, attendees were challenged to build a vision of what we hope computer science and Maker education will look like in 2030. Over the course of these discussions, a set of essential questions emerged that shape our vision of computer science and making in 2030 and inform the current research agendas being pursued. These questions

include: How do we make computer science and Making relevant to learners? What technologies, concepts, and practices do we emphasize? How does computer science and Making relate to existing subject areas? How and where do these experiences take place? If/how should they be assessed? How can we ensure computer science and Making instruction happens in equitable and accessible ways? How do we prepare teachers and educators to take on this responsibility? What is the role of researchers and policy in this process?

The answers to these questions reflect the values and priorities of those working on this wicked problem. By looking at the research currently underway, we can see the seeds of our 2030 visions being planted. The presenters in this symposium will each briefly lay out their unique vision for what computer science and Maker education will look like in 2030 and share how they are currently working to realize this future.

Objective

The goal of this session is to bring together leading computer science and Maker education researchers to share their visions of what instruction might look like in ten years. This symposium will provide a forum for these two communities to layout their aspirational goals and serve as an opportunity to engage in a critical dialog around values, priorities, and essential needs for the community. Further, this symposium will engage the larger Learning Sciences community in an open dialog about where we are, where we hope to be, and the gap between the two. By grounding this future-facing discussion in work currently underway, we explicitly demarcate the starting line and take stock of where we are, what goals and questions we are actively pursuing, and highlight gaps in current efforts relative to the larger visions of where we hope to be. In doing so, we seek to begin the conversation that will shape the agenda for these communities moving forward in a way that advances our goals and brings out the future we envision.

Format

The symposium will be formatted as an interactive poster session to engage in thoughtful discussions on computer science and Maker education. The symposium will begin with a brief presentation summarizing the big ideas from the two-day workshop that motivated this symposium followed by short introductions of each project represented in the session. The poster session will provide attendees the opportunity to explore and discuss research topics across several themes with computer science and making education such as infusing/integrating across multiple domains, relevant and responsive pedagogy, equity and accessibility, community building and partnerships, and assessment. The symposium will close with summative comments from our discussant and outline concrete next steps for those interested in continuing the discussion.

Implications

Given the increasing presence of computer science and Maker education, this symposium seeks to capitalize on the current excitement in these two areas and organize the existing energy towards desired ends. With the world becoming more computational, it is important to discuss how computer science and Making can be integrated across learning contexts in the near future. Equipping youth with the ability to think computationally and solve real-world problems is something that is being emphasized more and more across diverse disciplines, and as a result, we are progressing to an age where computer science and making are becoming relevant throughout disciplines.

Computer Science as a Foundational Literacy for Learning

David Weintrop, Janet B. Fofang, Margaret Walton & Janet Walkoe
University of Maryland

In 2030, we envision computer science education thriving across elementary (K-8) contexts serving a role similar to the roles that literacy and mathematics play today. By this we mean, computer science as a knowledge base that learners use as a means to express and explore ideas across domains. At times, this will take the form of programming and other times it will look like problem solving or creating with computational tools grounded in foundational ideas from computing and computer science. This view is grounded is diSessa's (2000) idea of computational literacy and takes seriously the idea that computation can serve as a medium for expression, communication, and exploration. We see computer science education across K-12 as playing a foundational role in precipitating this vision. A central challenge we currently face is understanding what the seeds of computational literacy look like in elementary grades and understanding how they fit into a larger trajectory across K-12 education.

In a step towards this envisioned future, we are developing a computational thinking-enhanced elementary mathematics curriculum designed to empower learners to engage in mathematical reasoning through programming. In this poster, we will present the big ideas of our curriculum, titled *Sphero.Math*, and articulate our vision of how

computational thinking in elementary mathematics classrooms can serve as the seeds of later computational and mathematical thinking. In pursuing this work, we draw inspiration from the work of Papert (1980) who first saw the potential for computing serving as a context for meaningful mathematics reasoning.

"Making" Stories: The Melding of Making and Literacies

Jill Scott
Indiana University

Information and communication are readily available to children at all times through their out-of-school digital practices. During these out-of-school times, children often are completely engaged as they immerse themselves in digital communication practices. We rarely see elementary children choose paper and a pencil to communicate, as it does not offer the connected, social, interactional affordances of digital practices. Yet, schools remain staunchly committed to paper-and-pencil, print-centric literacy practices. It seems imperative then, that there is a reimagining of literacy teaching and practices to include production-oriented Maker literacies that contain media production where multimodal, digital and artifact-based literacies converge (Wohlwend, et. al., 2018). As teachers consider the growing disparity between in-school and out-of-school literacy practices, we envision by 2030 there will be a blurring of the lines between making and literacy to better reflect the ways that children communicate and make meaning in the real world.

This poster examines a reimagined writers' workshop, one that shows the overlaps and melding of Maker education and literacy practices within an elementary school makerspace. It highlights how Maker literacies can be used by children to imagine, create, and share their own characters and films as a means of expanding what counts as literacy in digital times.

Maker Education for Individualized *and* Collaborative Learning

Yong Ju Jung & Heather Toomey Zimmerman
Penn State University

When it comes to 21st-century learner-centered education, interest-driven learning and collaborative learning have been emphasized. However, when dissecting what interest-driven learning and collaborative learning really mean, these two concepts may be contradictory: interest-driven learning focuses on providing supports for each learner's own interests (e.g., Ito et al., 2013), while collaborative learning entails collective goals for which, sometimes, individual preferences may not be considered. We propose that Maker education in 2030 should address individual learners' interests and moment-by-moment needs, and at the same time, orient them to the collaborative nature of making. Based on our analysis of interactions between children having conflicting interests during collective making at a current Maker education setting, we draw several implications for transforming makerspaces to be individualized *and* collaborative learning space by 2030.

Envisioning Debugging Cultures at the Intersection of Emotion, Problem Solving, and Identity

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The inevitability of encountering "bugs" in code can make learning to program emotionally intense, demanding of complex problem solving, and capable of shaping emergent discipline-specific identities. Researchers are now studying interactions between these phenomenological features of learning to program (Sengupta, Dickes, & Farris, 2018). Building on this work, we present a vision for 2030 computer science education in which learning environments encourage sustained teacher-student and student-student communication about *emotion*, *problem solving*, and *identity*, especially surrounding failure. In a step toward unpacking this vision, we draw on a design-research study that used art making to support reflection and communication on these facets of learning to program. Through the *portraiture methodology* (Lawrence- Lightfoot & Davis, 1997), we document the experiences of three middle and high school girl coders over 2½ years. Over this period of summer/weekend coding workshops, each student developed independent, confident, and generative programming practices. The portraits unpack how learners viewed themselves evolving at the intersection of emotion, problem solving, and identity, and they make a case for working toward

learning environments that invite participants, whether through art making or other forms of reflection, to surface, understand, and responsively support one another's unique experiences with failure.

Towards Democratization of Makerspaces: Youth Making Programs in Small-town and Rural Libraries

Soo Hyeon Kim & Andrea Copeland
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In the past decade, the potential of Making has moved beyond informal learning settings to schools, libraries, and museums. In 2030, we predict the Making practices will be further supported and sustained within local communities by centering these practices around public libraries serving as information institutions that provide democratic access to resources, expertise, and facilitation for community engagement. To realize this vision, our study addresses the lack of research at the intersection of making, community engagement, and rural libraries by investigating both the youth and the librarian perspectives related to community engagement, makerspace, and youth informal learning. Guided by situated learning theory that recognizes librarian and youth activities as situated within their everyday practices, prior knowledge, and culture, our research conducts a case study of small-town and rural libraries within Indiana through cultural probes (Gaver et al., 1999), semi-structured interviews, and co-design to identify the current status of rural libraries and identify facilitators for, and invisible barriers to establishing library makerspaces as sites of community engagement. In this poster, we present a context-specific model for implementing youth making programs within small-town and rural libraries based on our study findings.

Engaging Families in Authentic Design: Are they doing STEM?

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Humans face an increasing set of challenges. We foresee that much of education will look fundamentally different by 2030. One key factor of this involves how kids engage in STEM outside of school, particularly in their own homes. We have been researching how kids and caregivers can work together to engage in designing and addressing problems in their homes, schools or communities. In this research, kids and caregivers from traditionally underserved communities engaged in small design projects over the span of five months. Groups participated in monthly design and build meetings with the research team and a set of engineers who volunteered to guide families in the design process and add technical support. Families were expected to continue to prototype and test their designs outside of these meetings. Our goals are to have kids and their caregivers develop a greater understanding of what STEM is and what engineers do. Additionally, we aim to better both groups' attitudes toward STEM. In this presentation, we will discuss early results from this research along with the opportunities and challenges we faced in planning and conducting this work.

Reversing Explainable AI: Supporting Learners' Reasoning Activities with Artificial Intelligence

Gi Woong Choi
State University of New York at Oswego

It has been forecasted that the adoption of AI within the educational sector is imminent and that it will bring a huge impact on education. There have been many approaches to integrate AI into education, and many studies have focused on implementing AI for adaptive learning or learning analytics (Chassignol et al., 2018; Roll & Wylie, 2016). Following the theoretical notion of Salomon (1988)'s AI in reverse, I posit that integration of AI can be more than the technological integration. By 2030, AI will be integrated into human lives in a non-intrusive yet ubiquitous way, and this would require CS education to reach the broader public. Moreover, this calls for a need to engage students in learning how to integrate AI into their own lives. The presentation aims to revisit Salomon's (1988) argument of "*using AI to allow learners to emulate it and come to use it as part of their cognitive apparatus*" (p. 124) and report on my initial research approach toward integrating the concept of AI into CS Education in a less technical way for students. Such integration will help students to become familiar with AI which would become an essential competency for the 21st century.

Video Analysis of K-5 Students' Interface Interaction with Online Maker Portfolios

Monica Chan & Nathan Holbert
Teachers College, Columbia University

Assessment and evaluation are nascent areas in the field of Maker education. However, we believe that Maker-oriented assessment should primarily be student-driven -- emergent from individual and collaborative reflection -- rather than teacher-driven. Portfolios have been shown to be an effective mode for students to demonstrate authentic exploratory Maker journeys, technical mastery and metacognitive reflection (Keune & Peppler, 2017; Love, McKean & Gathercoal, 2004). However, creating a classroom culture that values the documentation of in-process construction, as well as completed projects, is challenging.

In this study, we examine fifteen K-5 students' use of a cloud-based portfolio system to document Maker projects that they work on in school. In addition to examining prior posts made by students, we also engaged students in a think-aloud protocol while they used the digital portfolio tool to make a new post. Our current observations mostly demonstrated that teachers were largely directing various modes of assessments, but our analysis reveals the various ways where the portfolio impacts students' reflection processes, students' mindsets towards receiving feedback within the interface, and students' desire for more features to document collaborative construction efforts. Through this study, we present suggestions towards a vision for designing and implementing seamless, authentic modes of assessment for K-5 learners in Maker environments.

Identity of an Inventor: Capturing Innovation and Entrepreneurship Critical Skill Competencies over Time through Portfolio Assessment

Leslie Flynn
The University of Iowa

By 2030, student teams working in incubator spaces to create prototype solutions to challenging problems will be the norm. This transdisciplinary approach to learning fully engages students in the innovation and entrepreneurial process. As they create, students will collect, analyze and reflect on individual, peer, and team critical skill competencies collected through a digital portfolio. The skills and mindsets are deemed essential by industry experts across multiple fields (Flynn, 2016). The portfolio documents self and peer quantitative data as well as qualitative descriptions of evidence to support rankings. The digital platform allows community partners across the country to provide mentorship and feedback to students. Longitudinal growth curve modeling indicates significant growth in competencies over time ($p \leq 0.001$, N=789 HS students), and growth is significant when disaggregated by gender and race. This is critical as these groups are currently limited in participating in the innovation economy fueled by computer science and invention (Bell, et al., 2018). Students' written responses illustrate explanations of identity attributes and why they changed or didn't. The work sheds light on how to facilitate a Maker and computer science movement grounded in an invention framework and rigorously assessed. The assessment tool, findings, and opportunities for research collaboration will be discussed.

Computing Education for Impact, Identity, and Empowerment

Mike Tissenbaum
University of Illinois at Urbana Champaign

Over the next ten years, young learners are going to increasingly find themselves in a world in which computing becomes inextricably entwined with nearly every aspect of life and work. With this proliferation of computing into their lives, just as Scratch has done for games, Wix and Squarespace have done for websites, and MIT's App Inventor has done for mobile apps, they will see a host of tools and platforms that reduce the barriers for them to create, shape, and impact their own lives and communities. As such, for many of them, there will be less of a need to understand the complexities of current programming languages, so much as it will be necessary for them to think of themselves as empowered citizens, able to recognize opportunities to impact their lives and those of others, and capable of using the tools available to create computational solutions to those opportunities. We define this reframing of computing education, focused on the development of one's computational identity, digital empowerment, and computational design thinking as *computational action* (Tissenbaum, Sheldon & Abelson, 2019). For this symposium, we will discuss how we are developing approaches for supporting today's youth in developing these skills and identities, towards enabling them to be the empowered creators of the next decade and beyond.

Problem Decomposition, Starting Point of Problem Solving

Kyungbin Kwon, Anne Ottenbreit-Leftwich & Thomas A. Brush
Indiana University

Problem decomposition is an essential skill for computational thinking and practices. Through a decomposition process, students divide a task or problem into simpler parts to devise a solution. However, there are a limited number of studies on how to teach and assess students' effective decomposition competencies in practice. In 2030, we anticipate that teachers emphasize problem-solving skills across subjects, and they will teach decomposition processes to support students to identify problems and develop solutions. Having the vision of this, the researchers examined students' problem decomposition competencies when designing solutions. The learning context was 6th-grade social studies classes where students were supposed to develop Scratch projects that demonstrate their ideas (knowledge) about social issues. As an instructional intervention, a scaffolded worksheet was provided to students to guide them through the decomposition process while designing their Scratch projects. The study will present how students interacted with the scaffolded worksheet, and the contents of decomposed tasks will be analyzed. This study will identify what cognitive skills are required in decomposition processes and suggest instructional strategies facilitating decomposition processes that can be adopted in various problem-solving contexts.

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