Reimagining Systems for Learning Hands-on Creative and Maker Skills

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ABSTRACT

In the last decade, HCI researchers have designed and engineered several systems to lower the entry barrier for beginners and support novices in learning hands-on creative maker skills. These skills range from building electronics to fabricating physical artifacts. While much of the design and engineering of current learning systems is driven by the advances in technology, we can reimagine these systems by reorienting the design goals around constructivist and sociocultural theories of learning to support learning progression, engagement across artistic disciplines, and designing for inclusivity and accessibility. This one-day workshop aims to bring together the HCI researchers in systems engineering and learning sciences, challenge them to reimagine the future design of systems of learning creative maker skills, form connections across disciplines, and promote collaborative research in the systems of learning creative skills.

CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; **HCI theory, concepts and models**.

KEYWORDS

learning systems design, learning creative skills, learning in maker spaces

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1 BACKGROUND

1.1 Motivation

In the last decade, HCI researchers have designed and engineered several systems to lower the entry barrier for beginners and support novices in learning hands-on creative maker skills, such as fabrication, circuit prototyping, and design. Examples of such systems include Trigger-Action-Circuits [1] that support circuit building by automating and simplifying the complexity of designing electronics [27], and SmartMakerspace that lowers the barrier for novices for fabrication through an instrumented workspace [15] and context-aware tutorial [24]. These examples demonstrate how we can leverage advances in enabling technologies, such as better sensing hardware, data-driven AI algorithms, and AR/XR [35] devices in fablabs and makerspaces [33] to engineer learning systems that tightly integrate physical and digital mediums through multimodal intelligent feedback and guidance in the context of physical hands-on skills. With advances in these enabling technologies, new possibilities and opportunities have emerged to support novice learners with creative maker skills and there is growing excitement in the systems engineering community in HCI to reimagine the design of learning systems.

Despite the growing research and excitement around the design and engineering of systems for learning creative and maker skills, these systems can be improved to support learning by (re)centering the design of these systems around the learner, the instructor, and the learning processes instead of centering them around their enabling technologies [18, 34]. HCI researchers in the learning sciences have noted that supporting learners of creative and maker skills in leveraging their cross-disciplinary knowledge, skills, and efficacy within and beyond the learning environment, can provide opportunities to reimagine environments for learning maker skills in ways that expand the cultural practices and knowledge bases [11, 40].

In this workshop, we invite discussions around the future of the design and engineering of systems for learning creative and maker skills by grounding them in the theory of constructivism, practices of artistic disciplines, and promoting inclusivity and accessibility. For example, we will discuss how the affordances of technologies can be leveraged in the design of these learning systems by grounding them in the theory and frameworks of constructivism to scaffold

learning: (i) using learner's interests, knowledge, cultural practices to inform their making activities (ii) promoting collaborative interactions (peer instructor) during maker activities (iii) supporting learning trajectories through engaging learners in their zone of proximal development [23, 28, 41]. Going beyond the scope of the affordances of technologies, we will reflect on current practices from artistic disciplines outside of engineering design, such as visual art, architecture, and sculpting, that can inform the design of systems to support creativity and transdisciplinary learning wtihin makerspaces [14]. Finally, through the discourse, we will examine ways to create opportunities for inclusivity and equity in the design of learning systems. With a rise in the practice of using remote and hybrid learning practices for teaching hands-on creative and maker skills that have conventionally relied upon in-person workshop based format, novel learning systems need to emerge keeping inclusivity and equity in mind.

We are at a point where there is a unique opportunity to reimagine the design and engineering of systems for learning creative and maker skills through the lens of learning sciences and ground these systems in existing theories, frameworks, and practices of learning creative and maker skills.

1.2 Topics for discussion

We propose this workshop to bring together researchers in HCI from both the disciplines - systems engineering and learning sciences and challenge them to

Reimagine the Design and Engineering of Systems for Learning Hand-on Creative and Maker Skills Through the Lens Of:

- **Constructivism and Constructionism** - Through discussions on leveraging the affordances of current technologies to design and implement the systems for learning in ways that incorporate learner exploration, learner-peer collaboration, and we aim to make these systems *learning-centric* and not just *technology-centric* [18]. In this discussion, we will exchange ideas and perspectives from both disciplines (systems engineering and learning sciences) on current trends, opportunities, and challenges in the design of learning systems, monitoring the learner's progress, evaluating learning, and providing support during the learning process. We will discuss this topic during the expert panel and group brainstorming sessions.

- **Artistic disciplines:** Through the exchange of knowledge and current learning practices in the artistic disciplines outside of engineering design, such as visual arts, architecture, interior design, and sculpture making, we aim to inspire new ways of supporting learning creative skills through iteration and prototyping [10, 21, 26]. By connecting to these other disciplines inherent in fabrication, but often neglected, we will explore how this integration expands the ways learners can create and participate within educational fabrication experiences. We invite practitioners and researchers from these disciplines to also discuss the challenges that exist in understanding, scaffolding, and assessing the learning of complex creative tasks during the learning process [9, 13, 30].

- **Inclusivity:** Through discussions on grounding the learner's making in their sociocultural practices, values, and goals that align with their identities, we aim to highlight the importance of designing learning systems that are inclusive and equitable for learners of different backgrounds, skills, and from different geographical regions [5, 32, 40]. Furthermore, the adoption of remote learning as a result of the COVID-19 pandemic created additional challenges for learning hands on making by restricting access to physical spaces, tools, and materials [12]. Remote making also suggested new opportunities for broadening participation by enabling educators to experiment with low-cost hobbyist equipment and by creating new incentives for maker activities like at-home personal fabrication and DIY electronics production [3]. We seek to examine strategies for future remote or hybrid learning approaches that serve under-resourced and underserved communities of learners rather than reinforcing existing inequities [11].

1.3 Goals of the Workshop (and how will they be achieved):

The goal of this workshop is to bridge the gap between (1) the research in the design and engineering of systems and (2) the research in the theories, frameworks, and practices of learning creative and maker skills. This workshop will provide a platform to bring together researchers in HCI from both these fields and provide an opportunity to:

- ***Exchange ideas and discuss opportunities and challenges across disciplines:*** We will lead multi-disciplinary expert panel discussions around the topics listed above. This expert panel discussion session will be recorded and the recording will be made available on the workshop website for asynchronous viewing.

- ***Promote collaborative research:*** We will lead brainstorming sessions with the workshop participants in smaller interdisciplinary groups and challenge them to reimagine ways of designing and engineering systems for learning creative and maker skills. The in-person attendees will brainstorm in smaller groups at the conference venue and the remote attendees will brainstorm in breakout rooms over zoom. We will make the experience reports and notes from these brainstorming sessions available on the workshop website for asynchronous viewing.

- ***Generate source material for interdisciplinary work:*** A repository of relevant cross-disciplinary literature and recommendations from the workshop will be made publicly available on the website to inspire new collaborative projects and interdisciplinary research.

2 ORGANIZERS

2.1 Dishita Turakhia, PhD Candidate, MIT CSAIL (main contact person)

Dishita Turakhia is a Ph.D. candidate at Massachusetts Institute of Technology, in the EECS dept. Her work in the HCIE group at MIT CSAIL focuses on designing systems for learning of hands-on skills such as motor skills, fabrication skills, and maker skills. She builds these learning systems using different frameworks from the learning sciences, such as adaptive learning [37–39], game-based learning [36], and reflective learning.

2.2 Paulo Blikstein, Associate Professor, Columbia University

Paulo Blikstein is an Associate Professor of Education and an Affiliate Associate Professor of Computer Science at Columbia University. A former student of Madalena Freire's lab school in São Paulo, Paulo has been deeply influenced by Paulo Freire's work. His current research focuses on how new technologies can transform the learning of science, engineering, and computation and how new machine learning-inspired methods can be applied in educational research [6, 8]. He created the FabLearn program, the first academic initiative to bring maker education to schools, and designed several platforms for creative making, such as Google Bloks and the GoGo Board. More recently, Paulo has been exploring the idea of Cultural Making, conducting research on how different learning communities–such as Samba Schools in Brazil and Thai rural villages–organize themselves and accomplish fabulously complex engineering and scientific tasks [7].

2.3 Nathan Holbert, Associate Professor, Columbia University

Nathan Holbert explores how children engage in testing, tinkering, and sense-making during play around topics or phenomena that they find personally engaging. In particular, he studies how children use intuitions about natural phenomena and scientific principles to interpret and assimilate central representations and tools found in play spaces, and how we might reconceive these environments to provide rich learning experiences that all children will see as highly connected to their personal values and goals as well as to formal tools and ideas [19]. His work is situated squarely in the constructionist tradition and often involves the design and creation of useful and powerful educational tools in the service of the refinement and development of cognitive theory [18]. His current research explores play and learning in diverse contexts (such as makerspaces, the beanbag chair, and the classroom) and domains (such as computer science, engineering, and the physical sciences) [17, 20].

2.4 Marcelo Worsley, Assistant Professor, Northwestern University

Marcelo Worsley is an Assistant Professor in Computer Science and Learning Sciences. He directs the technological innovations for inclusive learning and teaching (tiilt) lab, which aims to develop pedagogical and technological solutions for supporting learning among diverse populations in hands-on, collaborative, environments. More specifically, the goal of his research is to promote equity and advance society's understanding of how students learn in complex learning environments by forging new opportunities for using multimodal technology [9, 30]. The use of multimodal technology is multi-fold. First, the environments that he studies allow students to experience learning across a range of modalities. Second, he uses multimodal signal processing and artificial intelligence to study how student learning is demonstrated across different modalities and time scales. Third, he designs multimodal interfaces that support inclusivity and deepen student learning, while also considering ways to use multimodal data to support student and teacher reflection.

2.5 Jennifer Jacobs, Assistant Professor, University of California, Santa Barbara

Jennifer Jacobs is an Assistant Professor at the University of California Santa Barbara in Media Arts and Technology and Computer Science (by courtesy), where she directs the Expressive Computation Lab. She works across the fields of computational art and design, human-computer interaction, and systems engineering. Her research lab investigates ways to support expressive computer-aided design, art, craft, and manufacturing by developing new computational tools, abstractions, and systems that integrate emerging forms of computational creation and digital fabrication with traditional materials, manual control, and non-linear design practices [3, 21, 26]. More broadly, her lab examines how we can enable art and design professionals to leverage their domain expertise to develop personal software tools.

2.6 Fraser Anderson, Senior Principal Research Scientist, Autodesk Research

Fraser Anderson is a Senior Principal Research Scientist at Autodesk Research in Toronto. He is interested in a broad array of novel interfaces, interactions, and sensing techniques, especially those that help with learning and augmenting people's skills [1, 25, 33, 35]. Prior to joining Autodesk, he received a Master's and Ph.D. in Computing Science from the University of Alberta where he studied surgical skill acquisition, technology for physical and occupational therapy, and cognitive and motor learning aspects of gestural interfaces.

2.7 Jun Gong, Research Scientist, Apple Research

Jun Gong is a Research Scientist at Apple. His research spans a range of different topics in Human-Computer Interaction (HCI). He designs, builds, and evaluates novel input and interaction for emerging platforms, media, and technology to provide enhanced and compelling user experiences. Besides contributing new sensing systems to the field, he is also interested in creating fabrication and circuit prototyping tools to facilitate the exploration of interactive devices for people without a strong hardware background [15, 16].

2.8 Kayla DesPortes, Assistant Professor, New York University

Prof. Kayla DesPortes is an Assistant Professor of Human-Computer Interaction and the Learning Sciences at the NYU Steinhardt School of Culture, Education, and Human Development. Her research vision is to use computing education to empower learners who are typically marginalized by technology. To do this, she designs and studies artistic computing learning environments and technology. She works in collaboration with educators, learners, artists, and community organizations. This work has led her to explore ways for learners to leverage their cultures and values as they build expressive designs with computing. Her projects span across computer science, poetry, electronics, visual arts, photography, social action, machine learning, dance, and data science [13, 22].

2.9 Stefanie Mueller, Associate Professor, MIT CSAIL

Prof. Stefanie Mueller is an Associate Professor at MIT CSAIL. Her research focuses on lowering the entry barrier to personal fabrication [2], i.e. allowing more users to fabricate their own objects and increasing the complexity of objects users are able to make [4, 29, 31]. To this end, Stefanie's research lab develops novel prototyping toolkits that abstract away complex domain knowledge and enable users to focus on the end goal of what they are trying to build. Stefanie is also teaching several hands-on maker courses at MIT where has first-hand knowledge of the struggles students face when learning various maker skills.

3 LINK TO WEBSITE

Our website http://chi-reimagininglearning.com will contain the necessary information, motivation, and rationale behind the workshop. The website will serve as a platform for advertising the call for participants before the workshop, for archiving information about each submission, and for collecting documentation and outcomes from the workshop.

4 PRE-WORKSHOP PLANS

We are inviting submissions that focus on crossdisciplinary research in the area of learning creative and maker skills. Submissions can be of two types: (1) envisioned research projects, i.e. project ideas to support learning of hands-on creative skills, with contributions towards the design of learning environments, novel ways of sensing learning, measuring learning, and supporting the experience of learning the creative skills. (2) experience reports on research projects, i.e. in-progress or finished projects.

We will post our call for participants on our website shortly after notification. We will distribute the call for participation among our network, which includes researchers in the relevant disciplines - systems engineering and learning sciences. Participants must submit papers by February 20 and will be notified of acceptance by March 5. Afterward, we will send a list of participants to the workshop chairs. In order to allow ample time for discussion of each project and experience, a maximum of 15 submissions will be accepted. However, we will allow for up to 20 participants in the workshop in case more than one author of a submission would like to attend the workshop.

To align the composition of the organizing team with the goals of the workshop, the main organizers Dishita Turakhia, Prof. Stefanie Meuller, and Prof. Kayla DesPortes have already reached out to researchers of related disciplines and invited them to join the workshop organization.

As a result, the organizing team now also has researchers from the *Learning Sciences* field (Prof. Paulo Blikstein, Prof. Nathan Holbert, Prof. Marcelo Worsley) and from *Learning-Systems Engineering*, (Prof. Jennifer Jacobs, Fraser Anderson, Jun Gong). These organizers will act as ambassadors for their respective areas, i.e. they will provide an overview of research from their discipline to foster interdisciplinary collaborations.

5 WORKSHOP STRUCTURE

5.1 Expert Panel

The panel will consist of short talks of each organizer/ambassador highlighting recent research, challenges, and opportunities from their field. Afterward, participants will be invited to ask questions and discuss their own perspectives with the panelists. The goal of the panel and accompanying discussion section is to foster a better understanding of each other's field and to stimulate cross-disciplinary discussions.

5.2 Brainstorming Session

For the brainstorming sessions, we will start with the participants giving 3 minute talks about their cross-disciplinary workshop proposals. We will have short sessions with three presentations in a row, followed by an interactive brainstorming activity. The topics for this brainstorming will be centered around the topics described in Section 1.2, i.e. (1) leveraging affordances of technologies to support learning centered within contructivism, (2) adopting existing practices in artistic disciplines to support learning of creative and maker skills (3) adapting learning systems for inclusive learning, remote learning, and hybrid learning. We will prepare one whiteboard for each of these topics. Participants will gather at the whiteboard for the topic that most piqued their interest. For the brainstorming activity, the participants will be challenged to reimagine the design of learning systems around this topic. The participants will be encouraged to form interdisciplinary teams and identify new opportunities or existing challenges in system design and brainstorm creative solutions. They may choose to address a specific problem while learning a specific skill, or address a broader challenge in creative and maker skill learning. After 15 minutes of small group brainstorming on the design opportunities and the challenges around the topics, each group will present their results and recommendations for the future directions of research in an informal way to the other participants. The benefit of this activity is that each idea receives in-depth multi-disciplinary feedback, participants further get to know each other in small groups through discourse and discussions, and it fosters collaborative research.

5.3 Experience Reports

What does a successful cross disciplinary project look like? Participants who submitted experience reports will be invited to individually share their experiences to the group. A discussion among all participants will follow and will be facilitated by the organizers with the goal of drawing out factors that lead to sustainable and productive collaborations.

6 HYBRID SETUP (FOR IN-PERSON AND REMOTE PARTICIPANTS)

To provide an opportunity for both in-person and remote attendees to participate in the workshop, we have designed this workshop in a hybrid format. All the sessions can be participated in by both the in-person participants and the remote participants. For the remote participants, there will be an AV setup for dialing in remotely (for example, via Zoom). For brainstorming discussions, the in-person participants will form smaller groups for discussions and the remote participants will join breakout rooms for similar group discussions. The expert panel, experience reports, and organizer summary will be presented by the organizers to both - in-person participants and remote participants. The events will be synchronous, but all the material (such as recording of the expert panel session, and experience reports) will be made available on the website for asynchronous viewing. **In case of any unforeseen events, the workshop can also be conducted in a remote format.**

7 WORKSHOP SCHEDULE (ALL EVENTS SYNCHRONOUS)

All the events are in hybrid format, i.e. for both in-person participants and remote participants:

09:00 - 09:30 - **Welcome introductions and icebreakers**
09:30 - 10:45 - **Expert panel***
10:45 - 11:00 - Coffee Break
11:00 - 12:30 - **Focused brainstorming I**
12:30 - 13:30 - Lunch Break
13:30 - 14:20 - **Experience reports***
14:20 - 15:20 - **Focused brainstorming II**
15:20 - 15:40 - Coffee Break
15:40 - 16:40 - **Group and organizer summary***

* *(recorded for asynchronous viewing)*

8 POST WORKSHOP PLANS

After the workshop, with permission from the participants, we will share the contact data of all participants with each other to stay connected. During the workshop, we will capture the discussions and presentations and will publish them on our webpage for future reference.

9 CALL FOR PARTICIPATION

The following call for participation will be posted on the workshop website and distributed to the relevant HCI research community and other disciplines:

In the last decade, HCI researchers have designed and engineered several systems to lower the entry barrier for beginners and support novices in learning hands-on creative maker skills. These skills range from building electronics to fabricating physical artifacts.

While much of the design and engineering of these learning systems is driven by the advances in the technology, we believe these systems can be reimagined by grounding them in existing learning frameworks and by bringing in new perspectives from the learning sciences.

This one-day workshop aims to bring together the HCI researchers in systems engineering and learning sciences and challenge them to reimagine the future design of systems of learning creative maker skills. Our goal is to bridge the gap between between the design of learning systems and existing frameworks of learning, through exchange of ideas and cross-disciplinary perspectives. The workshop is designed to form connections across disciplines and promote collaborative research in re-imagining the systems of learning creative skills.

We invite researchers and practitioners of creative and maker skills across disciplines to submit their work to the workshop. Submissions can be of two types: (1) envisioned research projects, i.e. project ideas to support learning of hands-on creative skills, with contributions towards the design of learning environments, novel ways of sensing learning, measuring learning, and supporting the experience of learning the creative skills. (2) experience reports on research projects, i.e. in-progress or finished projects.

Workshop-Website: http://chi-reimagininglearning.com

Please send your submissions (maximum 4 pages, CHI format, PDF) until February 24, 2022 to: http://chi-reimagininglearning.com

Participants submitting an envisioned research project are required to include one sketch/image that showcases their idea.

At least one author of each accepted position paper must attend the workshop and register for the workshop and for at least one day of the conference.

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