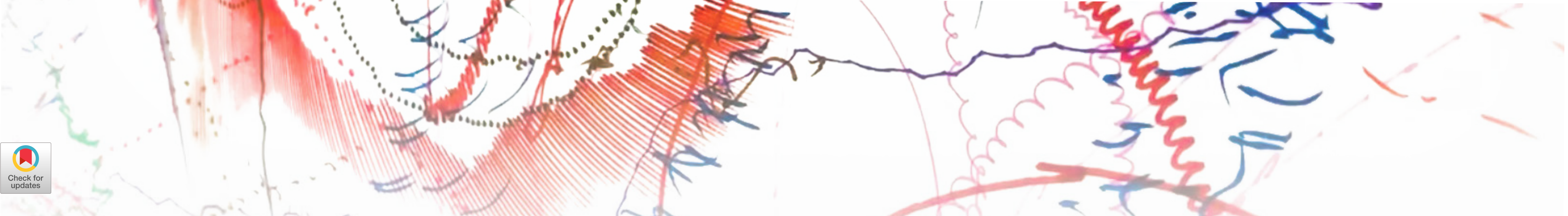

Revealing the Tuning Practices of Creative Learning Experience Designers

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ABSTRACT
We leverage the visual format and affordances of pictorials to make visible and call attention to the unseen design work of educators and designers of creative learning experiences in making and tinkering spaces. We document the process of design and iteration that took place as researchers and educators co-designed a learning experience focused on the intersection of artmaking, circuitry, and computing for participants in a public library makerspace. We present this visual case study as provocations for interaction designers, educators, and researchers who aim to engage people in creative learning experiences with technologies.

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facilitation; tinkering; making; maker education

CSS Concepts
• Human-centered computing

INTRODUCTION

Making and tinkering spaces provide a wide variety of tools, materials, and pedagogical support to enable participants to create and express themselves in new and empowering ways. Many of these spaces have emerged in organizations such as libraries, museums, and community centers. When making and tinkering contexts are oriented towards equity and grounded in community, they can be transformative, affirming spaces that "honor youths' histories while fostering their agency" [4]. Within these spaces, informal learning educators or facilitators enact important practices that enable the creative and equitable engagement of participants [5] [16]. In addition to working directly with learners, educators also engage in thoughtful design processes in which they create, test, and improve learning experiences. [7]

However, what often garners the most attention in research and design efforts are learners' experiences—missing an opportunity to consider the important role that facilitators play in the design and facilitation of those experiences. Vossoughi et al., argue that "equity lies in the how of teaching and learning"–that is, the moves that educators make as they design and facilitate making and tinkering experiences that attend to equity [15]. The lack of attention to the design practices of informal educators in making and tinkering spaces creates a "black box" around designing creative learning experiences–making it challenging for educators and researchers to learn from, evaluate, and build on these practices.

As interaction designers, educators, and researchers aim to engage people in creative learning experiences with technologies, it's important to consider the roles that educators play in this process. Educators mediate the experiences that learners have with technologies. They can adjust tools, materials, and facilitation practices to make a learning experience more, or less, relevant and accessible to learners. This process of adaptation can also be described as "infrastructuring", a process by which educators adjust the pedagogical, social, and material scaffolding in their contexts to make new learning experiences possible [6].

In this pictorial, we ask this broad question: "How can we use the visual affordances of the pictorial format to make the design processes that educators engage in visible?" Just as Jarvis et al., [8] describe the work of academic HCI researchers as being "visually-rich" and underserved by traditional academic formats, so too is the design work of educators in making and tinkering spaces. The research, design, and learning processes encountered in making and tinkering spaces are often rich in visual artifacts and heavily influenced by the community context. When this context is left invisible, readers miss out on valuable information that can support sensemaking. We draw from Sturdee et al., to make these unseen elements of research and collaboration visible [13]. Finally, we take inspiration from Karana et al., who leveraged the pictorial format to document a designer's journey and process [10]. Here we use the pictorial format to document creative learning experience designers' journeys and processes within the context of a co-designed workshop experience.

CONTEXT

We explore the idea of visualizing and valuing the collaborative design work of educators and researchers by documenting the design of an activity developed in partnership with educators at a library makerspace in a metropolitan city center within the Mountain West region of the United States. Our documentation included descriptive field notes written by research team members during makerspace visits as well as photos and videos captured by researchers.

The first author and an educator at this makerspace, Carly, aimed to develop a "computational tinkering" activity that engaged youth in playful, social, and cross-disciplinary experience with computing. This effort is part of a larger project that is collaboratively developing additional computational tinkering activities with informal educators around the US.

In this project, the roles of "researcher" and "practitioner" are intentionally porous [3]. Researchers often work directly with partner educators and learners in their contexts and are heavily involved in designing and testing new activities. Partner educators engage with research work according to their interest level and availability. This approach is rooted in our desire to work towards more equitable methods of partnering in research that disrupt the notion that researchers are the sole holders of all knowledge and expertise within a partnership–making space for the expertise, values, and interests of research partners and the communities they are embedded within. Additionally, this approach makes space for each contributor to bring their unique expertise to the collaboration. The team described in this pictorial brought together a wide variety of skills from electrical engineering, to educational program design, to qualitative research methods.

Carly played a major role in the activity's development and we specifically highlight several of her design moves. In addition to the first author who is a graduate student, a postdoctoral researcher and additional library makerspace educators contributed to the design and implementation of this activity. While the research team's goals are to examine and highlight the practices of informal educators in making and tinkering spaces, researchers also played roles as facilitators during design and development. This pictorial represents the collective design work of this team and everyone took on roles as learning experience designers.

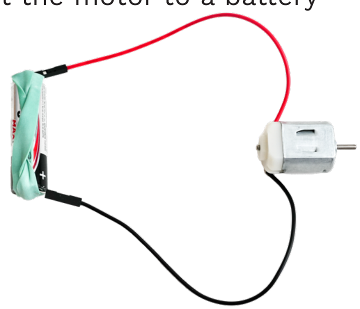
We begin with descriptions of the focal activity, materials, environment, and activity goals to ground readers as we illustrate the "tuning" of these elements. Then, we visualize five key moments that shaped our iterative design process and illustrate the concept of tuning. We carry the metaphor of "tuning", inspired by Karana et al., [10], throughout these moments to emphasize the intention and iteration that characterizes our process of designing creative learning experiences as we tune materials to support our values or tune the environment to support pedagogical goals. This subtle tuning process can significantly impact the outcome of the activity and, therefore, the experience that learners have.

Scribbling Machines Activity Overview

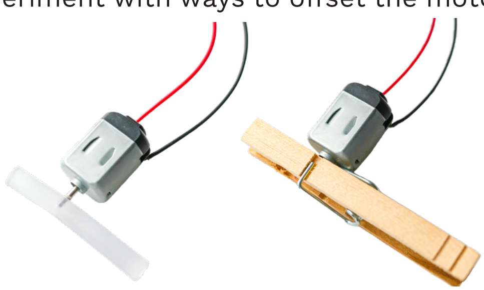
The activity in this pictorial builds on "scribbling machines", developed by the Tinkering Studio [14]. The Tinkering Studio describes a scribbling machine as "a motorized contraption that moves in unusual ways and leaves a mark to trace its path. Scribbling machines are "made from simple materials" and demonstrate "the erratic motion created by an offset motor". This activity was selected as a starting place for co-design by the makerspace educators because it resonated with their desire to support learners in recognizing that they can transform everyday materials into powerful tools for creating interesting projects and in demonstrating that technology and electronics can have creative applications.

The Tinkering Studio suggests the following steps to get started with scribbling machines:

1. "Connect the motor to a battery"

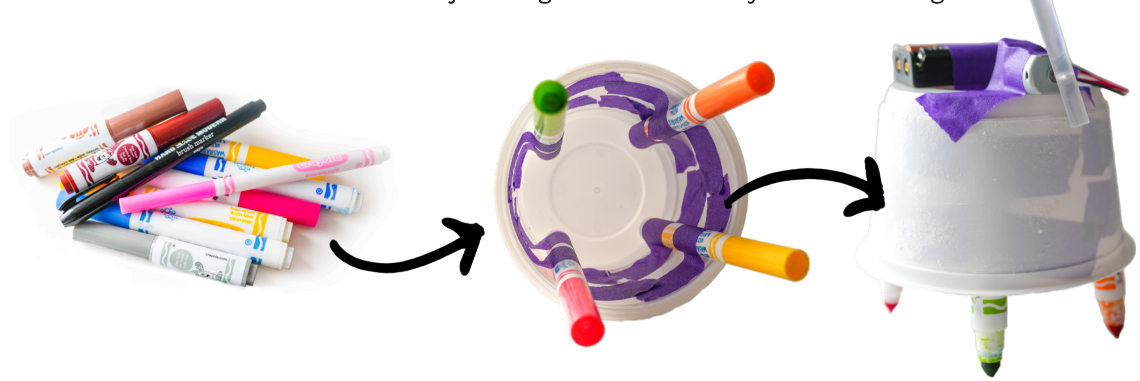


2. "Experiment with ways to offset the motor"



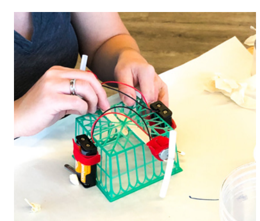
3. "Find or build a base and attach your offset motor to it"

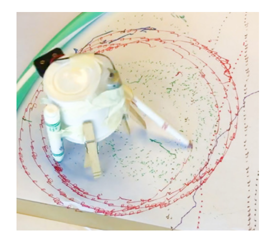
4. "Attach one or markers to trace the jittering movement of your scribbling machine"



5. "Turn it on and make some scribbles"

6. "Experiment with different designs"





Examples of scribbling machines created by makerspace visitors and educators.

Workshop Description

This pictorial describes how the scribbling machines activity was adapted, and then offered as a workshop experience to makerspace visitors. The workshop, titled "Art Bots" was a free, public workshop attended by local youth ages 10-16. The goals of the workshop represented a combination of Carly's goals for makerspace visitors and the research project team's goals for designing computational tinkering activities. Those goals included: supporting participants in exploring new skills, tools, and materials within the makerspace, providing participants with a positive, agency-building experience, and engaging participants in playful and creative experiences with computing.

The workshop began with a spirograph activity where participants created their own spirographs from a combination of 3D printed and cardboard materials and tested the spirographs, creating interesting patterns on large pieces of paper (Figures 1 and 2). Next, participants built scribbling machines and observed the unique marks that the machines created (Figures 3 and 4). Finally, participants incorporated computational materials like motors and sensors into their scribbling machines to introduce more complexity and interactivity (Figures 5 and 6).

We provide these images as context for the reader. Additionally, these images serve as a reminder that what is pictured here (the workshop) is often all that outside observers such as workshop participants or colleagues see. They do not see the process of iteration, testing, troubleshooting, and creation that educators and designers engage in to make these learning experiences possible.

Figure 1: Testing spirographs

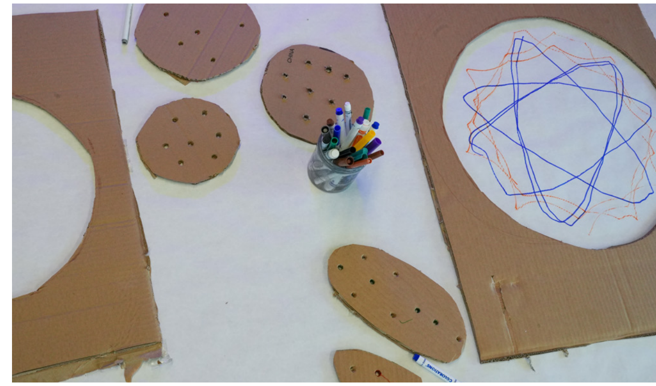


Figure 2: Creating cardboard spirographs

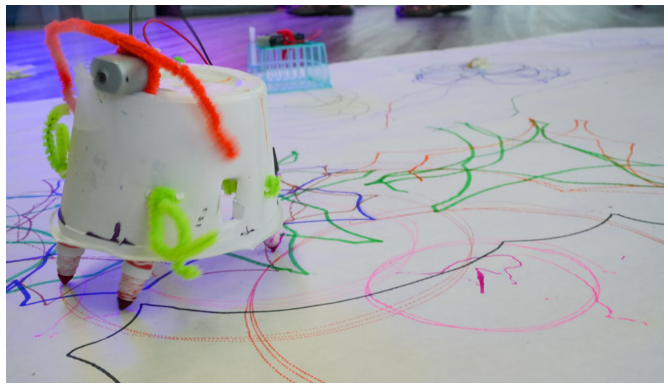


Figure 3: Observing a scribbling machine in action

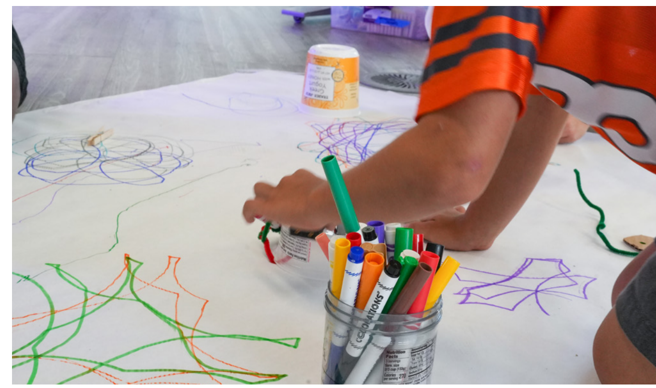


Figure 4: A participant tests their scribbling machine

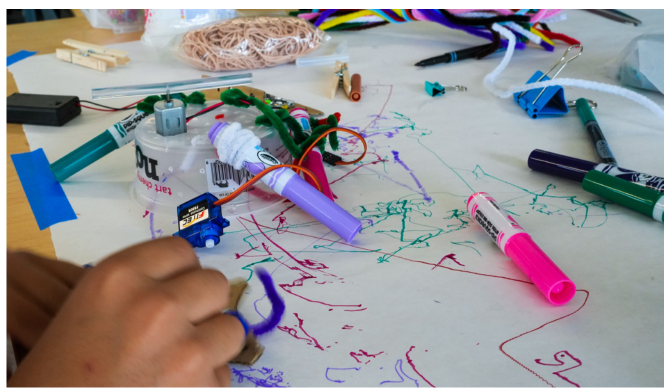
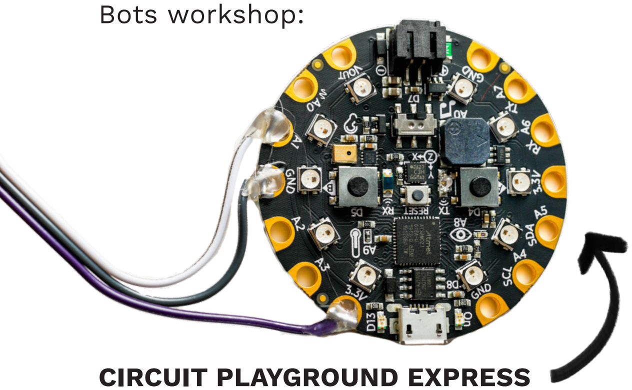


Figure 5: A participant adds programmable motors to their scribbling machine

Figure 6: Computational scribbling machine materials

Incorporating Computational Materials

A large part of our design process revolved around exploring how we might support participants in incorporating computational materials into their scribbling machines. By incorporating these materials, we aimed to extend the original goals of the scribbling machines activity by providing more variables and materials to tinker with, resulting in new types of motion and scribbles that were not previously possible. These are the tools that we provided to participants during the Art Bots workshop:



CIRCUIT PLAYGROUND EXPRESS

The Circuit Playground Express (CPX) is a microcontroller designed by the company Adafruit to introduce programming and electronics [1]. It includes several inputs such as light, sound, and motion sensors and outputs like LED lights, a buzzer, and pins that can connect to additional electronic components. In many makerspaces, educators must attend to budget constraints and often make do with existing materials, or reuse materials if possible. We selected the CPX in large part because the library makerspace already had a set of the boards available.

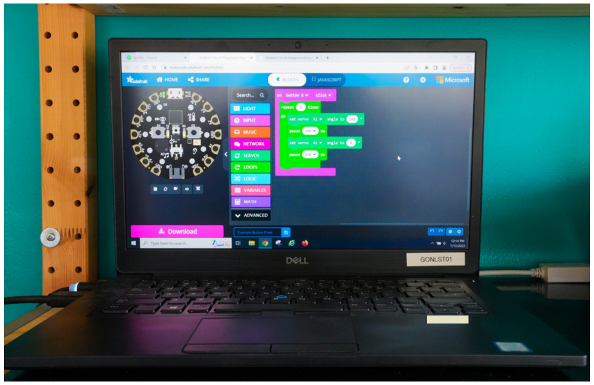
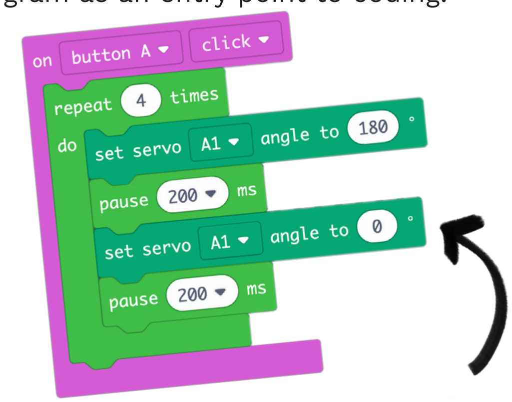


Figure 7: An example MakeCode program is displayed on a makerspace laptop

MAKECODE

We chose to use MakeCode [2] , a block-based programming website to code the CPX (Figure 7). Adafruit recommends this platform for beginners, and we wanted to design with beginners in mind as we anticipated that many workshop participants might be unfamiliar with or new to coding. Additionally, MakeCode makes it easy to create and share example code and starter programs. We shared these programs with participants and invited them to tinker with and change pieces of the program as an entry point to coding.



An example of a "starter program" shared with participants.

SERVO MOTORS

We incorporated positional and continuous servo motors into the activity and workshop design. These motors pair well with the CPX. They are relatively easy to connect to the board and to program. The servo motors can be attached to markers to create interesting scribbles and can attach to other materials to move the scribbling machine in a different way than the offset motor can move. Additionally, because the servo motors are programmable, learners can use code to control the amount, speed, or duration of the motors' movement and they can use sensor input from the CPX to make new interactions possible, e.g., a hand clap or flashlight can trigger the motor to move.

Tuning Materials in Context, with Community Members

Prior to planning the workshop, we shared the scribbling machines activity in the makerspace with community members (makerspace visitors) several times during "open lab" hours, where the makerspace is open to the public. These sessions provided valuable feedback as we tuned the activity setup and materials such as visitors' interest levels (did they stay and tinker with the machines for an extended period of time? Was there enough interest to offer a workshop?), how they used materials (did they encounter any difficulties while creating their machines? Might we need to adjust the materials we offer?), and what facilitation moves worked best to support visitors' learning. Tuning materials in context took several forms:

"Stress testing" the activity with visitors. Figure 10 shows the activity being tested with several makerspace visitors during open lab hours. Testing with learners generates valuable information about how participants navigate the affordances and challenges of materials.

Facilitators engaging in the activity as learners. Figure 8 shows researchers and educators building their own scribbling machines to familiarize themselves with the activity from a learner's perspective. Experiencing the activity in this way helped facilitate an understanding of how to support learners and allowed new ideas to emerge.

Tinkering with different arrangements of physical space and materials. Figure 9 illustrates how we experimented with dividing an activity table into a "making" side and an "observing" side and with letting people cut out and take home their scribbles. These ideas were not incorporated into the workshop due to lack of interest from participants during testing.

Figure 8: Researchers and educators build scribbling machines

Figure 9: Testing the arrangement of scribbling machine materials

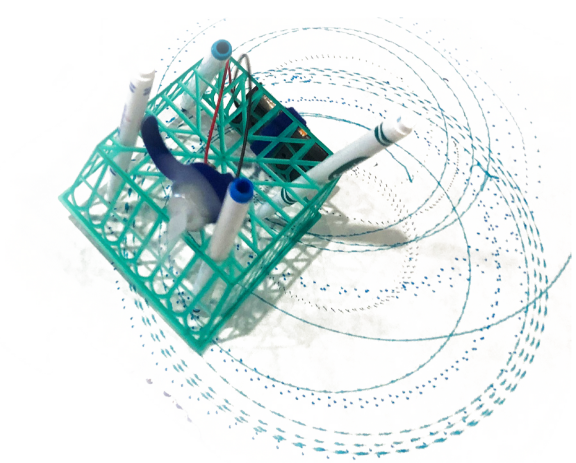
Figure 10: Makerspace visitors build and test scribbling machines

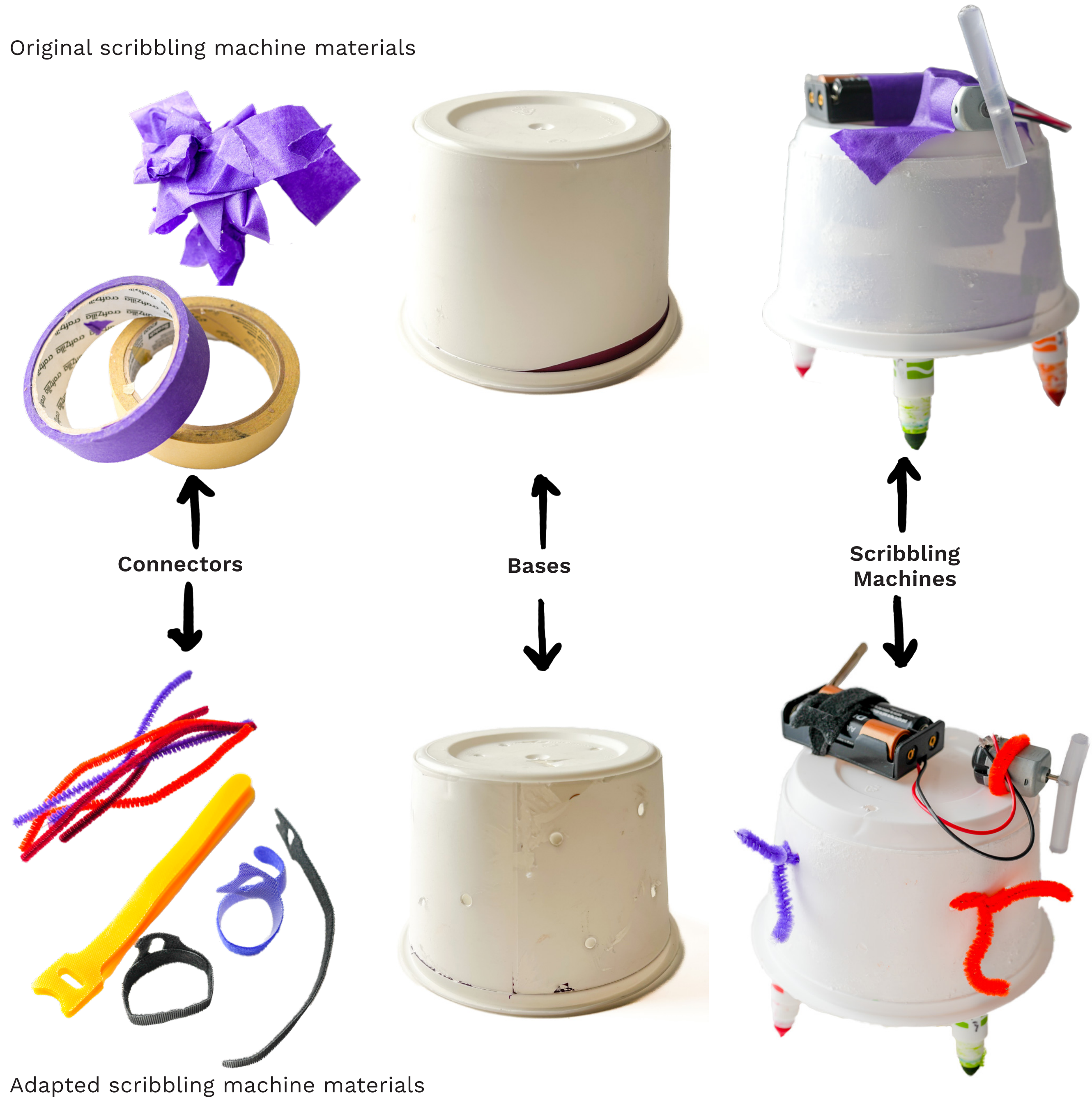
Tuning Materials to Support Educator and Community Values

While the scribbling machines activity already places emphasis on upcycling materials such as recycled containers, Carly noticed an opportunity to tune the materials even more towards reusability and sustainability. This move reflected her personal interests in sustainability as well as the makerspace community's focus on upcycling materials.

Carly noticed that a good amount of masking tape was used and then thrown away during this activity and challenged us to tune the scribbling machine material set away from single-use connector materials like masking tape and towards reusable connector materials like pipe cleaners and velcro loops.

Tuning the materials away from tape and towards reusable materials required tuning the scribbling machine bodies as well. Holes were punched into the scribbling machine bases to create places where pipe cleaners and velcro loops could be attached and secured and we also offered scribbling machine bases that already had slots such as berry containers. Ultimately, learners were still successful in creating scribbling machines using materials that were tuned towards sustainability and reusability.

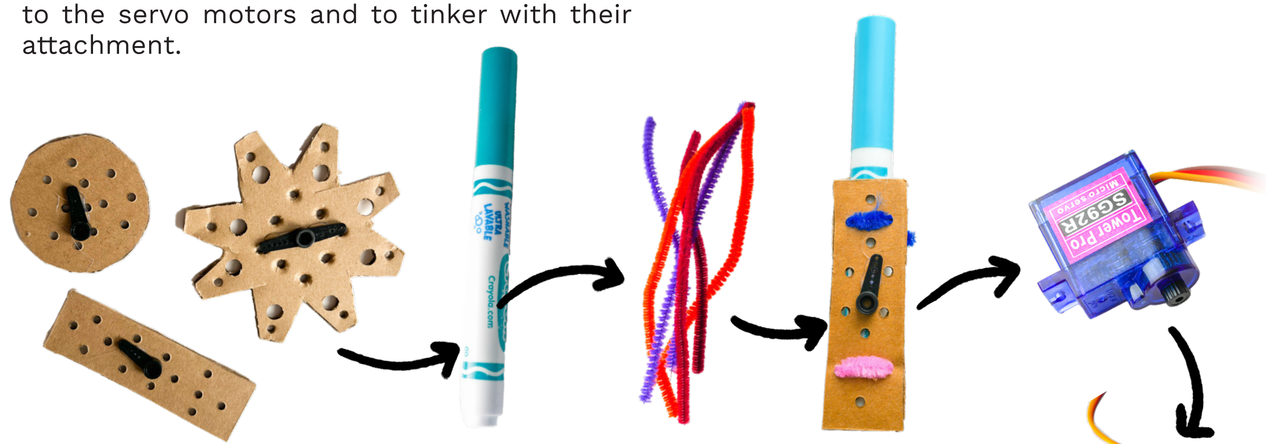




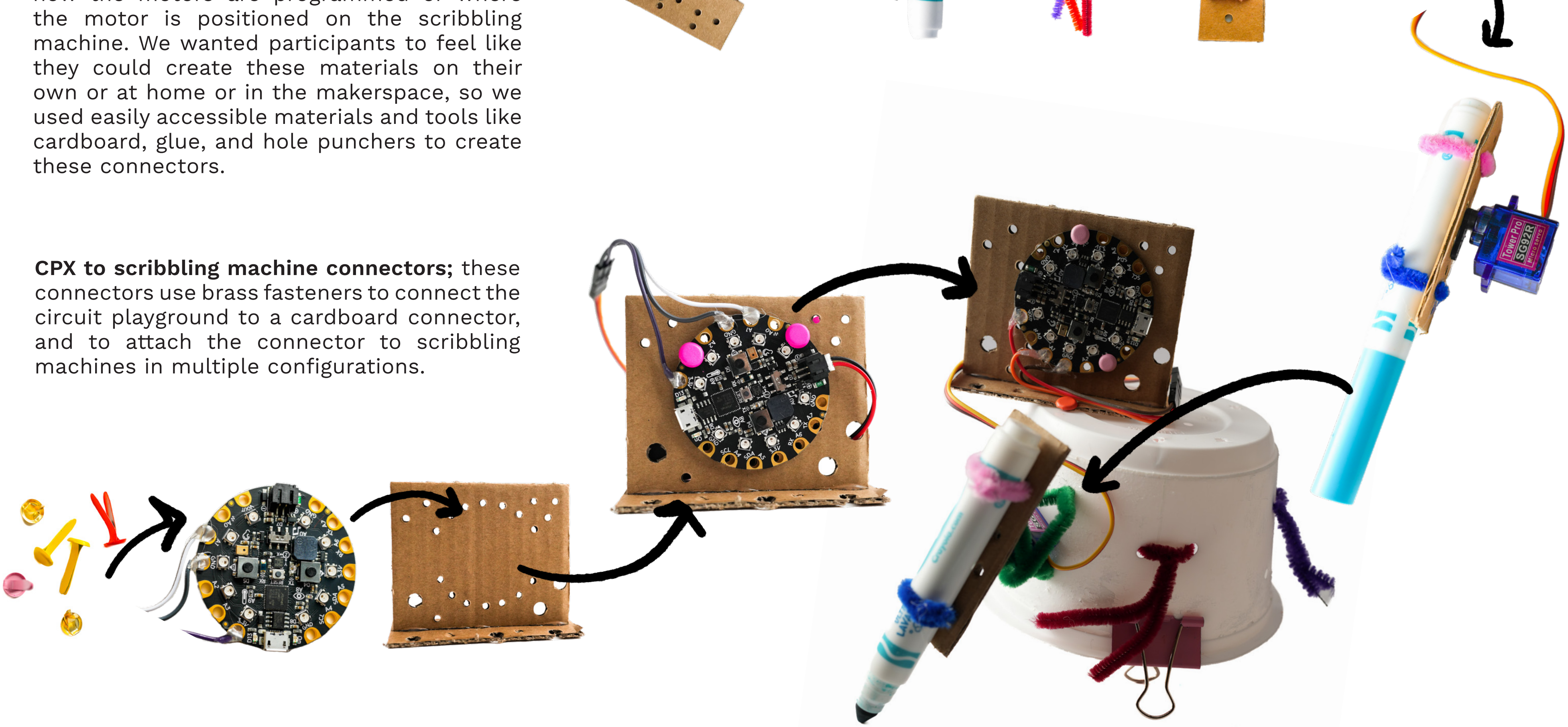
Tuning Materials to Extend Possibilities

Tuning materials can also look like building new materials and tools to support learners' explorations. We created a set of connectors for the CPX and servo motors that interfaced well with the existing scribbling machine materials. Our intention in creating these materials was to offer a starting point for learners that reduced the initial challenge of connecting computational materials to the scribbling machine and allowed learners to focus on tinkering with other variables like how the motors are programmed or where the motor is positioned on the scribbling machine. We wanted participants to feel like they could create these materials on their own or at home or in the makerspace, so we used easily accessible materials and tools like cardboard, glue, and hole punchers to create these connectors.

Motor to marker connectors; these connectors allow learners to connect one or more markers to the servo motors and to tinker with their attachment.



CPX to scribbling machine connectors; these connectors use brass fasteners to connect the circuit playground to a cardboard connector, and to attach the connector to scribbling machines in multiple configurations.



Tuning Materials to Avoid Uninteresting Technical Challenges

"Uninteresting technical challenges" are technical issues that have the potential to create frustration for learners or educators and do not align with the goals of the learning experience. For example, troubleshooting internet access on a laptop a learner is using to code a scribbling machine is likely to be an uninteresting technical challenge because it creates a frustrating barrier to the goal of tinkering with code. Uninteresting technical challenges can become barriers to implementing computational activities in makerspaces [11]. However, that is not to say that these challenges are never interesting or meaningful, but they must be the right challenges for the individual and the context–a concept Seymour Papert described as "hard fun" [12]. We tuned the computational materials in a few ways to tune the materials towards "hard fun" and away from uninteresting technical challenges.

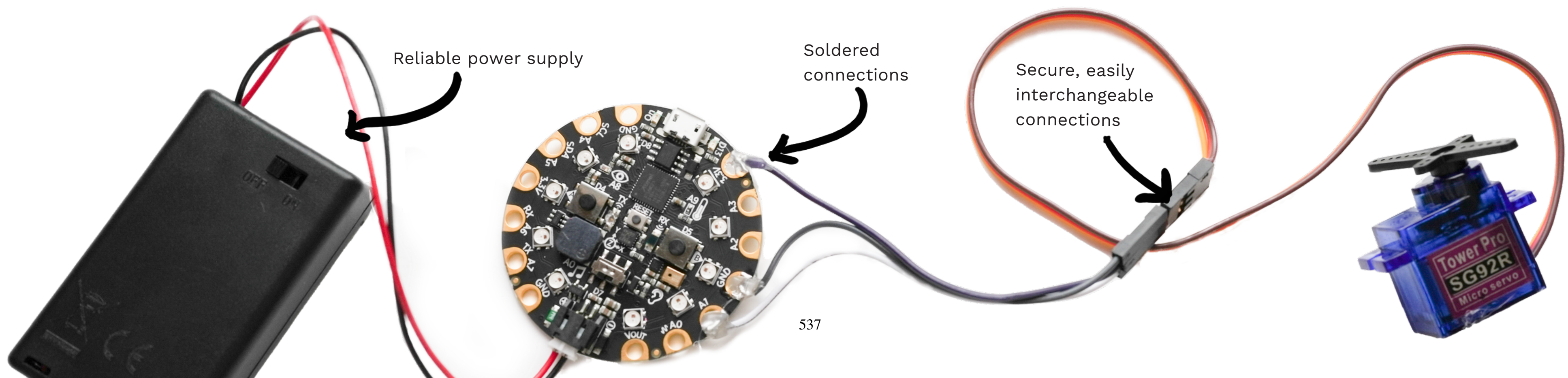
We experimented with battery packs, number of batteries, and use of pins on the CPX to provide the board with enough power to reliably move the motor, without causing the board to overheat. Overheating is an issue we

Figure 11: A researcher tests electronic components before the workshop to ensure everything is working properly

encountered during prototyping and didn't want learners to experience because of the possibility of burns and damage to the board.

We soldered connections to the CPX before the workshop to make it easier for learners and educators to troubleshoot motors and switch between the two motor types we used in the activity. Additionally, using connectors instead of soldering the motors directly to the board preserved some of the flexibility of the CPX, making it easier to use the CPX for different activities beyond scribbling machines. While there is value in learning how to solder and to connect circuits, these skills were beyond the goals of our workshop.

Finally, before the workshop, we tested and connected all the computational elements (the CPX, battery pack, and servo motor). While some of these steps may seem obvious from an outside perspective, we highlight them here to emphasize the importance of the small often overlooked steps that designers and educators take to create a positive experience for learners.



Tuning the Arrangement of Space and Materials

The environment that makerspace visitors walk into is an intentionally designed space. The arrangement of elements like materials, example projects, and workstations are carefully attended to by educators and can be tuned to support different types of learning experiences. For this workshop, Carly took care to tune the environment in a few different ways.

We provided different levels to work at (Figure 13 and 14). Some tables were set at a standing height, and there was a workspace prepared on the floor as well. This allowed participants to choose a workspace where they felt physically comfortable. Additionally, the shared tables and materials facilitate collaboration and cross-pollination of ideas between participants.

Figure 11: Scribbling machine workshop materials

Each table was stocked with its own set of curated materials (Figure 11) so that participants could concentrate on engaging with the workshop activities rather than trying to locate the items they needed.

Figure 12: Example scribbling machines

Scribbling machine examples were displayed on a table (Figure 12) and were used as demonstrations during the workshop to spark participants' interest, to give them an idea of how a scribbling machine works, and to model the idea that there is not one "correct" way to create a scribbling machine.

Figure 13: Carly prepares the floor workspace

Figure 14: The makerspace is arranged to support a variety of workspace configurations

CONCLUSION

In this pictorial, we highlighted five key moments that illustrated some of the tuning work we engaged in as learning experience designers. We used the metaphor of tuning to describe the infrastructuring practices we engaged in as we adjusted our materials, space, and facilitation practices to make a new learning experience possible. We documented our practice of testing the activity and materials in the makerspace with visitors and educators and described how this practice allowed us to tune the activity based on our observations of learners' interactions with the materials. We demonstrated how we adapted existing materials and created new materials to better align with the values of educators and makerspace visitors, and to support the integration of computational materials. We highlighted our process of technical troubleshooting as we attempted to provide learners with electronic tools that were safe, reliable, and facilitated playful experimentation. Finally, we showed how we adjusted the physical environment of the makerspace to support learners and encourage collaboration as they engaged with the activity.

As the HCI community, interaction designers, researchers, and educators more broadly imagine new tools, technologies, curricula, and design principles [9] for creative learning experiences, they can learn from educators' work to adapt these tools and technologies to fit their contexts. The work of adapting designs to fit a local context can be a major challenge that is often overlooked. In this pictorial, we document and share the moment to moment design decisions that educators and designers make as they adapted pre existing materials and activity structures. Building on the argument Sturdee et al., make–that visual storytelling can make visible those elements of collaborative research that might otherwise go unnoticed or unseen [13]–we argue that pictorials are a particularly promising format for visualizing educators' infrastructuring and design practices.

A note on privacy: all individuals visible in the images included in this pictorial have consented to their images being shared in this context.

ACKNOWLEDGEMENTS

We would like to acknowledge our collaborators and partners for making this work possible– with special thanks to Carly Tam for sharing her knowledge, space, and time with us. *A note on privacy: Carly has consented to sharing her name in this context.*

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