

Towards a Design Space of Short-Session Making Workshops for Middle School-aged Students

ISAM
2018
Paper
No.:
08

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INTRODUCTION

The College of Computing and Informatics (CCI) at the University of North Carolina at Charlotte (UNCC) opened a Makerspace in Fall 2016 for general use by all students, faculty, and staff. An important part of the CCI Makerspace mission has been outreach and we have developed a mobile Makerspace with a subset of materials and equipment that we use to conduct workshops outside the space. Based on our experiences, there are important open challenges in developing and delivering workshop content to engage participants effectively and at the right level for impact.

Previous work on workshops has reported on a variety of examples that vary in topic focus, delivery, and duration, from a training-focused series [9] to week-long courses to build community [8] to single-day sessions to ensure diverse interest [13], and other examples of empowerment [6], [12], [5]. We add to this growing body of work, focusing on short single-visit workshop sessions (2-hour) run either in our space or remotely aimed to introduce and empower.

Our primary goal in these workshops is to spread access to digital fabrication by exposing and empowering students. Makerspaces are vast with potential; you can do just about anything in them and connect to just about anything. As Fleming notes, “a visit to a Makerspace should leave you with the impression that the possibilities are endless” [7]. Ultimately the goal of short-session exposures is that students get some level of that sense of endless possibilities.

However, there are a lot of different types of activities we could run to try to capture this. Do we start with the technology then transition to the applications? Or start with a skill? Should we ground it in real-world situations or let students use their imagination? What parts should we scaffold versus let students figure things out on their own? Of course there is no one size fits all solution. But the more activities we run, the more we realize there are these key differences in the design of the activities that affect the experience of the students.

In this paper, we describe a series of making activities we ran in various contexts. We describe the goals of each activity and reflections on how it went. We use our reflections from the design and implementation to start to develop a set of dimensions along which to talk about important similarities and differences between workshops. While these activities and the dimensions are not comprehensive, they enable us to discuss some of the challenges and tradeoffs at different points along those dimensions. Though our workshops

have centered around middle-school students, we believe our findings illustrate themes that are relevant to the design of activities for any age group and are especially relevant to university Makerspaces like ours who are requested to conduct workshops for entry-level engagement.

ACTIVITY DESIGN

All activities were designed to expose and empower students to use digital fabrication and making tools. We wanted to give them a sense of what is possible and for them to realize that they could pursue it if they would like. In selecting activities, we chose to not focus solely on skills, as we believed that mindset is as important as skills. We also limited issues of safety and machine training by designing activities such that facilitators would always be the ones operating the machines. Our activity design philosophy is based largely on Project Zero’s definition of Maker empowerment as including a sensitivity, inclination, and capacity for making [1]. This means that an empowered maker (1) believes they possess the capacity to make, (2) they see the opportunity in the world around them to make, and (3) they have the motivation to actually go make something. These 3 values are more about mindset, which is what our activities focus on. In the following sections, we discuss four illustrative activities along with more specific goals related to each one. These activities are not intended as a comprehensive way to address our goals, but rather a representative way to discuss how these kinds of activities can do so. Table 1 summarizes the activities run and in what contexts.

Table 1 Summary of Activity Contexts

Activity	Level	Site	# Students	Time
Crazy Puppets	Middle School	CCI Makerspace / STEM Summer Camp	10	2 Hours
Starry Night	5 th Grade	Mobile Makerspace Remote @ School	25	2 Hours
Design Process	5 th Grade	Mobile Makerspace Remote @ School	25	2 Hours
Statement Pieces	5 th Grade	Mobile Makerspace Remote @ School	25	2 Hours

All activities include some aspect of 3D printing. While it was certainly a challenge to incorporate 3D printing in such short sessions, we felt it was important as 3D printing is still such a novel and exciting technology for those who have not

yet encountered it, that we felt it would have high impact as a tool of empowerment.

Data was collected informally by the facilitators in the form of observational notes from their personal experience. The focus of the observations were informed by the Tinkering Studio's Learning Dimensions Framework [4], which is a series of categories to help determine whether children are "on a pathway to learning" in an open-ended setting. We thus made observations on things such as the nature of students' engagement, collaborations, and verbalizations during the activity.

ACTIVITIES

A. CRAZY PUPPETS

This activity was designed for a group of 10 middle school students for two hours in our Makerspace as part of a summer STEM program.

Activity outline—The activity was centered around each student creating and customizing a puppet that lights up when its mouth is closed (Figure 1). We first walked the whole

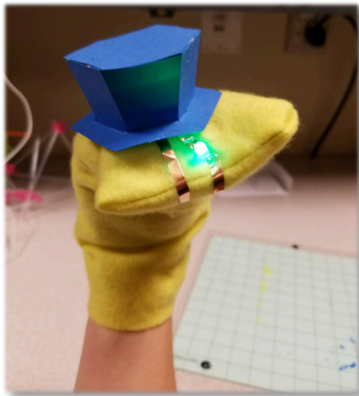


Fig. 1 Crazy Puppet

group step by step how to add the light to a pre-made puppet sleeve. We started with an introduction to electronics and circuits, letting them explore their LED and battery. Assembly involved attaching copper tape in certain areas, taping a battery, poking the LED through holes in the copper tape, and making sure everything aligned properly. We then broke students into groups and rotated them through the other technologies as stations. At the laser, they made facial features (moustaches, eyebrows) or accessories they requested. At the sewing machine, they could choose from strips of fabric, sew a decorative stitch using a computerized sewing machine, and fashion the strip into a scarf or hat. At the Cameo cutter, they made hats out of flat sheets of paper that they folded and taped. At the 3D printers, they could 3D model (they were given a 3D modeling tutorial using Tinkercad) or 3D print glasses or an accessory. They used hot glue to attach everything to the puppet.

Goals—The goals for the activity were to

- Expose students to a variety of machines (3D modeling and printing, laser cutting, integrating electronics, sewing, CNC paper cutting)
- Combine machines to make one object

- Allow students to use machines creatively while still providing constraints
- Have students walk away with an artifact that actually looks like something and they feel is their own

Reflections—The electronics portion was tricky as many of the steps require exact alignment and fine motor skills. However, students were engaged with the task and persisted to figure it out. Many of them adopted problem-solving strategies to isolate the problem.

The small groups in stations allowed the students to get close to the technology and engage in conversation with the facilitators. It also made room for more chances for spontaneous modifications or ideas. For example, some students requested that they laser cut a certain accessory.

The students were very excited about the puppets. They were showing them to each other and the facilitators, giving them names and personalities. Each of their puppets looked very different as they all had different ideas for how to customize it.

B. STARRY NIGHT

This activity and the next two were done in a series with the same group of students: 2 groups of 25 5th graders each in a 2-hour session each time. The visits were spread out over the course of a month, though these activities could have also been stand-alone workshops.

Activity outline—We ran this activity in 3 stations (3D modeling/printing, sewing/electronics, and Cameo cutting). We had previously sketched an outline of Van Gogh's *Starry Night* on a board (Fig 2). The activity centered on fabricating individual components and gluing them to the board for a collaborative piece. We first introduced the idea to the class and then split them into rotating groups. At each of the stations, the facilitator combined an introduction to the technology and how it worked with step-by-step instructions on how to make the components with that machine and how they would be part of the final piece. There was a little room for creativity and customization in the 3D printing and sewing stations.



Fig. 2 Partially completed *Starry Night*

At the Cameo station, students made stencils that they used to paint strokes in the sky. The facilitator had one computer and one machine, but would let students take turns modifying the pre-made file and sending it to the machine to cut,

talking them through each step. They also made tetrahedrons that would make up the mountain. These started out as flat sheets that they folded. These two components gave them a sense of the possibilities of the Cameo in 2D and 3D making.

At the sewing station, students made stars for the sky. They started with strips of fabric that they used a chosen stitch from a computerized sewing machine to decorate. They then used loose hand stitching along one side of the strip to scrunch up the strip into a star and cut slits in the outer edge. Students who finished this first part were given an LED and a battery along with a short verbal tutorial on how a circuit works. They were then encouraged to figure out how to attach the LED to the star they had made.

At the 3D modeling station, each student had a computer with Tinkercad open. They were given a verbal tutorial on how to control Tinkercad and an introduction to how 3D printing works. They were then told to make a house for the painting. The facilitator guided them through downloading, slicing, and transferring the file to the printer individually as they finished their designs.

Goals—

- Expose to a variety of machines and techniques: hand and machine sewing, CNC paper cutting (2D and 3D), 3D modeling and printing pipeline, basic electronics
- Combine unfamiliar digital processes with more familiar hand-processes like hand sewing, painting, folding, and gluing.
- Allow students to focus more on technique via focusing on one small component at a time while allowing a larger collaborative finished product to emerge as a result.

*Reflections—*At each of the stations, students were more interested in what they were working on than what their friends were making. We expected them to be more interested in what techniques the others were using (for example, what other sewing machine stitches looked like) or what others' pieces came out looking like. Students were also not very interested in looking at the compiled piece. Again, the focus was on their own contribution. They asked us many times if they could take their individual pieces home.

The students were most focused at the sewing station and had the least amount of focus at the Cameo station. This was perhaps because the sewing required the highest level of fine motor skills and the Cameo station only had something for one person to be doing at a time.

With automatic processes, students watched for a little but quickly lost interest. Even with the sewing machine, they would have their foot on the pedal but weren't really interested in what it was doing.

With manual processes, there was a wide range of skills and abilities. Some students struggled for a long time to thread the needle. There is a benefit to letting them work at it until they figure out how to do it as this can be an empowering moment, but for some students it was necessary for the facilitator to step in before they got too frustrated and help the

activity move along.

C. DESIGN PROCESS

This was the second activity we ran visiting the same 2 groups of 25 5th graders for 2 hours.

Activity outline— There were two parts to this activity, both centered on the idea of using 3D printing to solve real world problems. The first part started with an introduction to 3D printed prosthetics using videos and props to demonstrate how the mechanism worked to support people with limb differences (Fig 3). We then broadened the conversation to talk about exoskeletons and brainstormed other ways we could design devices that would extend the capabilities of our bodies. Groups of 4 or 5 students then made sketches and worked with cardboard, tape, string, and other familiar materials to build a prototype of their idea.



Fig. 3 Facilitators demonstrate exoskeleton mechanism possibility

The second part of this activity was focused on 3D modeling. We started with a group brainstorm about problems we have in the world around us and some possible solutions we could design to fix those problems. Students then worked in pairs to continue to brainstorm and 3D model and print their ideas using Tinkercad. As this was the second time these students were exposed to Tinkercad, we gave another introduction to how the controls work, but they were able to build on skills they had started to develop last time.

At the end of both activities, we talked about what aspects of the process were the same or different and what the benefits of prototyping with cardboard compared to 3D modeling.

Goals—

- Expose to real world applications of 3D printing
- Have students think about new ideas for where they could apply 3D printing in their own lives
- Expose students to the brainstorming + prototyping process in two contexts

*Reflections—*While students had creative ideas at the beginning of the exoskeleton session (i.e. a sticky tongue-like device to grab things, a bird-beak for getting things off a high shelf), by the end of the session they had all made devices that were essentially cardboard cutouts of regular human

hands.

When asked how their device would grab things, one group pointed to the binder clips they had attached to each finger, but they had not thought about how they would open and close the binder clips. It's true that binder clips can grab things, but the way they were using them in their prototype they couldn't actually perform that function, they could only represent it.

For the second part of the task with the 3D modeling, many groups of students wanted to make a fidget spinner. We redirected them to think of problems and solutions instead of fixating on an existing object. One group reframed the fidget spinner so it could cut grass as it moved.

Other groups made abstract representations of possible solutions to problems. One group made a robot to help clean their room. Another made microbots that would help you do literally anything. While these might be creative solutions, they have nothing to do with 3D printing. While the 3D models the students made gave them experience with 3D design, they were essentially using the 3D software as a sketching tool rather than a step in the prototyping process. Nevertheless, they were engaged and excited to have their pieces printed.

D. STATEMENT PIECES

This was the third and final activity we ran with the group of 5th graders. It revolved around creating felt and 3D printed statement piece necklaces.

Activity outline—We started out talking about things machines are good at compared to things humans are good at. We came to the conclusion as a class that machines are good at being precise and humans are good at being creative. We framed the activity as combining things people are good at with things machines are good at.

We had a series of pre-cut felt pieces from the laser that could either be fit together interlocking or could be glued in stacks or spirals. We first taught the students a few techniques of how they could manipulate the pieces and then let them loose to do whatever they wanted.

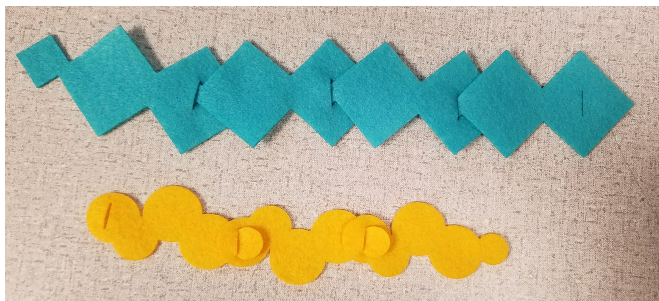


Fig. 4 Examples of interlocking felt pieces

We also took half the class at a time into the other room to do the 3D modeling portion. We told them to make a bead or a charm and also figure out how they were going to attach it to their statement piece.

Goals—

- For each student to have something they could take home with them as this was something they kept asking

- For students to spend most of the time being creative
- For there to be room for dialogue with the materials and reflection in action [15]
- For them to feel like they were making something, not the machine making something

Reflections—This activity was by far the most engaging for these students as they were completely focused on what they were doing. We saw evidence of students experimenting with the material, making plans, executing, and updating the plan when things did not go as expected. Some students collaborated with others and showed interest in what other students were doing, but for the most part they were focused on their individual task.

For 3D modeling, the most popular options were to write their name or initial. With the help of the facilitator, they all managed to have a hole in the object somewhere for stringing.

It was helpful to have already done a sewing activity in a previous week as students could build on that skill. They approached both the hands-on component and the 3D modeling with confidence.

DISCUSSION

In reflecting on the design and outcomes of our activities, we consider the running of activities as a design practice. Each activity has aspects to it that were designed based on decisions of the facilitators and certain criteria. A common act in design and research through design is to use a set of dimensions or a design space to consider the differences between designs and inform the design of new interventions [2], [19], [11]. We extract dimensions along which our activities are different, why we believe considering the differences along these dimensions is important, and challenges or tensions we uncovered along these dimensions (Figure 5). This set of dimensions is by no means complete. As we and others run more activities, we expect this list to grow as more key differences in designs become apparent.

A. CONTEXT AND FRAMING

In each of the activities, we framed making in a different light. This ranged from solving problems (Design Process) to self-expression (Statement Pieces) to the power of people / machines to come together (Crazy Puppets, Starry Night, Statement Pieces). Some of these frames dictate the way in which students view the purpose of making whereas others leave room for them to discover the purpose for themselves. This is critical to consider as one of the core maker capacities is about seeing opportunities in the world to apply one's own skills for making and considering this dimension could help increase the likelihood for a student to develop that sensitivity [1]. We wanted students to have an authentic making experience, but we found a tradeoff in types of authenticity. With the problem-solving workshops, we provided authenticity in the form of connection to real world applications. However, the making students engaged with in these workshops was representative of possible solutions (such as a 3D model of a robot) and thus did not get as real a sense of what is possible with the technology. Another au-

thentic experience is about exploration of materials, techniques, and self-expression. While students were much more likely to have this experience in the Statement Piece and Crazy Puppets workshop, it perhaps seemed more contrived to them as it was further removed from real life applications.

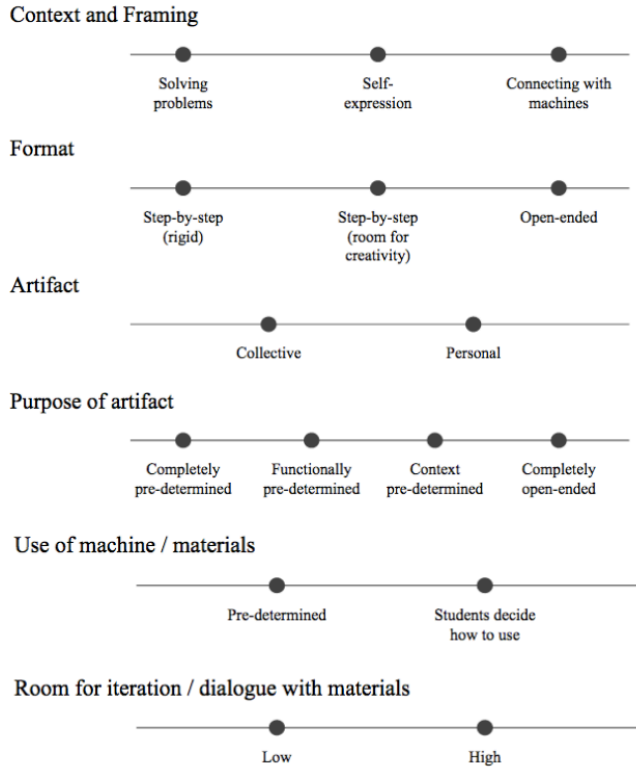


Fig. 5 Some dimensions to consider when designing short-session making workshops

B. FORMAT

Our workshops ranged in format from step-by-step (Starry Night and Crazy Puppets) to open-ended (Design Process and Statement Pieces). Within the step-by-step activities, there was varying room for creativity with the Starry Night activity being more constrained than the Crazy Puppets. Within the open-ended activities, there were different ways in which the activity was open-ended. The Design Process activity was guided by a design challenge, so the students were forced to have an idea-driven experience, whereas the Statement Piece activity had looser requirements. We provided a context, but the students had room for more exploration of the materials and didn't have to align their making with a specific goal all along.

This is also an important dimension to consider in terms of the core aspects of maker mindset, largely the capacity for making, which is not so much about having certain skills, but about believing that one can obtain the needed skills [1]. If students have too much scaffolding, they may have low confidence and depend on that scaffolding. However, without enough scaffolding, they can easily get frustrated before the activity is over. Vygotsky talks about the Zone of Proximal development as being the leap between what a learner

does and doesn't know and the size of that leap relative to their learning experience [18]. The appropriate size of that leap for an individual is a complicated and open question, but considering the different ways a workshop is formatted can help determine whether a workshop is providing scaffolding to those who need it and pushing students who can take that leap.

C. ARTIFACT

All our workshops revolved around the creation of artifacts. We either created one collective artifact (Starry Night), several artifacts in groups (Design Process), or each student created their own (Crazy Puppets, Statement Pieces). While collaborating maximizes potential for certain types of learning and creating a collective artifact could likely produce something more impressive and exciting than each student making their own thing in a short session, students repeatedly asked if they could take their piece home. Even something not very interesting was much more exciting to them if it was their own.

There was also a range of purposes of the artifacts the activities revolved around. This ranged from a predetermined picture (Starry Night), to a predetermined functional requirement (Design Process), to having a context, but having an open-ended purpose other than that (Crazy Puppets, Statement Pieces).

This dimension relates to maker inclination [1]. With inclination, it is about whether the students have the motivation to actually make something that they see the opportunity for. We believe inclination has something to do with personal connection to the domain or the purpose. Helping people is something that resonates strongly with many makers and motivates them to take action [16], [14], [10]. However, something else that might motivate someone is feeling ownership over an idea or being able to incorporate their own personal interests. We also saw the challenge of design fixation. With the exoskeleton part of the Design Process activity, students fixated on a design that was very similar to the one we showed them. We also expect that it is easy to fixate on the purpose of an artifact during an activity as also being the purpose of a Makerspace, but certain activities might help people see beyond that.

D. MACHINES AND MATERIALS

We can also talk about the varying ways in which the machines and materials were used. This ranges from us dictating the way in which each machine should be applied (Crazy Puppets, Starry Night) to allowing students to decide for themselves how they want to apply the machine to what they are making (Design Process, Statement Pieces). In some of the activities there was room for dialogue with the materials, where students could try something and iterate on it to see how appropriate it was towards achieving their goals (Design Process, Statement Pieces). It is difficult to incorporate slower processes such as 3D printing in an iterative way, but we found it is crucial to do so because students do not understand what is possible to make with a 3D printer until they have a few rounds of designing and printing.

The difference between dictating how a machine should be applied or not is also important because, as Somanath dis-

cusses, this results in different degrees to which the materials embody learning [17]. For example, if students are told what role 3D printing has in the activity, they do not learn as much about 3D printing as when they get to decide “how can 3D printing be used in this context”. We see this as related to the aspect of maker mindset of sensitivity, as being able to apply different tools or materials to different contexts can widen the range of opportunities one might see.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grant No. (1723744) and by NCWIT.

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