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Artifacts as Pollen: What Makes a Makerspace Successful

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Abstract

As fab labs and makerspaces proliferate across the US and Europe, many are calling for them to be integrated into schools alongside classrooms. However, it is still largely unknown how these types of environments affect students. To better understand this issue, we set up a three-month workshop where students from a predominantly low-SES, Latino school came into a fab lab and worked on two large-scale projects. Using a mixed-methods approach, we found that students became more comfortable with technology, developed autonomy and confidence, learned to accept failure, and valued working with their peers. We also discovered that the influence of the fab lab reached into the community as well. The artifacts produced by students in the fab lab spread beyond the fab lab like pollen, helping to combat negative perceptions of science and math in the community.

Objectives or Purposes

The purpose of this paper is to examine the types of learning that occur when academically successful, low-SES hispanic and latino students spend extended periods of time working on projects in a digital fabrication workshop (fab lab).

Theoretical Framework

Fab labs and makerspaces are proliferating widely across the US and Europe, and non-profits that encourage the mixing of these types of environments with traditional schooling are also appearing rapidly (e.g., MakerEd, FabLearn, Fablab@School). It is still largely unknown how these types of environments affect students. Do students learn things in these spaces that they can not learn in traditional classrooms? Papert, following in the footsteps of Piaget, writes that the most powerful learning experiences happen when students build projects that are personally meaningful to them (Papert, 1980). Because these spaces dedicated to digital fabrication provide people with tools that make it easier than ever to create complex and sophisticated objects, it follows that these environments should be sites of powerful learning.

Fab labs and spaces like them are notable in that they bring together the high tech (laser cutters, 3d printers, microcontrollers, computers) with the low tech (hammers, saws, drills). This commingling of high and low tech is intentional, and is designed to create a space where people from communities that do not typically enter STEM fields can become comfortable and familiar with programming, design, and computation (Blikstein, 2008). This is not only an attempt to break down the division between high- and low-tech, but is an attempt to use the funds of knowledge of those communities to break down psychological barriers that keep people from entering STEM fields (Moll et al, 1992).

Participants

14 high school seniors (9 girls, 5 boys) from a charter school in the San Francisco Bay visited a digital fabrication laboratory on a university campus two times a week for 1 hour per visit. All of the students, with the exception of one, were hispanic and latino, and all were from low-SES families. These students had either applied to be part of the workshop or were selected by the teacher, and all were high-performing in their school. All of the students except one went on to attend four-year colleges.

The Workshop

The students visited the lab before school, coming in at 8 AM and staying until 9:15 twice a week. The workshop was the second part of a year-long physics course. The first half of the course was taught entirely by Mr. Teo, the high school science teacher, and was not part of this study. The workshop in the digital fabrication laboratory was led by Mr. Teo and two of the authors. Over the course of three months, the students worked on two projects that required them to design, test, and built using the tools found in the fab lab.

The Projects

The students worked on two long-term projects over the course of the workshop. The projects were structured so the students had to meet certain, specific goals but were allowed creative freedom otherwise. The first project, called the Omni-Animal, had students designing their own three-dimensional animal in a vector drawing software and cutting out pieces using the laser cutter from a two-dimensional piece of plywood. The students were given an initial template to work from and created a wide variety of designs.

The second project was the creation of a Rube Goldberg machine. The students were broken into groups of two with each group working on one part of the machine. Each group was required to use a GoGo board in their design to add motion, react to the environment, or create an effect. The GoGo board is an introductory microcontroller platform that is useful for teaching programming and basic electrical engineering (Sipitakiat et al., 2004).

Data Sources, Objects, or Materials

Post Interviews with Students

6 of the 14 students were selected to take part in 30-minute long interviews at the end of the workshop. These interviews were semi-structured and consisted of 14 questions broken into three sections. The first section asked about the students' impressions of the fab lab. The second section asked about how their family and friends perceived the work they were doing in the fab lab. The final section asked them to discuss memorable moments, likes, and dislikes. (See the Appendix for the full interview protocol.)

Artifacts and Programs

Throughout the workshop we photographed the artifacts that the students were making, saved the design files, as well as the programs that they were writing to control their GoGo boards.

Results

The open-coding process

The interviews were open-coded by one of the authors using the online qualitative analysis platform Dedoose. The process initially resulted in 55 different codes. These were eventually collapsed into two broad categories: success inside the fab lab and success beyond the fab lab (Table 1).

Category	Codes	Examples
Success Inside the Fab Lab	Changed perception of technology	"I like things that are simple and I feel like laptops can be complicated but then I learned how to program and I thought that was pretty cool so I actually like programming stuff now."
	Confidence	"Now I am [confident] because now I know how to work it basically. Before it was like I never tried it and stuff like that."
	Excited about digital fabrication	"I wanna… work with the 3D thing, 3D cutter, the 3D printer, see how that works, make myself one something, that'd be really cool."
	Feelings of accomplishment	"[I was excited about] actually getting to use the stuff and design things and put it together and make things that actually worked. The accomplishment of actually making something."
	Freedom to fail	"You're gonna mess up, you know you're gonna mess up, so you know that you're gonna learn about that mess up, so later on that's not gonna happen any more."
	OK to ask for help	"Here I get to work with the rest of my peers and asking for help is usually something that I find very challenging … here I feel more comfortable asking others for help if I don't really understand something."
	Learning to make things	"[My favorite part] was the whole process of making that thing, the whole process from beginning to end."
	Working as a group	"I will definitely remember… doing everything together as a group with my friends"
Success Beyond the Fab Lab	Peer validation	"I showed them to my friends and I was like "look what I made" and they were like "where'd you make that?... that's cool."
	Family validation	"[If I brought my dad to the fab lab] he would be like a kid with a new toy."
	Showing off things made	"[I showed] my little sister because I'm secretly trying to brainwash her to love science."
	Giving artifacts as gifts	"I showed it to my little brother and he was like "that's cool" and he took one."
	Excited to continue learning	"But I kinda want to learn to use [the computer] in more ways than to just watch a show or write an essay."

Table 1: Categories and codes from the interviews

Success Inside the Fab Lab

During the interviews with the students, a few strong themes emerged. The first major theme concerned the things that the students valued in the workshop. The six things that came up in multiple interviews were:

1. Becoming comfortable with technology
2. Learning to build real, physical objects
3. Developing autonomy and confidence in a safe environment
4. Failure as success, or learning to fail
5. Working together with their peers
6. Freedom to be creative

These features, taken together, are one description of what success inside a fab lab looks like. The first four themes all had to do with learning experiences and personal growth that occurred in the fab lab. Not only did the students learn and grow, but they valued the process of learning and growing.

The first change, “becoming comfortable with technology,” is the one we expected to see happen in a number of students. While most of the students started the workshop already comfortable and excited about technology, a few of the students were uncomfortable and afraid. One of the students, Yolanda, recoiled when she saw the laptops on her first day in the lab: “So I'm not really into technology so when I heard I was going to a lab I was like- ah great… I just saw a lot of like laptops and I was like ah- danmmit… When I saw the laptop I was like ahh technology.” Over the course of the workshop, Yolanda’s relationship with technology changed drastically. She went from an active dislike of computers to wanting to learn more about programming: “I like things that are simple and I feel like laptops can be complicated but then I learned how to program and I thought that was pretty cool, so I actually like programming stuff now… I want to learn how to do more things with the programming.”

One of the strongest themes to emerge from the coding process was that the students highly valued the opportunity to work together with their peers on a long-term project. This was often tied up with the students developing autonomy and learning to build real, physical objects, hinting that these three things may all hang together on a deeper level. When asked what she would remember most from the workshop, Amba said “I would think it would just be like just the memories of doing everything together as a group, with my friends….” Yolanda said that she valued “the feeling of freedom… you’re allowed to explore more, you’re able to put your ideas out there and just contribute… and come up with a project together as a team.”

Success beyond the Fab Lab

Another theme to emerge, and one that was unexpected, was that students took things they had created out of the fab lab to show them to their friends and family. The reactions of friends and family to the things the students had made were positive. Students who had failed to sign up for the class, or who had dropped out before the workshop, expressed dismay when seeing the things their peers were making. Amba tells the story of showing a friend the dinosaur she made (Figure 1): “I have a friend who dropped the class and she was like, ‘Dammit, I should have just stayed!...’ She thinks it’s pretty cool that we get to do this stuff.”

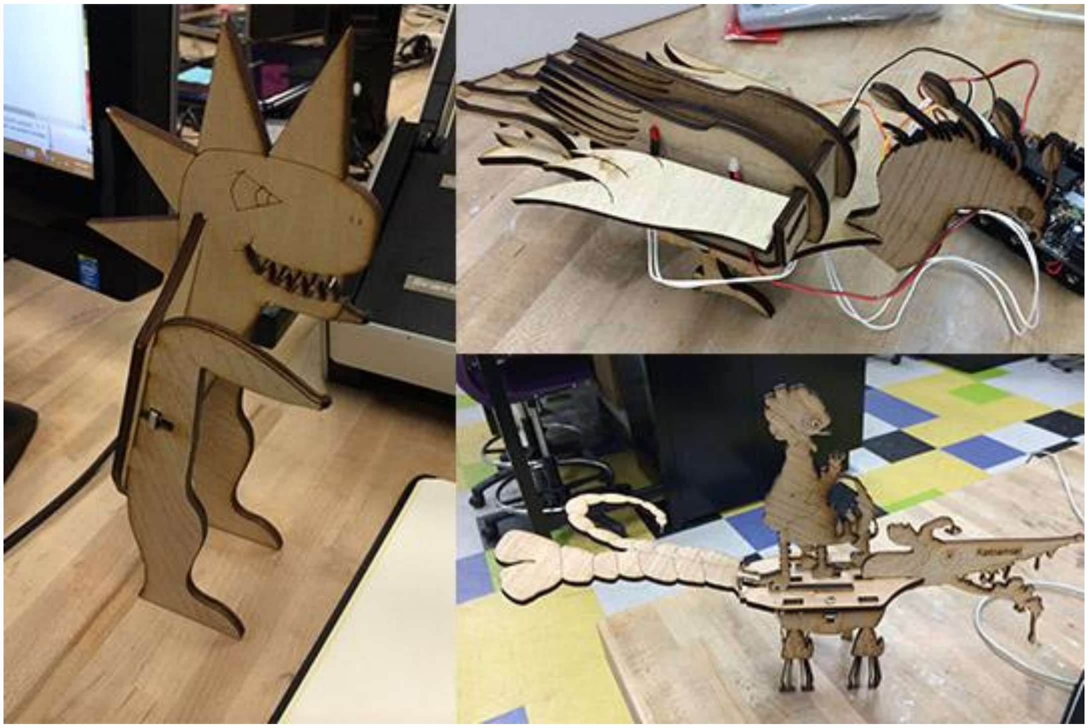

Figure 1: Examples of projects that students took home with them

These artifacts served as concrete evidence that the students could use to show their friends and family that the things they were doing in Physics class weren't scary and inaccessible, but interesting and fun. This is not merely our interpretation; this is how the students described using the things they'd made. Clara explained how she felt people in her community view science and mathematics: "I guess because it's very uncommon in my community to pursue a career in the sciences or in math of any sort... so math has always been challenging for some of my peers, or just people around my community…." She then goes on to explain how she uses the things she makes in the fab lab to protect her sister from her community's negative opinion of STEM: "[I showed] mostly my little sister because I'm secretly trying to brainwash her to love science… I guess because it's very uncommon in my community to pursue a career in the sciences or in math of any sort. so... I dunno, I just try to convince her that it's cool and it doesn't have to be something alien."

The artifacts produced by students in the fab lab spread beyond the fab lab like pollen, helping to combat negative perceptions of science and math in the community. This is a feature of the workshop that would not have arisen without the combination of the freedom to create personally meaningful projects with the ability of the laser cutter to rapidly produce multiple, physical copies. It is this combination that allows the positive effects of the workshop to escape the laboratory and spread out into the community.

Scientific or Scholarly Significance of the Study or Work

Prior work looking at digital fabrication in education has discussed the ways that working in the fab lab affects attitudes towards science and technology, raises confidence, and increases knowledge (Blikstein, 2013). Our study provides further evidence of these effects. What this study adds to this body of work is the discovery that artifacts which leave the fab lab in the hands of participants can be used to help change attitudes and perceptions towards science, math, and technology in the larger community. This provides evidence that the effects of the fab lab are not only felt at the local level, but they also spread out into the community as well.

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Appendix: Semi-Structured Interview Protocol

Impressions of the Fab Lab

- When you first came into the fab lab, what was your first impression?
    - Were there any tools that you were familiar with?
    - Were there any tools that you had never seen before?
    - Were there any tools that you got excited about?
    - Was anything intimidating?
- Now what do you think of the fab lab?
    - What are your 3 favorite tools, and why?
    - What is your most favorite tool, and why?
    - Are there still things that you are uncomfortable with?
- Are there any moments during your time here that stand out to you?

Perception: Family and Friends

- Have you told your family about any of the things that you've been working on?
    - If so, what did they think?
    - Did you tell your friends? What did they think?
- If you were to convince a friend to join the lab next year for this same program, what would you tell her/him?
- If you were to bring your mother and/or father (or guardians) into the fab lab, how do you think they would react? (NOTE: Find out what the home life is like and use that to inform the next few questions)
    - What kinds of things would your dad like? What would he make?
    - What about your mom? What would she make?
- What do your parent(s) do for work?
- Do they have any hobbies?

Memorable Moments, Likes and Dislikes

- When you think back on this in a year, what are going to be the things that stand out?
- Did your experience in the workshop change the way you think about yourself?
    - e.g., using technology
- If you had to convince someone to take this class next year, what would you tell them?
- If you could make any changes to the fab lab, what would they be?
- If you could make any changes to the workshop, what would they be?