Physical Computing, Prototyping, and Participatory Pedagogies

Make-a-thon as interdisciplinary catalyst for bottom-up social change

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This paper describes a recent make-a-thon event to engage architecture students with physical computing systems while working with engineering and entrepreneurship students. Focusing on the scale of the object or device, the pedagogical goals were to create a productive, transdisciplinary exchange--a pluralistic blend of design charrette, engineering hackathon, and entrepreneurial pitch competition. The Arduino platform and active learning methods were deployed in order to engage with a novice, diverse group of students, leading to outcomes that were responsive to the ever-shifting technological landscape and could be spun into future commercial ventures.

Keywords: *Physical Computing, Prototyping, Pedagogy*

INTRODUCTION

The traditional role of the architect as form-maker and representationalist is being increasingly challenged as systems grow in complexity amidst disrupting technologies foregrounded by environmental degradation and precipitating diverse social issues-the incoming 4th industrial revolution, notwithstanding. However, as architects' individual roles shift in relation to the built environment, pluralist methods of pedagogy can catalyze new models of architectural agency by exploring physical computing and prototyping as bottom-up social change in a participatory design context-integrating an interdisciplinary approach that hybridizes production modalities from contemporary 'hackers' and 'hustlers' (engineers and entrepreneurs, respectively). Ezio Manzini similarly emphasizes this perspective shift of looking at a city as organizations of people rather than buildings in order to design for social change (2015). As methods of the architect are analyzed, so too will the engineer's and entrepreneur's to discern where a productive exchange can take place for building bottom-up social change.

Therefore, with make-a-thon as method-which blends a design charrette, an engineering hackathon, and an entrepreneurial pitch competition-this paper examines participatory pedagogies with tech-augmented material engagement and radical pluralism. Using the make-a-thon as a case study for prototyping a participatory design pedagogy, a new hybridized language of design is seeded in a collegiate environment: students work in interdisciplinary teams, learn new skills (such as hacking/making with Arduino), and scope solutions for problems they identify-ultimately testing the bottom-up approach to solution generation. And while this case study is situated within a collegiate context, this paper will conclude by projecting how this interdisciplinary material engagement can expand to an urban scale through institutions that already routinely democratize space and resources (such as the public library). To bring in the architectural models of pedagogy (and practice), and hybridize them with the production modalities of the engineer and entrepreneur, is to establish a new cross-modal and interdisciplinary approach that catalyzes bottom-up social change.

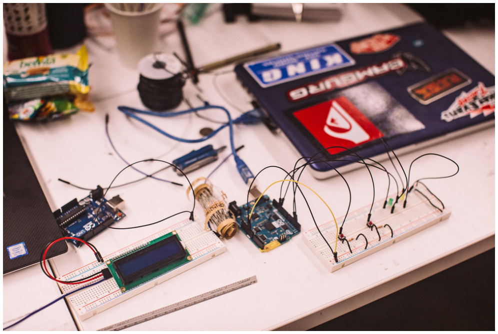

Figure 1
Photograph of typical physical computing prototype setup with Arduino microcontroller and other hardware. Photo credit: Michael Raspuzzi.

PHYSICAL COMPUTING + PROTOTYPING

By "physical computing" we mean active, physical systems that sense, compute, and then actuate using a variety of hardware components as coined by Tom Igoe and Dan O'Sullivan in their book of the same name (2004) nearly fifteen years ago as colleagues in the Interactive Telecommunications Program at New York University. Comprised of components like a microcontroller, sensors, motors and other actuators as shown in figure 1, physical computing also requires scripting skills in order to program the system and its behaviors. These systems require skills and knowledge that span multiple knowledge domains and disciplines, and in fact, the more sophisticated the system, the more complex the process of coordinating and integrating multiple disciplines in executing it (Vermillion 2014a). Given this, the process of building these systems is an opportunity for transdisciplinary pedagogies and practices based on a type of disciplinary 'pluralism' as discussed later in the paper.

Physical computing also reflects larger societal and business trends of collecting and aggregating data as inputs to making things responsive, smarter, automated, and/or autonomous. These days, enormous amounts of data are generated and collected daily and enormous amounts of capital are invested into finding ways to monetize this data. "Big Data" has become the primary catalyst for entrepreneurial innovations in our knowledge economy. These technology-based systems–whether disruptive or incremental–are transforming the built environment at various scales.

Cybernetic Cities + Autonomous Architectures

While Archigram's speculative Walking City project playfully pointed to a future of cities physically reconfiguring themselves as a collection of robotic buildings, our cities have always been cybernetic systems as articulated by Gordon Pask (1969). In other words, our urban environments have always been comprised of layers of complex, adaptable systems that are informed and adjusted by feedback loops, and these systems easily pre-date digital technologies. However, with the ubiquity of digital information and "smart" devices, municipalities are deploying cybernetic systems at the urban scale in the pursuit to become "Smart Cities." This framework of incrementally integrating data and cybernetics into our existing cities to optimize these urban systems has been made possible by the relative ease of collecting, sorting, and aggregating data via computing (Townsend 2014).

Kinetic or interactive architecture–being that there are multiple ways to name and classify (Achten 2011) architectural systems that can respond to data and change form (Schumacher et al. 2010)–are of a scale and complexity that make them relatively rare within our current built environment. So complex, in fact, that Chuck Hoberman claims that an architecture of change will require new theoretical and conceptual frameworks for design that span across a variety of disciplinary understandings (2015, 102). The need for new conceptual frameworks suggests rethinking teaching and learning in ways that, on the one hand, can span multiple disciplines with tasks that require divergent thinking, while on the other hand, can utilize each discipline's expertise to solve small, specific problems (convergent thinking) on the way to a satisfactory outcome.

Interactive Objects

With the urban and building scales in mind (but much too large to address), the "object" scale was chosen as a focus with more appropriate complexity for the make-a-thon prototyping via physical computing. Scaling back the complexity was especially important as most of the student participants had no experience with physical computing hardware or scripting and had to be brought up to speed very quickly while generating and refining ideas and prototypes in-situ. The object scale was also important in terms of student understanding–by thinking in terms of an object or device that could be plugged into the 'Internet of Things', or otherwise was interoperable with smart phones or other mobile devices and cloud computing, students could connect ideas to technology that they interact with on a routine basis.

PLURALISTIC PEDAGOGIES

The make-a-thon became a vehicle to test different strategies that would allow for a more pluralistic pedagogy that would combine design, engineering, and entrepreneurship. In order to scaffold the make-a-thon agenda, active learning methods were used, since these methods have shown to provide students with discipline-specific skills, but also life-long learning skills (Barrett 2010). As digital technologies have become mostly ubiquitous, they are also constantly changing and evolving and the authors feel that the ability to "learn how to learn" is paramount to sustaining a computational fluency for students throughout their academic and professional careers.

The case-study was conducted using a problem-based learning model. Problem-based learning involves immersing students in an open-ended problem, within which they can learn and apply discipline-specific skills while also learning and developing strategies and skills for the problem-solving process itself (Barrow 1996). This is a form of active learning in that students take responsibility for their own learning and obtaining or constructing new knowledge, usually in small teams. As learning is primarily self-directed, instruction is limited to scaffolding the design problem(s) to allow for students to cumulatively grow more self-reliant and instructors serve as guides and mentors to question or challenge the learning process (Schmidt et al. 2007). Additionally, a number of the following considerations, parameters, and constraints helped to shape the pedagogical outcomes of the make-a-thon.

Figure 2 Photograph of Arduino coding workshop over one afternoon during the make-a-thon. Photo credit: Michael Raspuzzi.

Purpose, Theme, and Timing

The make-a-thon agenda was structured and introduced around an open-ended provocation, framed as the "Future of Food." By using a universally understood topic we hoped to be inclusive of multiple, differing understandings, experiences, and rituals involving the harvesting, preparation, and consumption of food. And while the mentors and students discussed some larger, contemporary issues around food resources, the student team inquiries remained open-ended to be shaped by discussion and negotiation between team members during the ideation phase of the workshop. In doing so, the students were actively responsible for defining and constructing their own understandings of their project and the team-generated outcomes rather than passively receiving a problem to solve from tutors (Jonassen 1997).

Taking place over an intense three days and two evenings, the make-a-thon was programmed with a number of events to address and generate ideas, identify a variety of problems, and work on team-building. For instance, along with just work and tutoring time, skill-building tutorials and workshops (figure 2) were also included along with speaker presentations, group/team meetings, and meals.

Multi-disciplinary Collaborations

The make-a-thon was composed of 68 students from the University of Nevada Las Vegas. Sign-ups were voluntary and open on a first-come, first-serve basis in order to attract self-motivated student participants. While many different disciplinary majors from across the campus were represented, three categories were especially well represented in the student applicant pool–the design fields (architecture, landscape architecture, graphic design, sculpture), engineering and science (mechanical engineering, civil engineering, electrical engineering, computer science, mathematics, computer engineering), and business fields (entrepreneurship, finance, management and administration, etc).

The 68 students comprised 17 multi-disciplinary teams with 4 members each–the teams were composed with the goal of distributing disciplinary expertise throughout the team pools. Not to understate the significance of social interactions with team-based work, once teams were assigned, each member took personality and entrepreneurial core competency tests to better understand individual and team-based strengths and weaknesses. These steps were taken to try to ensure a successful shared/team work environment where everyone team member was valued and made important contributions to the final outcome. Importantly, this prepares students for working within teams based on diverse but complementary skill sets and knowledge (figure 3) in ways that are quick and temporal but also productive (Speaks 2006; Steele 2006).

Figure 3
Students worked in teams of four on parallel tasks Photo credit: Michael Raspuzzi.

Figure 4
Students giving final "pitch" presentation to judges. Photo credit: Michael Raspuzzi.

Iterative Prototyping Using the Arduino Platform

Physical prototyping materials such as cardboard, plastics, foam core, etc were provided for students as well as drawing supplies and cutting tools. The goal for each team was to start simple with the prototyping and build up complexity and sophistication in form-factor and behavior in an incremental fashion. In order to keep this process moving forward, workshops were conducted to cover topics such as problem mapping and ideation, arduino scripting and prototyping, design thinking, and making persuasive sales pitches.

As mentioned above, the primary microcontroller platform used for the make-a-thon was Arduino. Arduino has a quite large and active user community that provides online resources for learning and testing ideas. This allowed for novice students to quickly learn the basics of prototyping a responsive system. Often, in the spirit of hacking, structured play (Schrage 1999), and other novel or unconventional ways of combining or re-appropriating existing technologies, the students would start with an already existing system and adapt it to a new purpose. In this way student learning was reinforced with assimilation and accommodation (Piaget 1950) to recall and combine prior knowledge with new knowledge in order to create something new or to modify something old in a novel way. Often in the ideation and prototyping processes, disparate concepts or tech-niques can be repurposed and combined to create something novel. For most students, “playing” with an Arduino and scripting was brand new and therefore a mistake-prone process that would sometimes lead to happy accidents. Discoveries or new combinations of technologies through their “mis-use” are nothing new to architecture, for example, Greg Lynn repurposing animation software like Maya to produce architectural propositions (Lynn 1999), or Gramazio and Kohler adapting flying quad-copter drones to stack masonry in precisely patterned configurations (Augugliaro et al. 2014).

Business Proposals and Pitch Competition as Incentives

In parallel with the prototype development, each team was required to develop a business pitch slide presentation in order to concisely present a persuasive value proposition to a target market. The Make-a-thon itself culminated with a juried pitch competition (figure 4). Rather than giving grades or course credits, the make-a-thon incentivized participation through awarded prizes and chances to spin off the prototype into a commercial venture with in-kind help donated by entrepreneurship organizations based off of the results of the pitch competition.

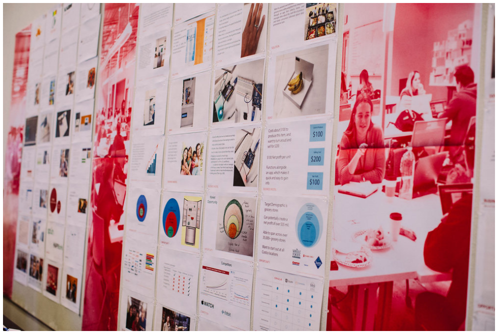

Figure 5
Examples of printed design and marketing information generated by each team. Photo credit: Michael Raspuzzi.

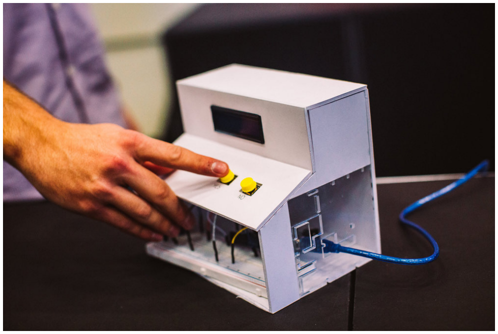

Figure 6
An example physical prototype in the development stage. Photo credit: Michael Raspuzzi.

APPLICATION + RESULTS

Each make-a-thon team had a set of interconnected tasks to perform and products to deliver and these multimodal processes and deliverables presented opportunities for different paths and entry points into the process for each student based on interest and experience. For example, design and marketing information had to be produced (figure 5), physical prototypes were fabricated (figure 6) in tandem with developing a physical computing system to govern each prototype’s behavior (figure 7), and an entrepreneurial “pitch deck” was developed to persuade judges about each idea’s commercial viability (figure 8). The final resulting prototypes were photographed and publicly displayed after the pitch competition (figures 9-10) to demonstrate the accomplishments of each team with only three days of work.

The make-a-thon's pace was ambitious and much was learned about how to setup any similar events in the future. For instance, more tutorials and resources would need to be better front-loaded in the agenda in order to cover the skill-building workshops and give time for students to absorb and re-apply the information. Another important aspect that was missing from this first version of the make-a-thon was getting the students to more formally reflect on their experience either through a townhall-style debriefing session, a journal, or a survey. Beyond closing the experiential learning loop, these feedback instruments could also lead to a better understanding by the organizers of what to adjust in future events.

Participatory Pluralism

Beyond a diverse array of fields or disciplines, the make-a-thon was also an attempt to measure a demographic pluralism–how inclusive and participatory could we make this event, particularly towards under-represented groups. Of the 68 student participants, 30 were female–a traditionally under-represented group in both architecture and technology-related fields (Doyle and Senske 2017). We hope to raise this ratio in future events.

Our university's demographics situate UNLV as the most racially diverse campus in the United States [1], yet our graduation rates are lower than they should be. We hope that make-a-thons and other similar programs can be catalysts for bringing students together in inclusive ways that spur productive exchanges and lead to understanding and empathy. We also hope that these events, which require our students to leverage their studies towards entrepreneurial ends helps to remind them of the value of their education, how it can be applied outside of academe, and looking beyond just a grade or university transcripts.

Figure 7
Development of physical computing behavioral system and integration with prototype. Photo credit: Michael Raspuzzi.

Figure 8
A team giving their pitch deck presentation to competition judges. Photo credit: Michael Raspuzzi.

CONCLUSIONS AND FURTHER TRAJECTORIES

For this first make-a-thon, the primary learning objectives were to: compare the role of the architect against that of the engineer and entrepreneur while exploring which tools are best suited for democratizing solution building; establish a methodology of cross-modal and interdisciplinary design practice through extracurricular events (such as the make-a-thon) while exploring innovative material engagement implications for teaching (and practicing) architecture; and explore how this prototype can expand to a larger scale while decentralizing the role of the future interdisciplinary architect. This project also radically collapsed, and therefore innovated, multiple disciplines into a hybridized condition that offered added flexibility and versatile adaptability in a number of contexts. And while this prototypical "make-a-thon" is situated as a short annual event, in the future we intend to coordinate similar events to build off of this initial program. We see this first step as an opportunity to build a community of designers and other professionals that are ready and eagerly engaged to jump up in scale to make our built environments responsive and "smarter." We see these make-a-thons as a precursor to this scaling up in size and complexity, similar to past examples of material and computing investigations from our past teaching that expand further into design studio pedagogy (Vermillion 2014b).

Figure 9
Finished prototype of a system that monitors plant growth and other vital parameters (light, humidity, etc). Photo credit: Michael Raspuzzi.

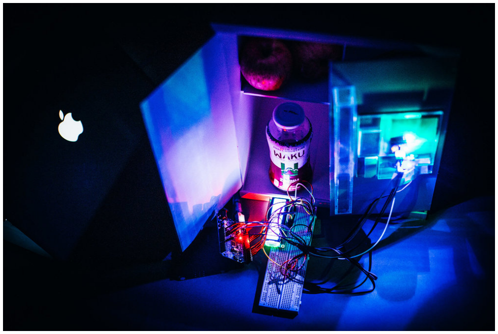

Figure 10
A final prototype for a smart attachment to a refrigerator that measures a user's biometrics. Photo credit: Michael Raspuzzi.

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