MakerCart: A Mobile Fab Lab for the Classroom

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ABSTRACT
As Fab Labs are fast becoming ubiquitous in the learning landscape, we are addressing some of the issues faced in the traditional school settings of incorporating them into the classroom. This article describes the tools, layout, and function, both physical and social, of a mobile Fab Lab that is being introduced into a K-8 school environment. This mobile Fab Lab, or MakerCart, is designed to address the space, and funding constraints that affect many schools in their ability to incorporate Fab Labs as a component of their instructional and curricular frameworks. We are also developing systems to help teachers incorporate the tools and processes of Fab Labs into their pre- existing educational culture through methods of collaborative, shared documentation strategies.

Categories and Subject Descriptors
K.3.1 [**COMPUTERS AND EDUCATION**]: Computer Uses in Education – *Collaborative Learning*

General Terms
Documentation, Design, Human Factors.

Keywords
Fab Lab, Make, DIY, Design, Craft, Creativity, E-textiles, Makey Makey, Scratch, Mobile Cart.

1. INTRODUCTION
In an effort to integrate Fab Lab tools centered on craft, and studio-based processes into the classroom, our group has implemented a Mobile MakerCart at a project-based K-8 charter school. In addition to introducing craft-based physical computing projects to the children, a guiding principle behind the MakerCart is to give teachers the opportunity to develop familiarity with the MakerCart's tools and processes in order to be able to envision the ways in which they might be able to develop their own curriculum for use in the classroom.

The cart, housing a laser cutter, 3D printer, sign cutter, sewing machine, and various circuit building components and tools, is a flexible platform designed to circumvent the school's space issues, move the tools freely within the school, and also to fulfill one of the school's missions of moving out and interacting with the broader community. The initial project being run through the cart is a DIY Sound Studio where the children have been learning the basic physics of sound, starting with making lo-tech record players out of needles, solo cups, and chopsticks, to crafting their own soundscapes in Audacity and Garage Band, and playing them through Scratch/MakeyMakey based instruments. These projects are designed to be iterative and carried through into other projects to deepen and enrich the children's processes of making, and the objects themselves.

A major component of the projects done by the children is one of engaging in reflective processes that are intended to guide them toward developing studio habits of mind. Incorporating these reflective processes as part of the work itself, one of the next projects to be introduced through the MakerCart is the writing, and crafting of a book that will incorporate and be interactive with Scratch programmed environments through circuits built into the book. This project is intended to incorporate multiple elements of literacy through having the children craft richly layered narratives that interconnect across multiple media.

2. MAKERCART MODEL
The Fab Lab environment, and its flagship tools; the laser cutter, sign cutter, CNC router, and 3D printer, is the rapid prototyping space that affords the capacity to design and "make almost anything [4]." The introduction of these machines in scaled down versions, from smaller floor models about the size of a small milling lathe, to units that fit on a desktop, have allowed the rapid prototyping of ideas into objects to move from the domain of engineering, and industrial applications, to a broader group of users. Fast becoming ubiquitous, these spaces are bringing design-problem thinking, and "making" into community centers, and learning environments, and are becoming more prevalent in both formal and informal learning spaces. Fab Labs are being designed and constructed in libraries, museums, and education institutions around the country. The range of users is as varied as the different Fab Lab environment they're working in, from children designing objects in drag and drop 3D modeling programs like TinkerCad that are then built with a 3D printer, to wildlife conservationists creating a replacement beak for an injured bald eagle, artists creating interactive art works, to communities building objects to fill a specific need, such as the creation of a free wireless network called FabFi in Jalalabad, Afghanistan where communities are "using common building materials and off-the-shelf electronics to transmit wireless ethernet signals [2]."

Incorporating Fab Labs into schools is becoming more prevalent, and foundational and educational organizations are developing systems to make it easier for schools to adopt Fab Labs. For example, FabLab@Schools [3], a project run through Stanford University's Transformative Learning Technologies Lab, is a program to both assist schools in building Fab Labs of their own, but also serve as the center of a network of the participating schools. The model is one of open source information sharing that creates opportunity for building the knowledge base of the entire network. The primary method of introducing Fab Labs into schools tends toward placing them in fixed locations within the school, whether it is a reconfiguration of a pre-existing space, or the purpose-built construction of a new space. A Fab Lab that also serves as learning space creates unique needs, so this affords a school the opportunity to have a dedicated location that can be structured to meet those demands. However, as space and funding may not always be available for a purpose built facility this may not be an option for introducing the Fab Lab into many schools.

Following on principles of not simply providing the tools, but in fact working to foster the culture of Fab Labs within the pre-existing teacher culture our group has developed a Mobile MakerCart, and a set of pilot projects for the teachers to begin working with. The pilot projects have been developed to introduce the children at a K-8 project-based charter school to the tools and processes of the Fab Lab environment in a design studio-based atmosphere.

The cart is an industrial machine shop tool cart with an additional unit attached for storage. The main cart as shown in Figure 1, is 47” wide by 29.5” deep with two roll out trays behind a locking double door, and stores the 40W CO2 laser cutter, vinyl sign cutter, and 3D printer as shown in Figure 2. An attached hanging storage unit houses a sewing machine, filament spools, soldering stations, and various hand tools, as seen in Figure 3. The cart is scaled to provide an ample working surface for the primary fabrication tools to be set up on.

These tools that form the backbone of the digital fabrication environment of a Fab Lab allow for the rapid prototyping of designs into objects. Three of the tools featured on the cart fall into one of two categories, subtractive, or additive. Of the two subtractive tools the laser cutter cuts and engraves materials such as paper, acrylic, and wood from 2D designs crafted in design programs such as Adobe Illustrator, and Inkscape. The vinyl sign cutter also works from Illustrator, and Inkscape to cut out patterns from adhesive backed vinyl sheet commonly used in the sign industry. Both the laser cutter, and sign cutter can be used to cut circuits from conductive materials to be incorporated into various projects. The 3D printer is an additive tool that builds up either ABS, or PLA plastic in layers to create a final three-dimensional object. Once limited to building only from designs created in highly complex design environments, the 3D modeling programs available today are greatly simplified drag and drop object based environments such as TinkerCad, which are well adapted for use by children.

Fig. 1

Fig. 2

Fig. 3

After having assessed the school's space constraints the cart was designed to allow for all of the tools to be stored in a small footprint as the school lacks the physical space to house the tools in one permanent location. It also became evident in the process of assessing the school's needs that even if the space were available that there would be several different demands placed on it, and that it would need to be a flexible space to meet multiple instructional functions beyond those of a Fab Lab. In the process of the needs and use analysis, it became clear that a solution was needed that could allow for the Fab Lab to be self contained, and be able to meet the varying needs of the range of curricular, and instructional activities by all of the teachers. The flexibility and large range of affordances of the Fab Lab tools as they can be utilized across multiple disciplines is one of the elements that the MakerCart leverages, and may enhance in some way by the very nature of its mobility.

The MakerCart not only is a solution to space constraints, but the Fab Lab is now able to meet the teachers in the environment of their own classrooms, thus potentially providing a higher degree of exposure and interaction with the tools by the teachers. We believe it is the increased exposure to the processes of working in the Fab Lab environment that will allow the teachers themselves to develop projects appropriate to their own curriculum, and instructional practices in the classroom.

3. SAMPLE UNITS

A major component of the project is drawing the teachers in to working with the MakerCart by guiding and assisting them through various projects delivered through the school's Passions classes. The Passions are an interest driven class period that is delivered in three-week blocks, four days a week, 40 minutes per period. The Passions are in part conceived by the students, and in part guided and developed by the teachers. Passions classes range from yoga, to duct tape jewelry, to Star Wars, to one of our group's initial projects, the DIY Sound Studio. The format of the Passions sessions is an open, interest driven, and play oriented environment. Many of the classes have no specific structure to them and often resemble something akin to the unstructured, self-organized play found in recess periods.

The open structure of the Passions classes has allowed us to develop pilot projects that build from our previous work in informal learning spaces with computational textiles projects, and work stemming out of the Computer Clubhouse [1, 5]. Two projects we are introducing through the maker cart are the DIY Sound Studio, and the Interactive Book Project. The direction of the projects is that they follow, and grow from the previous one.

In the DIY Sound Studio, Figure 4, children explore the basic physics of sound through model making, design challenges, and working within both analog, and digital spaces of exploration. The children start out building model eardrums with latex stretched over the rim of a plastic solo cup, and sing/speak to it in order to "see" sound as vibrations as salt dances around on the latex. They were then introduced to the design challenge of making a record player with a needle, solo cup, and a chopstick after a discussion and demo of records as a physical imprint of sound waves on a material. The principles of electromagnets were taught, and their function in driving sound through speakers demonstrated. Speakers were used to visualize sound with a cornstarch and water mixture to make a non-newtonian fluid that "dances" to various frequencies. Following this introduction to speakers, the children were given a design challenge of creating their own speakers using copper magnet wire, magnets, and various "speaker cone" materials such as plastic cups, paper plates, and bowls, and pie tins as seen in Figure 5.

Fig. 4

Fig. 5

In conjunction with the speaker building exercise the children were introduced to Audacity, an open source sound editing software. The children used Audacity to generate tones for the speaker projects, and to extend the capacity of Garage Band, which many of the children already had familiarity with. Between using Audacity, and Garage Band, the children composed their own sound environments that they then played through their DIY speakers.

For the final project at the end of DIY Sound Studio, the children were introduced to programming instruments in Scratch, and playing those programs with external objects run through the object interface board, Makey Makey. The children were also introduced to the steps required to import their sound designs into Scratch to personalize their instruments further. This final component of the DIY Sound Studio is intended to allow the children to segue into the next pilot project, which will involve the crafting of an interactive book.

The Interactive Book Project will work from the children's knowledge through the prior DIY Sound Studio, and begin to engage them in crafting a final object by working across and through multiple levels of technology, and concepts. This project involves the children in creating a simple six page folded paper book using what's referred to as the 'zine fold. The children will develop a storyboard for their six-page story, and write out, and draw in their story. From the story they have developed in the

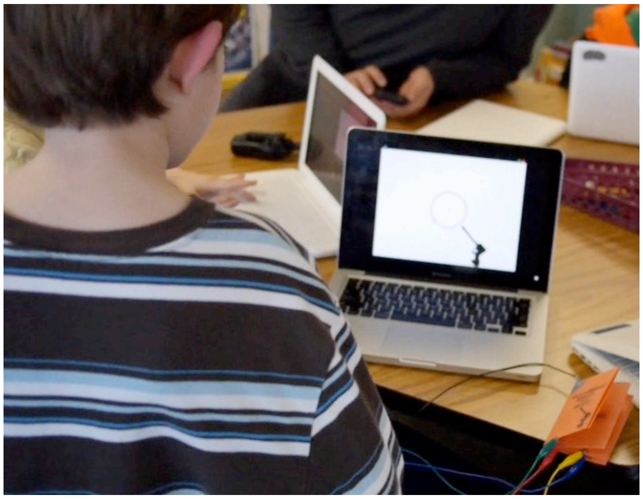

Fig. 6

book, the children will create connected elements by programming events in Scratch. Circuits will be drawn into the book, which will then be connected to a Makey Makey board in order to trigger the programmed events in Scratch, as seen in Figure 6. In this way the story that the children develop will potentially have multiple layers of concept and meaning across the multiple media, yet will function in concert as a whole. This project has capacity to deepen the children's learning processes through the embodied cognition of the book making as it relates to the programming environment, much in the way that Seymour Papert's Logo Turtle [6] connected the children to programming through an embodied experience.

4. DISCUSSION AND CONCLUSION

These projects as illustrated in this paper, while a considered part of the broader MakerCart project have also been developed to introduce the MakerCart concept to the teachers, staff, and children at the school. As many of the tools, pieces of equipment, and materials have been going through the ordering phase, and have been trickling in we are currently engaging these projects through a low-tech lens, albeit one that does incorporate digital design environments. Currently in the plan is to allow for each new project to build upon the last, and develop it further with each new fabrication tool that comes in to populate the MakerCart.

The introduction of new technology into the classroom has often shown to be difficult to establish in a sustainable way. Our process has therefore been one that includes the teachers in the learning process along the way as each project, and use of a new tool is introduced. We hope the introduction in this way will build a core group of teachers that can then be the mentors who show the next round of teachers the use of the Fab Lab tools.

The primary design considerations for developing the MakerCart at this school were the budget, and space constraints. We've found that working through those design constraints have afforded a Fab Lab platform that is potentially beneficial in that it may work to both extend the school further into the community while simultaneously expose elements of the community to Maker/DIY culture, and the tools of the Fab Lab. We are already engaged in working with the local public library to bring the cart to them for their summer programming initiative to bring fabrication tools, and physical computing to the community.

6. REFERENCES

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