ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016

New Orleans Jazzed about Engineering Education

Paper ID #15700

Implementation of a Mobile Makerspace in a K-8 School (Work in Progress)

Mr. Brian Patrick O'Connell, Tufts University Center for Engineering Education and Outreach

Brian O'Connell received his undergraduate degree in Mechanical Engineering from the University of Massachusetts at Amherst in 2006. He then worked for Kollmorgen Electro/Optical as a mechanical engineer developing periscopes and optrontic masts. In 2011, he returned to academia to pursue his Doctorate in Mechanical Engineering at Tufts University in Medford, Mass. He aspires to become a professor of mechanical engineering after graduation focusing his research in engineering design, educational technologies, and engineering education.

Implementation of a Mobile Makerspace in a K-8 School - Work in Progress

This paper describes a work in progress aspect of the Novel Engineering research project at Tufts University, a maker cart developed for participant support. This research project provides an approach for teachers to integrate engineering into their curriculum with greater ease. In this program, students develop functional solutions to problems they've identified from various literary sources and then develop their solutions for, typically using found materials (cardboard, string, duct tape, craft sticks) and the commonly associated classroom tools for use with such materials. During previous implementations, students sometimes create more of an arts and craft model rather than a functional engineering solution to their identified problem. One of the attributing factors to this issue has been student's pre-existing associations with the materials, leading to a mentality that since these are arts and crafts materials, building dioramas and similar items are acceptable outcomes with them.

A recent opportunity to develop a solution to this issue came about while engaging in a larger scale implementation of Novel Engineering at a local K-8 urban school. Their administration has contracted school-wide professional developments and encouraged their entire staff to make use of this approach in their classrooms but had concerns about available tools and materials. They led to an interest in creating a makerspace to accommodate this increase in engineering activities and consulted with our research group to develop it as part of our implementation, but dedicated space was not yet available. To provide teachers the tools and materials they needed to improve these activities, we developed a mobile solution to the problem by creating a maker cart that teachers can roll into their classroom. This cart provides tools and materials that students likely have no counterproductive associations with, and its design encourages thoughtful use of those items. We introduced the maker cart into the school in January 2016. As a work in progress, conclusive data is not yet available. This paper describes its development and the reasoning behind its configuration and content.

Introduction

The following paper describes a participant support effort within Novel Engineering at Tufts University, a mobile makerspace to support engineering activities in classrooms at an urban K-8 school. At the time of writing, this effort was still a work in progress, one at a stage where data was quite limited, and any definitive results did not exist. Therefore, this paper describes the initial development and design of the maker cart and its introduction to the teachers who would begin using it.

The parent project provides an approach for teachers to integrate engineering into their curriculum. As part of Novel Engineering activities, Students identify engineering problems from the literary sources they already engage with as part of the existing curriculum and then develop functional solutions to those problems. During professional developments introducing this approach to new teachers, one of the more common concerns is what tools and materials are needed to support such activities. Typically we recommend using found materials (cardboard, string, duct tape, craft sticks) and readily available classroom supplies for the design and construction of these elementary engineering artifacts. These are also the materials provided during professional developments and used to run through introductory activities with the PD attendees. These materials typically affiliate with arts and crafts projects though and are not what one usually pictures when asked to think of engineering.

Our PD helps train teachers to be aware of that issue and the need to continually encourage students to maintain an engineering mindset while they design and develop their solution. It is not an overwhelming issue but one that does require some vigilance on the part of the teacher. With the school-wide adoption of this approach in a local urban K-8 school and their interest in providing new tools and materials for student engineering activities, an opportunity of convenience was identified to affect how students associate with the tools and materials they use during these activities. During discussions with the administration, a dedicated makerspace came up several times as a means to accommodate the foreseen increase in hands-on engineering activities within their school and as a resource to provide better materials and tools for those activities. The subject of this paper serves as the initial step towards that idea and examining its effectiveness in encouraging more meaningful engineering in such a community, a portable makerspace in a cart to service the school until a dedicated space becomes available.

Background

The thesis question behind this effort is can the quality and extent of engagement in the practice of engineering be improved by making certain materials and tools available and even prominent. A basic aspect of this inquiry is determining the inherent role that tools have on the engineering students engage in. The value and import of materials and tools go far beyond their face value. They tend to serve a purpose, something that the user is supposed to do with them, fundamental within their design. That typical use sometimes leads to certain associations with those materials and tools, whether designed in such a way that they naturally are utilized for that associated purpose or passing on an understanding that a specific tool is only used for a specific purpose.

These associations can have some influence on how students engage in activities with them, such as engineering and design[1]. If someone walks into a room of children holding mixing bowls, wooden spoons, flour, frosting, and eggs; the likely assumption made will be that baking is about to occur and with that assumption may include a mindset, even if it's an unconscious one. The same may apply when classrooms make use of arts and crafts materials for an engineering activity; the student mindset may lean more towards their initial observation of the available resources and the associations with them rather than the instructor's intention. You can go against that assumed purpose to discover new capabilities, but that requires some flexibility of thought and creativity, especially if your experiences with that material or tool have been very narrow and specific. New materials and tools can also inspire a student's solution though and influence how they proceed with their engineering and design practices. Exposed to new resources, an opportunity to engage without underlying suggestion exists. That freedom from preconceived associations can allow for some novel thinking and new implementations [2, 3].

Researchers observed this association several times during fieldwork for this project, manifesting in students particpating with the activity in a non-engineering mindset and producing non-functional final products inconsistent with the learning goals of the activities. In these cases, students' engineered solutions share more characteristics with dioramas rather than the desired functional artifacts capable of solving the engineering problem. In some cases, students outright sacrifice functionality in order to decorate and work on the cosmetic aspects of their build or have to be dissuaded from some itesm since they admittedly only want them to add artistic value to their construct. The use of scissors, glue sticks, construction paper, and the like led to initial designs being more like those from an arts and crafts activity. The student's primary focus on decoration and aesthetic instead of thoughtfully designing functional solutions to their problem reinforces the conclusion that some students were not treating the activity as an engineering challenge.

In these cases, considerable effort is required on the side of the instructor to encourage students to focus on engineering a functional solution with these materials instead of using them in a manner they're used to. The hope behind this effort is that new associations with engineering can develop with the tools we provide or even simply with the maker carts presence. If the cart being in the room making new tools with more overt engineering associations available to the students leads to students initially engaging in engineering without prompting, similar resources in other schools may be capable of doing the same.

Overall Design

The Novel Engineering Maker Cart is constructed from a commercial of the shelf (COTS) mobile cart with a variety of drawers to organize the various components (See Figure 1). Attached to the cart are two COTS 7-gallon trash bins and a custom tape dispenser. The bins serve as receptacles for a variety of building materials. Initially, they were stocked with cardboard items, such as paper towel tubes and tissue boxes, and some larger scrap pieces of cardboard. The tape dispenser is custom made to fit onto the cart. It is constructed of laser cut

Figure 1: Assorted Views of Maker Cart

acrylic and bonded with hot melt adhesive (HMA, aka Hot Glue). It holds five rolls of electrical tape in the standard array of colors, three rolls of masking tape, and three rolls of duct tape. There is also a container for the teacher with items determined unsafe if left for general use. It accompanies the cart but is not physically connected so it can be held separate from the cart by the instructor. Currently, it contains a fixed blade utility knife, replacement blades, and the 9V batteries for the electronics. There is also a clipboard with sign up sheet for the teachers at the school.

The current content of several of the drawers are listed in Table 1. They contain components organized into following categories: marking and measuring, wires and electronics, hand tools, fasteners/string, adhesives, pliable materials, Makedo™ tools/fasteners, and treasures. The Makedo™ tools/fasteners drawer contains several Makedo™ toolkits, a set of tools and fasteners designed for creative cardboard construction[4]. We dedicated several drawers to treasures; these are specialty material added by teachers for specific projects such as assorted scraps of various fabric materials for wearable solutions.

Table 1: Content of Selected Categories

Marking and Measuring	Wires and Electronics	Hand Tools
6" Digital Calipers	Wire Stripper/Cutter	Diagonal Pliers
150 cm Flexible Tape Measure	Assorted Stranded Wire	End Cutting Pliers
25 ft by 1 in Tape Measure	Assorted Solid Wire	Bent Nose Pliers
110 lb max Digital Hanging Scale	Alligator Clip Test Leads	Long Nose Pliers
Graphic Compass	Single Pull Single Throw Switches	Flat Nose Pliers
Set Squares	Red and Green LEDs	Groove Joing Pliers
Protractor		Slotted Screwdrivers
8" Level		Phillips Head Screwdrivers
Contractor Pencils		

Fasteners/String	Adhesives	Pliable Materials
1/4" Braided Elastic	Gorilla Brand Glue	Pipe Cleaners
Bundling Twine	Glue Gun and Glue Sticks	Plasteline Modeling Clay
60 lb Monofilament Line	Double Sided tape	
Assorted Zip Ties		

The maker cart also includes several features to simplify its organization and use. Custom foam inserts serve to arrange the components precisely and provide a visual reference for returning them to the proper place (See Figure 2). The electronics are all prewired to allow for efficiently achieving electrical connections using alligator clips test leads to clip onto the contact rings soldered to the wiring (See Figure 3). Laminated instruction cards are attached to the cart to help inexperienced students properly use some of the tools and materials (See Figure 4).

Figure 2: Foam Insert for Tool Organization

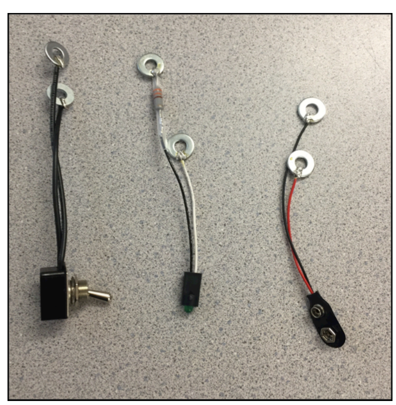

Figure 3: Pre-wired Electronics

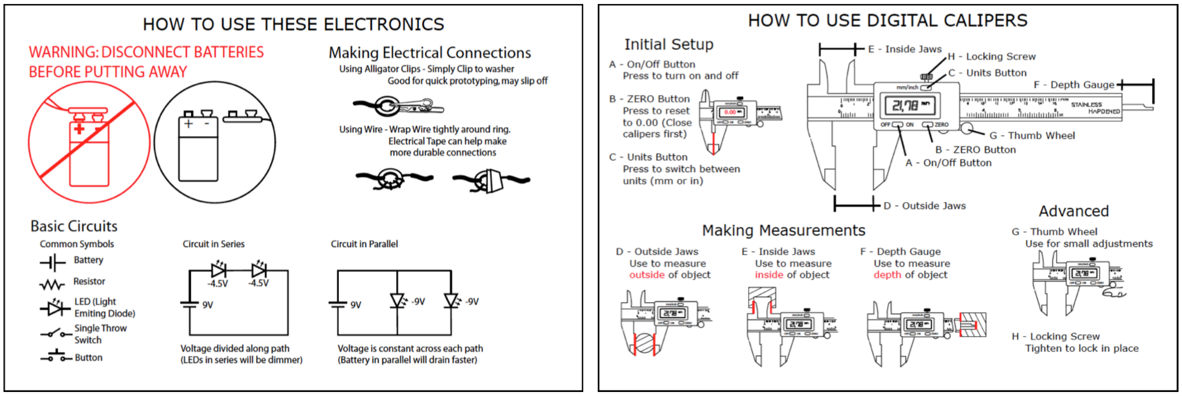

Figure 4: Example of Instructional Cards

Design Reasoning

Several sources informed the selection of tool and material content within the maker cart. A similar project at Tufts University for the development of a modular mobile makerspace heavily influenced the content but other various maker-related resources were utilized for their published lists of tools and materials commonly associated with maker-related activities[5-10]. The most influential would be the Stanford D.School's prototyping cart. They make use of a well-organized categorization for the content of their prototyping carts; pliable materials, structural items, connectors, utensils, and treasures[11]. This system helped provide some structure for the inclusion and exclusion of many items since original brainstorms produced lists that were far too long and expensive for implementation.

In the majority of Novel Engineering activities, recycled materials are commonly used as the structural items, so larger bins were provided for those. Various fasteners and adhesives are included to serve as connectors. Various hand tools and measurement devices represent utensils and the plasteline and pipe cleaners sit firmly in the pliable materials category. Electronics and some unusual items serve as treasures, but several drawers remain empty to encourage the staff to include some of their own such as materials intended for specific projects like the assorted fabrics. This organizational structure functioned as a starting point to narrow our initial lists, but the final selection criteria for the various materials was a marked difference from those tools and materials available in the classroom or those typically associated with arts and crafts. The idea being that this uncommonness and likely unacquaintedness provides a potential for the development of new engineering based overtones with the tools and materials for the students and therefore the potential to improve the engineering of these classroom activities through such associations.

This mindset took into consideration what students already had access to as well as how they are typically used. Classrooms already contain scissors, so we did not include any similar cutting tools. The final configuration includes MAKEDO cardboard saws though due to their dissimilarity to the available cutting tools and their uncommonness. One finds rulers and yardsticks in most classrooms, leading to their exclusion. Digital calipers and a digital scale are included since it is unlikely that elementary age students have come across these types of measurements tools. That newness will hopefully inspire enough curiosity that students use them and their availability only during engineering activities will influence student mindset when they're in the classroom.

Their novelty of such digital measurement tools is also hoped to encourage greater use of during projects, causing more precision measurement to factor into the student's engineering. The same is true for many of the other items. We included carpenter pencils since, although they use pencils daily, these may be different enough to encourage their use for marking measurements and sketching of designs, leading to a new association with these writing devices as engineering tools. The electronics allow students to include some switches and lights as part of their project but the cards also include the schematics for the available circuitry, and clear shrink wrap leaves all components visible. Instead of more of the standard glue and glue sticks they already have in the classroom, Gorilla Glue is provided. The cart includes Plasteline as a modeling material instead of something more familiar like playdough. Even the tape dispenser, which includes types of tape that the students are likely familiar with, has aspects of its design intended to lead to a more nuanced use of the material. By hard mounting the dispenser to the cart, students are forced to take tape as they need it which we hope leads to students thinking much more about how much they need at any given time.

Initial Observations

As stated earlier, this cart is a work in progress. The development of a useful participant support resource has only recently progressed into a functional, testable design. In January 2016, the maker cart was introduced to the teachers during professional development. Their initial feedback helped improve the design but also showed a positive reception of the new resource. Their comments led to the inclusion of a separate container for teacher's only tools as well as the instructional cards to assist students with using the various new items. One teacher used it soon after those upgrades and provided some initial observations on its implementation; not enough for useful data but some anecdotal feedback. They noted that the measurement devices were indeed a curiosity for the students and saw significant use, validating some of the design decisions. They also had little difficulty using them. The electronics became almost too distracting; with students wanting to use simply them in their solutions; not because they supported the engineering task at hand but rather for their novelty alone. The students' eagerness led the teacher to regulate access to the electronics, requiring exact reasoning for wanting them before allowing integration of them into their project.

As more use of this cart occurs, we intend to observe how students use it with particular attention to how they use the items from the cart as opposed to the things they have available in the classroom. We hope to see some difference in how the students use the tools provided by the maker cart and those they have around the classroom. Novel Engineering continues to collect video and observational data in classrooms at this pilot school during activities and of student solutions, some classrooms using the maker cart and others using their own resources. After the spring 2016 term, the research team will interview the teachers directly as well as engage with them during summer PDs. During these interactions, researchers will initiate discussion on why they brought the maker cart in their classroom, how they made use of it, and what they observed in their students' engineering. These data will hopefully show some difference in how students take up engineering when provided new tools they can associate with such tasks or just show no difference between how they typically do so with their everyday glue stick and scissors in hand. Until then, the maker cart is scheduled for use in several more classrooms and will continue to be a resource at that school. This WIP may not lead to the development of maker carts in more schools as part of Novel Engineering but understanding the influence of the materials and tools helps to improve the project's professional development with new teachers and better direct them to bring meaningful engineering activities into their curriculum.

This project is funded by the National Science Foundation DRK-12 program, grant # DRL-1020243. Any opinion, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. The author would also like to thank the Center for Engineering Education and Outreach at Tufts University for their support.

Bibliography

1. Ashby, M. F., & Johnson, K. (2013). *Materials and design: the art and science of material selection in product design*: Butterworth-Heinemann.
2. Lipson, H., & Kurman, M. (2010). Factory@ home: The emerging economy of personal fabrication. *A report commissioned by the US Office of Science and Technology Policy*.
3. Klahr, D., Triona, L. M., & Williams, C. (2007). Hands on what? The relative effectiveness of physical versus virtual materials in an engineering design project by middle school children. *Journal of Research in Science teaching, 44*(1), 183-203.

4. MAKEDO™. (2016). MAKEDO™ Cardboard Construction. Retrieved from http://www.make.do/
5. Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing modern knowledge press.
6. Gabrielson, C. (2013). *Tinkering: Kids Learn by Making Stuff*. Sebastopol, CA: Maker Media, Inc.
7. Krishnan, G. (2015). *Designing a Mobile Makerspace for Children's Hospital Patients: Enhancing Patients' Agency and Identity in Learning.* (PhD), Vanderbuilt University. Retrieved from http://etd.library.vanderbilt.edu/available/etd-08182015-034719/
8. Moorefield-Lang, H. M. (2015). When makerspaces go mobile: case studies of transportable maker locations. *Library Hi Tech, 33*(4), 462-471.
9. Gierdowski, D., & Reis, D. (2015). The MobileMaker: an experiment with a Mobile Makerspace. *Library Hi Tech, 33*(4), 480-496.
10. Hasso Plattner Institute of Design at Stanford. (2014). *How to Make a SparkTruck: AN OPEN-SOURCE GUIDE FOR ANYONE MAKING AN EDU-MAKER TRUCK*. Retrieved from https://docs.google.com/document/d/14Z7kaBYsU90LmA8ozaXfqet6cNtDtORswRG3-Xzjbho/edit?usp=sharing_eid&ts=569820a6
11. Doorley, S., & Witthoft, S. (2011). *Make space: How to set the stage for creative collaboration*. Hoboken, NJ: John Wiley & Sons.