Paper ID #35522

Full Paper: Student-developed plans for use of maker spaces in a self-selected creative design project

Dr. Benjamin Daniel Chambers, Virginia Tech Department of Engineering Education

Benjamin Chambers is an Associate Professor of Practice in the Department of Engineering Education at Virginia Tech, and Director of the Frith First-Year Engineering Design Lab. He is an interdisciplinary scholar with three degrees from Virginia Tech, including an MS Civil Infrastructure Engineering, MS Entomology, and a PhD in Environmental Design and Planning. His educational research interests include student creativity, and the built environment as an educational tool for engineering and biology.

Full Paper: Student-Developed Plans for Use of Maker Spaces in a Self-Selected Creative Design Project

Introduction

This full paper examines student plans for the use of a campus maker space in a self-selected creative design project. Design and creation is an important part of learning engineering, and our institution's first-year engineering program dedicates the better part of the second semester to a team-based iterative design process. To support this process, our program provides first-year students with an exclusive maker space, the Frith First-Year Design Lab. This space is primarily utilized for team projects in the second semester. Access to and inclusion of maker spaces in first-year programs has been shown to help students develop engineering skills [1-3], and to develop confidence in their abilities [4].

In order to give students more opportunities for creative hands-on work, a self-selected creative design project was developed and administered in several first-semester class sections over several years. This design project was conducted in several stages: ideation, planning, creation, demonstration, and reflection. Of particular importance was a planning assignment, in which students developed their ability to create plans and estimate project needs, and also estimate time commitment in order to keep the project manageable. This paper uses the submissions to that assignment to examine how first semester engineering students create plans for self-selected maker space projects.

Specifically, this paper addresses the following questions: when planning after being given freedom to make anything within the capabilities of our first-year maker space, 1) What sorts of things did students choose to make? 2) What tools and machinery were students most likely to want to use? 3) How did students scope their projects in terms of time and money? 4) How clearly did the students develop and communicate their plans?

First-Year Program and Maker Spaces

This assignment sequence was given during the first semester of a two-semester first-year general engineering program at Virginia Tech, serving over 2000 students per year. The first semester focuses on the understanding of engineering problems, including context and scope. The second semester focuses on the design process. Students explore these topics and develop technical, research, and writing skills through individual and team projects. All students must complete the program before selecting a specific discipline or major.

In support of the design experience, the program maintains an exclusive maker space for first-year engineering students. This space includes 3D printing, laser cutting and engraving, CNC machining, as well as traditional workshop hand and power tools. There are also plenty of free materials available for student use. Students are encouraged to use the space for personal projects. However, the space is primarily used by students working on team projects for the second semester course, many of whom are then using it for the first time, and some may not use it at all depending on how their teams assign tasks.

Project Context

In order to allow students more opportunities for hands-on work, guarantee an individual opportunity for exposure to the process of design and creation, and manage safety training schedules, a self-selected creative maker space project was designed and assigned by one faculty member during the first semester of the general engineering program. In this project, students completed a series of assignments culminating in the making and sharing of their creations. The maker spaces project sequence has undergone some revisions to assignment texts and submission requirements over the last three iterations, but the structure remains the same. Each version included the following primary components:

1. Safety training: Completion of the necessary online training to use the space.
2. Idea generation: Three ideas for possible projects with descriptions.
3. Plan of action: Materials, tools, process, and timing plan for creating their project.
4. Creation and demonstration: Making the project, and sharing it in a devoted class period.
5. Reflection: Narrative reflection on the process and lessons learned.

Students were given structured opportunities to discuss their ideas and progress with their classmates throughout a ten week sequence. This period allowed students more time to consider their designs and complete equipment training, and also to work the project into the pre-existing course schedule that is shared with other instructors in the program.

Assignment

This paper focuses on the plan of action assignment (Appendix A), which included three elements. The first was a short narrative with at least one paragraph explaining what they were making and why, and another paragraph describing the plan. The second was a table that outlined the materials the project would require, where they were to be sourced (students were strongly encouraged to use the materials provided free to all users of the maker space), and the expected prices. The third was a process table explaining the process of creation step-by-step, including the required tools and expected duration for each step. Guidelines specified a maximum expected time, which for the semester examined was a total of two hours of active time. Completion of this plan assignment was required before physical creation of the projects began.

Methods

The project was assigned by a single member of the instructional team in their sections over the course of three fall semesters. The submissions examined in this paper were drawn from the most recent iteration of the sequence, delivered in Fall 2019. The project was not given in Fall 2020, when the course was administered remotely. After institutional review board approval, student consent, and compliance procedures, a total of 145 submissions were available for analysis. Submissions were coded for several characteristics related to cost, materials, tools, time, purpose, and specificity of process steps.

Cost coding was based on the number of line items which were either free, or paid for. Plans could be entirely free, mostly free (50% or more of line items), partially free (<50% of line items), or entirely paid. When students indicated prices were a fallback in case free materials were unavailable, those lines were coded as free. The total estimated cost of each project was also recorded. When it was unclear whether prices were per unit or total for the line, they were assumed to be the total price. Packages of multiple items (e.g. screws) were recorded as the full price of the package. Materials were coded according to several general categories (e.g. 3D printer plastic, wood, fasteners & fittings, etc.). Unique or uncommonly selected materials were not reported in this paper. Tools were coded according to general categories and the specific charismatic equipment available in the space (i.e. 3D printers, CNC, and laser cutter).

Process was coded according to the level of detail included, and how repeatable their steps were. Categories included very broad, moderate detail (enough to generally understand the process), specific details, and specific details including dimensions (generally fully repeatable). The total active process time was also recorded. When time ranges were given, the midpoint was recorded. Active time did not include running time of laser cutters, 3D printers, etc., nor the time to learn a piece of software or equipment or to obtain materials, though some students included these things in their process tables.

Projects were coded according to the primary purpose, with the broad categories of art/decoration, furniture, furniture accessories (things that attached to or were meant to be placed on other furniture), tool-related items, and novelties. Specific descriptors for types of things were also coded, to provide more detail on what sorts of things students most often chose to make. Those more specific categories representing >5% of submissions were reported.

Results and Discussion

Students developed ideas for a wide variety of projects, but many fell into a few broad categories (Table 1). Over half of the plans were to make furniture or furniture accessories, and another quarter were for art or decorations. Similarly, among those furniture or furniture accessories, many chose shelving or other storage and organization items for their dorms. In fact, almost 80% were related to living spaces for decoration or utility. Whether the item was meant as a gift was not captured in this analysis, but determining what is intended for personal use could shed more light on intent. To avoid influencing project selection, the documentation did not include a list of possible projects, though some collages of ideas were given on slides in-class. However, adding prompts to explore purposes or an ideas list to the assignment text may be useful for students who struggle to find ideas.

Students were encouraged to use the free materials available in the first-year maker space, or to recycle or upcycle existing materials. While only 48% of plans relied entirely on free materials, the majority at least partially relied on them (Table 2). The average total plan cost was $15.13, or $29.24 if all free plans are excluded. However, this is significantly skewed by a single very expensive project that would cost over ten times more than the next most expensive plan ($810 for a plan to make an electric longboard). Removing that outlier drops the average total cost to $9.61, or $18.69 if the free plans are excluded. While it was preferred that students not spend extra money on this course, students that were able to spend money (mostly) chose to spend no more than it would cost to go out to lunch in our town. Additionally, many of the items students had planned to purchase included fasteners and adhesives, which they would have found available free in the maker space. In future iterations, it may be helpful to provide students with a more comprehensive list of materials that are available for free in the maker space.

The availability of free materials was made clear to students partially to support equity. While half of the plans included purchased materials, this is not inequitable from a grade perspective, as pricing did not affect the grading of the plan, and all completed projects received the same grade (100%) for the demonstration portion of the project. Whether the students who spent more on their projects had different satisfaction or appreciation of the project would have to be studied in future iterations of the project sequence. However, there were many free creations that were very well received by the class during the demonstrations.

Table 1. Purpose and type

Primary purpose	Plans	Primary type	Plans
Furniture accessory (attachment, hutch, etc.)	32.4%	Toy	9.7%
Art or decoration	26.2%	Shelving	9.0%
Furniture	20.7%	Model or miniature	8.3%
Novelty item	11.7%	Box	7.6%
Tool or tool-related	6.9%	Desk organization accessory	7.6%
Other	2.1%	Coaster	6.9%
-		Wall hanging	6.9%

Table 2. Project plan costs, materials, and tools.

Use of free materials	Plans	Materials	Plans	Tools	Plans
Relies entirely on free materials	48.3%	Wood (hardwood, softwood, plywood, etc.)	59.3%	Hand tools (hammer, screwdriver, etc.)	53.8%
Mostly free materials (>= 50% of items)	24.1%	Fasteners & fittings (nails, hinges, etc.)	39.3%	Power tools (drill, table saw, etc.)	42.1%
Some free materials (< 50% of line items)	11.7%	3D printer plastic	30.3%	3D printer	30.3%
All line items are paid	16.6%	Adhesives (glue, etc.)	29.0%	Laser engraver/cutter	14.5%
-		Coatings (paint, sealant, stain, etc.)	20.0%	CNC/router machine	3.4%
		Metal sheets	5.5%	-	
		Recycling/trash	4.8%		

Plans most often utilized hand and power tools (Table 2). Nearly a third involved 3D printing, which if used alone does not require much physical work, though students did acknowledge the time spent drafting models. Printing plastic is also conveniently free in the maker space. The space's CNC was indicated in only 3.4% of plans, indicating underutilization. The reasons why students selected particular tools were not captured by this assignment, but it is notable that hand tools are familiar, and 3D printers are novel to many students are well known due to regular media attention. Our program will be promoting the CNC in future semesters, to increase utilization and better distribute student activity in the space.

A majority of plans called for the use of wood or engineered wood products, which are freely available in the maker space. Only 4.8% of plans called for materials that would otherwise be put into the recycling or trash. The material selections align with the stocks of free materials in the lab, though it is unclear whether this is because of appropriate stocking, or because of the relative visibility of different materials. Material selection may also be driven by the appropriateness of materials for selected equipment. The 3D printer, laser engraver, and CNC all have limitations on what can be used, though not all possibilities are commonly used. Adding easily accessible lists of possible materials for each, both on training materials and through QR codes on the machines themselves, could increase the variety of material selections made by students.

Student plans indicated an average total active time of 100 minutes. Only 17% of plans went over the suggested time limit of 120 minutes. About 84% of students described their plans in at least enough detail that they could be generally understood by the teaching team (Table 3). This was the minimum level of detail deemed appropriate during grading, indicating that the student had both thought through their process, and effectively communicated it. A very high level of detail and dimensions was not expected, and throughout the project students were reminded that the first iteration of a plan seldom works perfectly, that they will learn many new things by doing them the first time, and that all this is an important part of the design process. One concern with projects as open-ended as this one is that students will struggle to appropriately scope or plan their work. However, this assignment resulted in plans that were scoped appropriately for first-year students. Plans were mostly laid out with enough detail for instructors to understand, were mostly within the recommended time range, and cost the student little or no money. The multiple in-class reminders and discussions about plan scoping may have helped with this, and will continue to be included in this and similar assignments in our program.

Table 3. Plan process step detail levels.

Level of detail	Plans
Plan steps are specific enough to be consistently followed, including dimensions	21.4%
Plan steps are specific enough to be consistently followed	31.7%
Plan is moderately detailed, enough to give a general sense of how to do it to anyone	31.7%
Plan is very broad, and would be difficult to repeat	15.9%

Appropriate scoping of individual student projects is also important from a resource management perspective. Earlier iterations of the project sequence allowed for plans scoped as large as 5 hours. This was reduced primarily for student workload management, but partially also so that students were not competing for access to the limited space in the dedicated first-year lab facilities. The iteration of the project examined in this paper was limited to one instructor, and a bit less than 10% of the total program enrollment. A short project plan duration requirement may be important when such assignments are broadly adopted by instructors, and would be necessary if all 2000+ students enrolled in our program were participating in versions of this project. It might also be necessary to stagger due dates between instructors.

The plans analyzed in this paper were the final step before students went to the maker space and actually began making things. The assignment successfully resulted in plans that demonstrated that students had considered the time, tool, and material needs for their design projects. The creation, demonstration, and reflection parts of this project have consistently been engaging and valuable, but analysis of those other stages, and of the project as a whole, are left to future work.

This paper reports on the types of projects that first-year engineering students self-selected during the planning stage of a creative design project using a campus maker space. It examines the appropriateness of plan development and scoping, and finds that the assignment resulted in properly scoped and achievable plans. These results will be of interest to educators teaching design and project planning to first-year students, and to those interested in developing self-selected creative projects. They may also be of interest to managers of maker spaces dedicated to those students by indicating popular material and tool choices in self-selected projects.

References

[1] M. Z. Lagoudas, J. E. Froyd, J. L. Wilson, P. S. Hamilton, R. Boehm, and P. Enjeti, "Assessing impact of maker space on student learning," in 2016 ASEE Annual Conference & Exposition Proceedings, 2016, p. 26298.

[2] P. Taheri, P. Robbins, and S. Maalej, "Makerspaces in First-Year Engineering Education," Educ. Sci., vol. 10, no. 1, p. 8, 2020.

[3] M. Galaleldin, F. Bouchard, H. Anis, and C. Lague, "The impact of makerspaces on engineering education," Proc. Can. Eng. Educ. Assoc., 2016.

[4] R. J. Morocz et al., "Relating student participation in university maker spaces to their engineering design self-efficacy," in American Society for Engineering Education Annual Conference Proceedings, 2016.

Appendix A

Purpose:
This assignment will help you develop your ability to create plans and estimate project needs. It will also help you understand the needs for your creation before you devote any resources to it.

Task:
Select an idea to carry through to completion. It is recommended that you use one of the three previously generated for Maker Spaces Ideas, but is not required.

Develop a plan for making your creation. Your plan should include a maximum of two (2) hours of active time in which you will actually be working on your creation. Time spent with tools or creating computer files for fabrication counts as active time. Waiting for a fabrication machine or glue to dry does not count towards active time.

Your plan must include a materials table. At minimum, there should be columns for material names, quantities, prices, and sources. There is a materials table in the provided template.
Your plan must include a high-level process table explaining steps and tool requirements. There should be separate rows for each discrete step. At a minimum, your table should include columns for step names, step descriptions, time estimates, and tool requirements (denote tools that require additional training). There is a process table in the provided template.

Your submission should also include a narrative explaining your creation. At minimum, one paragraph of the narrative should explain your creation and your motivations for creating it. At minimum, one paragraph of the narrative should explain your plan and how you developed it. Your narrative should also address any anticipated difficulties specific to your project, and how you are planning around them. There is a place for this narrative in the provided template.

Deliverables:
- .pdf of your plan of action, created using the provided template, including
  - Materials Table
  - Process Table
  - Project Narrative
  - Citations for any sources used

Primary Grading Criteria:
- Completeness, quality, thoroughness, and thoughtfulness

Hints and Resources:
- We do not recommend selecting a more involved project, in case creating it takes longer than you expect.
- DIY guides online can help you figure things out. If you use one, be sure to cite it using IEEE style.