# Student-Designed Elective Class on Maker Methods and Culture
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### INTRODUCTION

Universities have developed many models for integrating making and makerspaces into the curriculum [1]. Models range from assignments that incorporate making into traditional classes to non-credit workshops that invite participants to learn to use particular pieces of equipment or digital design tools to semester-long courses required for a student's major that fully integrate making principles [2-4]. In semester-long maker courses, the topics covered span design methodologies to mechanics, electronics, programming, or materials science. In addition to course goals related to acquiring specific content knowledge, many maker-infused courses seek to increase engagement [2], improve self-efficacy in design [5], and build interdisciplinary teamwork and client interaction skills [1]. For the most part, these for-credit courses are conceived and driven by faculty. However, relatively few full-semester for-credit courses are designed by students apart from the student-designed courses at University of California Berkeley under the DeCal program, which are typically 0.5 to 2 credit hours.

In this paper, experiences with a student-designed 3-credit-hour elective class on maker methods and culture are presented. The student who designed the course incorporated two elements that particularly resonated with students who took the class. These were a flexible grading scheme and submission of weekly assignments through a personal portfolio website. The goals of the course and the corresponding curriculum are discussed, along with experiences of instructors who offered the course and students who took it.

### Background

Incorporating making into curriculum provides opportunities to engage learners more fully than traditional lectures or laboratory exercises. The benefits of a maker approach in higher education can be traced back to educational theory from such luminaries as Dewey, Montessori, Papert, and Piaget [6]. Makerspaces provide the physical location and means to perform making but culture also plays an important role in bringing new participants into making and building and advancing knowledge. While hands-on constructivist learning is considered a core element of maker learning, the cultural aspects of making and makers is also important. Blikstein [6] notes that the creating of shareable artifacts were an enabler of the maker movement going back to Papert's work. Participants who are new to making benefit from the sharing of artifacts and personal processes and explorations through blogs. Such websites as Thingiverse, github, and hackaday provide mechanisms for sharing artifacts, whereas sharing through personal websites and individual blogs adds a dimension of approachability and insight into the maker process of iteration and acceptance of intermediate failures as learning opportunities. Hira [7] proposes a conceptual framework for realizing the potential of makerspaces that considers the interactions of three elements: people, means, and activities. As institutions of higher learning seek to employ elements of making to improve educational outcomes, this framework is useful in considering the role that students may play in achieving those educational benefits.

### Origins of Maker Course

Institutions of higher education rely on faculty to define the curriculum. As a result, institutional approaches to incorporating making in courses often reflect institutional needs. Faculty may include aspects of making in their courses to increase engagement or provide perspective to address challenges in learning difficult concepts. On the other hand, student-designed making workshops likely reflect students' perceived needs. For example, students may develop makerspace workshops around the needs of clubs (e.g. CNC machining for vehicle clubs) or around specific areas of curiosity (e.g. electronics, coding, textiles, bio-hacking).

The origin of the class described in this paper begins with a 5th year student in the School of Individualized Studies at the Rochester Institute of Technology who wanted to teach a class in making. The student had a substantial background in making and skills related to electronics, coding, software, Arduino, and rocketry. He had gained these skills through experiences as a project coordinator for several campus clubs. The student sought out the manager of the campus makerspace and proposed the idea of a 3-credit class. The makerspace manager recommended a faculty member to partner with to cover the institutional requirements for offering the course. The course was co-designed and co-taught by the student, makerspace manager and faculty member, with the student taking the lead and the others providing guidance and support.

### Curriculum design

The curriculum plan of the maker course was designed over two months. Among the decisions to be made were 1) whether to have a common fixed project for all students or to let students choose their own project (students could choose their own project to encourage agency and ownership), 2) how much time to give to student projects (4 out of 14 weeks), 3) whether to have scaffolded or relatively independent assignments from week to week (independent assignments to have less dependency if a student missed a week due to COVID), 4) what grading scheme to use (a flexible, choose-your-own-adventure approach) 5) what tangible deliverables students would make each week (typically produce an artifact each week and document it on their personal portfolio website by the next week.)

Due to scheduling constraints, the course was offered as a 3-hour block once a week. The weekly course plan was broken into 60-minute segments with active learning at the forefront [3], although some weeks this was not fully achieved.

### A. *Weekly Implementation Process*

The student, faculty member, and makerspace director met after each class for 1 hour to debrief on how the class went. Content plans for the next week were fine-tuned over the weekend and the team met for 2 hours each Monday to review plan for the week's activities and ensure lab resources and instructional plans were in place.

### B. *Kit and Materials*

Students purchased a lab kit of parts covering most of items consumed in the class. Some materials, such as the resin casting materials, were provided by the makerspace without charging to students. In future years, many of the components in the kit could be provided on a rental basis, e.g. protoboards.

### C. *Goals for the course*

The high-level goals for the course were to encourage more student use of the makerspace, promote development of a maker mindset in students (a bias towards low-resolution prototyping, documenting and sharing successes and failures with others, and offering time and expertise to help others in the makerspace), and create a maker portfolio as documented in a personal maker website/blog. The final curriculum for the course is shown in Table 1.

### D. *Grading scheme*

The student creator of the course proposed a grading scheme where students could choose to spend their time on the aspects of an assignment that were of most interest to them. Examples of this chose-your-own-adventure style of grading are included in Appendix I.

## Methods

An end of the semester, a survey was used to assess students' experience. The survey consisted of 8 Likert scale questions and 5 free response questions. The Likert scale questions targeted aspects of student self-agency, collaboration, sharing, the likelihood of using the makerspace in the future, and the likelihood of recommending the course to others. The free response survey questions, shown in Table 2, inquired about the aspects of the course that were most impactful for students.

***Table 1. Curriculum by Week, Theme, and Topic***

| Theme | Week | Topic |
|---|---|---|
| *Maker History and Culture* | 1 | ***Intro, Sharing Culture*** |
| *Draw It to Make It* | 2 | ***2D Drawing*** |
| *Draw It to Make It* | 3 | ***3D CAD*** |
| *Inspiration, Upcycling* | 4 | ***Inspiration - Teardown*** |
| *Draw It to Make It* | 5 | ***3D Printing*** |
| *Smart and Interactive* | 6 | ***Electronics*** |
| *Smart and Interactive* | 7 | ***Arduino Programming*** |
| *Exploring Medias* | 8 | ***Silicone Molding*** |
| *Smart and Interactive* | 9 | ***IoT*** |
| *Ideation, Exploration* | 10 | ***Final Project Time*** |
| *Exploring Medias* | 11 | ***Multiple Media*** |
| *Sharing Through Documenting* | 12 | ***Final Project Time*** |
| *Sharing Through Documenting* | 13 | ***Telling Your Story*** |
| *Sharing Through Presenting* | 14 | ***Final Project Time*** |

***Table 2. Free response survey questions***

| |
|---|
| What was the most impactful experience that you had in this course that you have not had in other courses? |
| Which aspects of the course (ie. grading scheme, weekly projects, broad scope, website submission, lessons during class, time in the construct) worked? |
| Which aspects of the course (ie. grading scheme, weekly projects, broad scope, website submission, lessons during class, time in the construct) did not work? |
| What would you like to see in future offerings of the course (things to keep, things to cut, things to add or change)? |
| Tell us about how this course has changed you or your perspective on your major. |

## Results and discussion

The student-designed maker course was offered in spring of 2022 as a 3-credit elective open to all students at the university. Enrollment was capped at 18 students due to space restrictions in the makerspace and to avoid overloading the use of popular equipment in any given week. With little advertising, the class quickly filled. The 18 students enrolled in the class represented 10 majors and 5 colleges, and were mostly second- and third-year students.

### A. *Response to Likert Questions*

Responses to the Likert questions are shown in Fig. 1. All respondents agreed they were more comfortable pursuing personal projects involving making after taking the course. Seven of eight respondents saw the value of collaborating with others in the maker environment, even for personal projects. Most students felt more comfortable sharing their process missteps and successes, though some students did not.

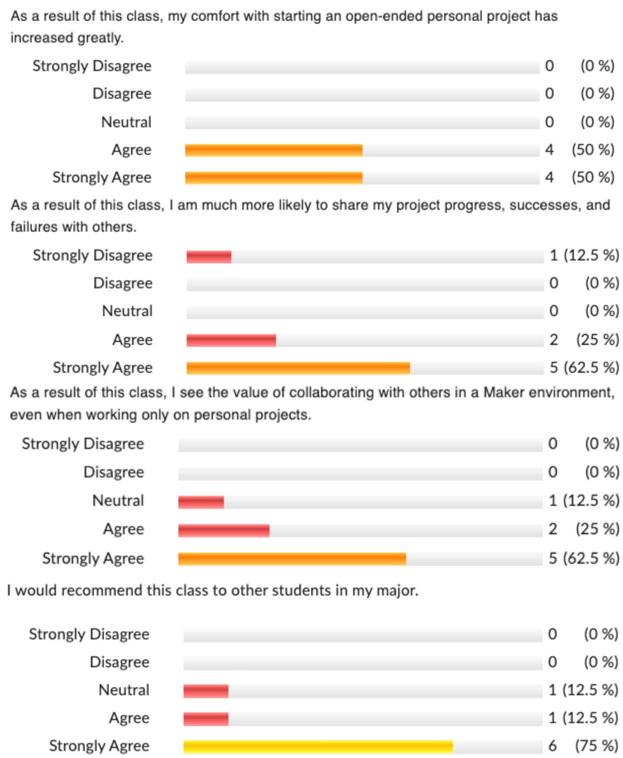


***Fig. 1. End-of-course anonymous survey results for Likert scale questions. All respondents agreed they were more comfortable pursuing personal projects involving making after taking the course. Seven of eight respondents would recommend the maker course to students in their major. Seven of eight respondents saw the value of collaborating with others in maker environment, even for personal projects.***

Seven of eight respondents would recommend the maker course to students in their major.

### B. *Most Impactful Experiences*

Students found benefit in collaborating with others in the makerspace, even when working on personal projects. Here is a student's comment about their most impactful experience:

> *"It was when I was able to speak with others about my progress with my personal project. This is the only course I had ever had where I was able to discuss my work with others and ask for feedback and suggestions. And to my surprise, they were eager to help me!"*

### C. *Flexible Grading Scheme*

Students found the flexible grading scheme very appealing and many students commented on it.

> *"The rubric/grading style where there were multiple ways to get the same points was a great touch."*

### D. *Personal Portfolio Website for Submissions*

Most students found the production of the personal website to be enjoyable and useful, although some students would have preferred submission using a word document or PDF.

> *"The website is a must-keep; this is one of the best things I learned from the class."*

### E. *Lessons Learned by the Instructors*

Students have grown more accustomed to flipped instruction modalities. Several students recommended that more of the course be offered using pre-work videos to enable self-paced learning, especially for the CAD portion of the class. In future offerings of the course, pre-recorded resources can be created for components of the curriculum that are likely to remain unchanged from year to year.

To manage faculty workload, the course could be offered as a series of one-session workshops taught by teaching assistants who are students that have previously taken the class.

## Limitations

The survey results may suffer from survivorship bias as the number of survey respondents was approximately half of the total class population.

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**Appendix I – Grading Scheme Examples**

### TEARDOWN GRADING

*A score of 100 will give you 100%. (This rubric is intended to give you the freedom of choosing what you want to focus on.)*

**+30: Inspiration slide finished**

+5: What kind of fasteners did they use? (screws, glue, snap, …)
+5: Identify one part that you couldn't recognize (take a photo)
  +5: What is the purpose of it?
+5: What were a few things that were surprising or unusual?
+5: Identify a marking on the product - what does it mean?
+5: What was the hardest part of taking the product apart?
+5: Include at least 2 pictures
+10: How has technology improved since this product?
+10: Identify differences in the materials used, soft and hard plastics, sheet metal vs castings, and printed circuit board and electronics
+5: Was this product designed to last forever, to be repaired, or to be landfilled?

**+30: Enhancement slide finished**

+15: Show a render of the CAD model
+5: Look up online reviews for the product. Does it fix a complaint found in an online review?
+5: Does it fix an accessibility issue, e.g. would this make it easier for a person with limited dexterity or limited vision to use the product?

### CAD GRADING

***A score of 35 will give you 100%.***

+10: Model an existing thing from measurements, include a photo of it as proof
+20: Use a canvas image
+15: Print/manufacture your model
+5: Model multiple components and use joints
+10: Explain how the thing you modeled could help you or people around you if it were 3D printed
+10: Use a tool/feature that was not covered in class
+10: Create a drawing using Fusion's Drawing workspace
+5: Include tolerancing
+25: Make an animation or simulation using Fusion
+25: Use generative design
  +5: Add a decal
  +5: The decal is your logo
+5: Edit appearance
+10: Create a render

**Appendix II – Materials for Maker Course Student Kits**

| Week/Topic | Item | # per Student | Extended Price |
|---|---|---|---|
| Low resolution prototyping | Foam core sheet 4mm | 1 | $5.35 |
| Low resolution prototyping | Xacto knife | 1 | $1.07 |
| 2D Design | 2.25 inch button materials | 2 | $0.40 |
| 2D Design | 1/8th inch plywood | 1 | $2.09 |
| 2D Design | Nametag magnet | 1 | $1.00 |
| MP3 Player | DFPlayer Mini MP3 Player | 1 | $5.90 |
| MP3 Player | 5V battery bank | | $0.00 |
| MP3 Player | Breadboard | 1 | $3.33 |
| MP3 Player | Micro SD Card | 1 | $3.00 |
| MP3 Player | 4 Ohm Speaker | 1 | $5.00 |
| MP3 Player | Flush cutters/Wire stripper | 1 | $2.75 |
| MP3 Player | Breadboard button pack | 3 | $0.39 |
| MP3 Player | PCB prototyping board | 1 | $0.00 |
| Programming Micros | RoboRed Arduino board Yourduino | 1 | $12.00 |
| Sensors | Ultrasonic distance sensors | 1 | $1.50 |
| Sensors | I2C OLED display | 1 | $2.80 |
| IoT | Arduino Nano 33 IoT | 1 | $18.40 |
| IoT | Level Shifters | 1 | $1.70 |
| Multimedia | Silicone rubber | 1 | $7.22 |
| Multimedia | 2-part resin | 1 | $3.17 |