Making Across the Curriculum: Multidisciplinary Making at Folsom Lake College

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INTRODUCTION

Makerspaces in academic settings have gained in popularity in recent years [1], becoming available to such a degree that many believe incoming students will come to expect these facilities on campus [2]. While a new body of literature on academic makerspaces is growing, much of it relates to the practical aspects of designing, outfitting, and managing these spaces [3]. To date, there are far fewer published resources on how universities have adapted or created new curricula to best use their makerspaces [4], and the majority of these reports focus on engineering students and skills (e.g. [5], [6], [7] [8] [9]). But making can be used as a valuable pathway to these same skills in other disciplines, such as math [10] and science [11].

Making applied to disciplines outside of Science, Technology, Engineering, and Math can empower students who don't have an overt interest in these courses of study, to develop the same skills and mindsets that benefit STEM students and professionals. One of very few examples of curricula delivered, at least in part, through a campus makerspace showed the power of making in non-STEM disciplines to attract and retain students who would not otherwise think to enter a makerspace or major in science [12]. This empowerment and broadened access to the type of skills to be learned in a makerspace aligns well with the primary mission of the California Community Colleges, which endeavor to bring quality academic and vocational instruction to all of the state's residents, contributing to California's economic growth, and preparing students for transfer to four year institutions. Despite the vast number of students these institutions of higher learning collectively serve, the potential for activating students toward STEM skills through making experiences [13], and the benefit to students entering the 21st Century workforce of developing a maker mindset [14], there is virtually no published work specifically focused on community college maker-aligned curriculum. Examples of how various faculty can be activated toward incorporating making for their students are likewise rare. This paper is intended to provide such a resource and a case study of a co-developed non-STEM course that heavily features making experiences for students.

IMPLEMENTATION

Setting. Earning its initial accreditation in 2004, Folsom Lake College (FLC) is a comprehensive, public community college serving the communities of eastern Sacramento and western El Dorado counties in California. Of the college's over 8,000 students, 61% are aged 18-24, and 71% report that their primary educational goal is to transfer to a four-year university. The FLC Innovation Center is a 1,700 ft^2 makerspace dedicated to serving these students. Increasingly, the Innovation Center has become a recruitment tool for the college, and a popular stop on regular outreach tours for prospective students and community groups from throughout the service area. In this way, the Innovation Center is well-positioned to develop the maker mindset in students traveling the pipeline between FLC's service area and many other institutions of higher learning.

Folsom Lake College, home to the Innovation Center, was among the 24 California Community Colleges to receive competitive funding from the statewide CCC Maker Initiative in 2016. [15] In operation since 2001, the Innovation Center houses collaborative work areas surrounded by prototyping equipment including 3D printers, CNC machines, a laser cutter, digital embroidery machine, sewing machine, and related makerspace tools and technologies. In addition, the lab features dedicated space for digital audio and video recording. The Innovation Center hosts workshops on topics ranging from digital fabrication technologies to design thinking. Five student workers support the day-to-day operations of the space, and interface with faculty, staff, students, and community members during weekly open-access lab hours. Innovation Center efforts are coordinated by a full-time faculty Instructional Design and Development Coordinator, who oversees makerspace operations and provides professional development support to other faculty so they can incorporate making practices into their courses and curricula.

Supporting the necessary learning culture begins with developing the faculty. Making-aligned educative practices follow from a long line of well-known and widely embraced pedagogical theory [16]. While these philosophies highlight the importance of authentic, personally meaningful, active learning to how learners build their knowledge, the most common mode of instruction in post-secondary education remains focused on direct transmission (and not as often the application) of certain skills. The National Research Council noted the need to move from a skills-based, technical literacy approach to a technical competence that requires more practice applying in-depth knowledge [17]. Fostering the types of learning experiences that justify increased adoption of makerspaces on college campuses therefore requires a shift in the teaching culture, and thus professional development and support for how to effectively use these resources.

Faculty play a crucial role in building support for maker activities and in bringing making into the curriculum at FLC. It has been critical to employ a comprehensive strategy for helping faculty infuse maker activities in their practice. This approach incorporates both direct professional development experiences, and ongoing support for faculty as they engage students through making.

In 2016, the college's makerspace coordinator collaborated with the current statewide Project Director for the CCC Maker Initiative, and with Sacramento Hacker Lab, a local makerspace, to create a two-week faculty professional development maker academy. The academy was focused on helping faculty incorporate design thinking and prototyping tools and skills into their courses. Eight faculty representing five different regional community colleges completed the training, developing and presenting prototypes of course activities and lesson designs.

Ongoing professional development for faculty includes technical skill-building, instructional design support for the development of curriculum—including student learning outcomes—and prototyping instructional activities and manipulatives for faculty to use in the classroom, using rapid prototyping tools and techniques. The Instructional Coordinator is actively involved all of these activities, including co-developing curriculum with faculty from across campus.

Once faculty develop familiarity with a maker mindset, they are ready to begin developing maker activities for use with students. At FLC, this development is carried out with the recognition that presenting multiple points of entry for faculty with various skill levels and comfort with incorporating new ways of teaching into their practice is essential to adoption. This intentional effort to infuse maker activity and mindset into courses and programs of study serves multiple purposes: to provide long-term sustainability for the space and its programs, and more importantly, to change the college culture to benefit students.

MAKING THROUGH THE CURRICULUM

The following examples represent a continuum of faculty engagement in making activity and curriculum integration (Fig. 1), in order of effort, low-to-high. In each of the examples, faculty model maker mindset behaviors, either by developing makerspace projects with which students interact within the context of a course activity, or by providing op-

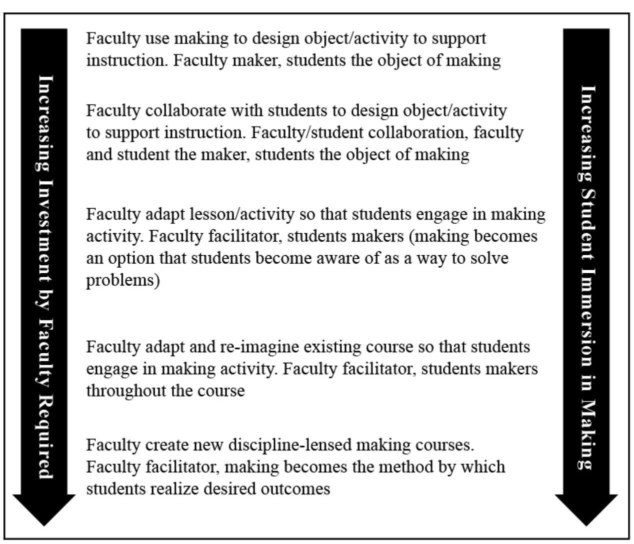

Figure 1. Continuum of maker activity and its intersection with curriculum

portunities for students to engage in maker activities.

Faculty use making to design object/activity to support instruction. Faculty wishing to incorporate making into their courses commonly begin by developing an object used to support instruction. For example, a Chemistry faculty member collaborated with the Instructional Coordinator in the makerspace to create UV development boxes, to be used by students in a hands-on cyanotype print-making activity. In the first prototype iteration, the faculty member repurposed discarded lighting fixtures, adding commercially available UV LED spotlights. For the second iteration, the faculty member built upon his experience, using power tools and laser cutter to create from-scratch wooden boxes, which he then equipped with an internal array of UV LED and an integrated cooling system, assembled and soldered from components scavenged from desktop computers.

Faculty collaborate with students to design object/activity to support instruction. For faculty with ideas and enthusiasm, but who lack skill or experience, partnering with students has proven an effective model to help those faculty to begin to engage with making. This often takes the form of a faculty member collaborating with a skillful student or group of students to design and develop a model or manipulative to support an existing lesson, with the bulk of the technical production being the responsibility of the student. Examples include a collaboration between History faculty and students to create 3D-printed and laser-cut game pieces for a classroom test review activity, and Mathematics faculty working with students to design and print a variety of manipulatives to support Calculus and Trigonometry instruction. In cases such as these, the Instructional Coordinator who runs the makerspace knows the skillsets of the students who frequent the space and connects faculty directly to the students with the most appropriate expertise.

In both of the preceding examples, the focus is on the faculty, and on their use of makerspace resources independently or in collaboration with students to create objects to support instruction. In doing so, they are demonstrating application of elements of the maker mindset and design thinking, including collaboration, prototyping, and iteration. Further, in both of these examples, faculty spend time in the makerspace, modeling behaviors that in many cases lead students to become engaged with maker activity. As faculty become comfortable with both the maker mindset and prototyping skills, they transition from applying the skills and mindset in their own practice to understanding the empowerment afforded through making, and begin to intentionally develop activities through which students engage with making.

Faculty adapt lesson/activity so that students engage in making activity. The next level of faculty incorporation of making into curriculum integrates into an existing course one or more activities that involve students in making. For example, students in *Early Childhood Education 342: Constructive Math and Science in Early Childhood Education* spent a class session in the makerspace to engage in a facilitated design thinking activity, leading to the development of prototypes of math and science activities for young children. Having been introduced to the makerspace, several students returned to develop additional prototypes for class projects.

Faculty adapt and re-imagine existing course so that students engage in making activity. The next model of faculty engagement activity represents a deepening commitment to the maker mindset, and a corresponding increase in the time required to modify both curriculum and classroom practice. For example, Business faculty modified a traditional course in entrepreneurship to incorporate design thinking and maker activities, resulting in what is essentially a new course: *Business 357: Entrepreneurship, Innovation, and New Enterprise Development*. Formerly a traditional course in entrepreneurship, leading to the development and presentation of a business plan, the curriculum was redesigned to focus on design thinking in the business development process, and to provide opportunities for students to utilize the makerspace for product prototyping and iteration. Students are able to design and develop physical prototypes, when formerly they might have simply focused on conceptual drawings. Further, through iteration made possible by rapid prototyping equipment, students can produce more sophisticated and more developed products, expanding the universe of possibility for new business endeavors.

Faculty create new discipline-lensed making courses. The creation of new discipline-lensed maker courses represents deepest commitment to making on the part of the faculty member, and a corresponding commitment in time. Several of FLC's faculty have embraced an effort to create new courses in a variety of disciplines, incorporating design thinking and the maker mindset. This intentional development of maker courses in non-STEM disciplines represents an interest in expanding the student pipeline to include students from a variety of majors and fields of study. In partnership with the Innovation Center's Instructional Coordinator, FLC faculty are developing a variety of courses in STEM and non-STEM disciplines, including an Anthropology course, titled "Ancient and Modern Making," a course in History titled "Making History," and an Environmental Studies course in which students will use making to address problems related to environmental topics such as water, waste, and energy. In each of these hands-on courses, students will integrate making with the theoretical frameworks and habits of mind of their respective disciplines. Two discipline-lensed making courses have been fully developed and approved by local and district curriculum committees: *Early Childhood Education 452 - Making for Educators* to be offered in fall 2019, and *Sociology 479 - Making Social Change*, which was piloted in fall 2017.

SOC 379: Making Social Change Course Design. The first of FLC's discipline-lensed making courses to be offered, *Sociology 379 - Making Social Change*, was developed over a two-year period as a collaboration between the Innovation Center coordinator and Diane E. Carlson, Ed.D., Professor of Sociology. Through formal processes at the local, district, and state levels, the course was approved for California State University and University of California transfer, and incorporated into college degrees and certificates, including Interdisciplinary Studies: Social and Behavioral Sciences (A.A. Degree), Modern Making (16 unit Certificate), and Sociology (A.A. for Transfer (AA-T) Degree).

Development for this course began with the identification of Student Learning Outcomes (SLOs):

- Employ social movement theories to analyze the historical, social, economic, political, resource, and geographical contexts of social movements and their organizations.
- Evaluate the relationship of social movements and social movement organizations to technology and tools.
- Assess ethical dilemmas and choices both within social movements themselves and in relation to the tools and technology they use.
- Evaluate the relationship of access to tools and technology to power and empowerment.
- Research, design, develop and prototype possible solutions and responses to social justice issues, using a variety of technologies, tools, techniques and materials.

Working forward from the SLOs, faculty developers identified a variety of representative social movements and tactics, then mapped those social movements to makerspace skills. As part of the curriculum development process, prototypes of potential course activities were shared with students during two preview events held in the makerspace, in an effort to learn from students how the course might impact their lives and the issues that were meaningful to them, and to gauge interest in the activities themselves. The pilot of the course, co-taught by Dr. Carlson and the Innovation Center Coordinator, was offered in fall 2017. The course met in the college's makerspace, and 12 students enrolled and completed the course.

With a focus on hands-on activities, skills development became a prerequisite for helping students achieve the SLOs for the course. In an effort to gauge interest and experience in a range of makerspace tools and areas of project interest, and to help identify students who could scaffold their peers, students completed skills and social justice issues inventories during the first class session. Throughout the course, students were provided direct instruction on foundational skills, including basic shop safety, personal protective equipment, the safe operation of hand and power tools, fabrication and prototyping tools, including laser cutter, CNC, 3D printer, vinyl cutter, sewing machine, basic circuits and electronics, and makerspace-related software, including vector drawing and three-dimensional modeling software.

Course Flow. Each course session began with a discussion of a social movement or tactic, and students had the opportunity to apply their learning by completing hands-on projects. For example, week seven readings and discussion focused on the Zapatista National Liberation movement, leading to a broader class discussion about the role of muralism, graffiti, and protest art in social movements. Students then worked independently to create a work of protest art, based on a social issue of their choosing. (Fig. 2) Using Stencil Creator (http://stencilcreator.org/), a free online tool, they created vector files, then prepared those files for the laser cutter, ultimately creating stencils that they used to spray paint the walls of an impromptu gallery created outside of the makerspace. Each hands-on activity became an assessment opportunity, as students demonstrated competency through synthesis of their understanding of core Sociology concepts, and through application of maker skills and processes, all while navigating issues of scale, resolution, the affordances of various materials, graphic file formats (e.g,. vector versus raster), and the software required to create and prepare files for various rapid prototyping technologies.

Final Project. For their final projects, students were asked to use the design thinking process to develop and prototype projects to make visible, inform, draw attention to, solve, empower, or connect to a social justice issue of their choosing. Students were placed into instructor-designed groups; group composition was based on an assessment of student maker skills, and on social justice issue affinity. The groups chose the basic social issue around which their project would be designed (e.g., food insecurity, reproductive rights and sexual health), then completed basic research on their topic and its implications for the local community. Employing design thinking methodology, students next interviewed community members and visited organizations related to their issue, then synthesized those learnings to develop problem statements, which they presented to faculty for back. Continuing through the design thinking process, they brainstormed and refined potential solutions, leading to the development of prototypes, synthesizing their understanding of the tools and tactics of social change, and using the digital fabrication skills they had developed through weekly hands-on projects. Finally, students presented their projects and prototypes to the class and to invited members of the college community.

One group worked with a local Planned Parenthood chapter to design an outreach event on the FLC campus, based on the problem statement: “Planned Parenthood needs a way to communicate to students the range of health services it provides.” The students coordinated with representatives of the organization to schedule an event on campus, including a display to help educate students on the services provided. One of the group’s students was skillful at sewing and embroidery, and the group created a quilt to display at the event, representing the “A-Z of Planned Parenthood.” (Fig. 3) They prototyped individual squares to determine the

Figure 2. A student commits her stencil to the social movement art display as part of the Making Social Change course.

***Figure 3. Students and Planned Parenthood staff display a final project from* Making Social Change.**

overall layout and arrangement, then used the Innovation Center’s laser cutter to cut shapes and letters that were appliqued to 26 larger squares of fabric. To encourage passersby to interact with the quilt, students designed some of the squares with pockets to hold literature related to various services provided by Planned Parenthood. They assembled and machine sewed the squares together, and measured, cut, and assembled a PVC pipe frame to support the quilt. The prototype completed, students coordinated with Planned Parenthood to display the quilt at an informational table on campus. The combination of “traditional” fiber arts skills, with the use of the laser cutter enabled one group member to extend her existing expertise to digital fabrication technologies, while providing her with opportunities to scaffold her peers in their own skill development. After the conclusion of the course, group members adapted the display frame to enable them to march with the quilt in the 2018 Sacramento Women’s March.

DISCUSSION

Piloting a new course often presents new challenges, and opportunities to improve. Here are the lessons learned from running the first *Making Social Change* course in the Innovation Center.

Lesson the First - Skills Development Takes Time. Faculty reported underestimating the time it would take for students to develop the necessary skills to effectively utilize the various pieces of makerspace equipment. Technical skills are not a given, perhaps especially for students in non-STEM disciplines, and students began the course with varying levels of experience in using software. For version two of the course, to be offered in fall 2018, faculty hope to find ways to help students develop the skills asynchronously, through an increase in the incorporation of online tutorials, and by exploring additional ways to foster peer-to-peer support and skill development.

Lesson the Second - Bottlenecks in Workflow. As students developed skills and became more comfortable using various prototyping technologies, machine access became a bottleneck. Potential solutions to this problem include adapting protocols for machine access, and scheduling and increasing makerspace open lab hours, enabling students to work independently outside of the scope of the class. Additionally, machine use patterns will inform makerspace equipment planning.

Lesson the Third - Design Thinking and the Maker Mindset. Students were unfamiliar with design thinking as an approach to problem solving and solution development, and had to be guided away from working on a solution before employing empathy to create precise and actionable problem statements. To help students achieve course outcomes, they were given opportunities to practice design thinking during in-class activities, and were accountable for providing evidence on all steps in the process during their final project presentations.

Student self-assessment. At the conclusion of the pilot offering of *Making Social Change*, students were asked to reflect on their experience, and the degree to which they felt they had achieved the outcomes of the course. Students reported feeling empowered by the skills development. One student shared:

"I'm really proud of what I did in the final project, and I also think I pushed myself to new limits in the other aspects of class too. I HATED the day we used power tools because that stuff just freaks me out, but I did it anyway and it actually really helped when I moved into my new place. I was able to use my own drill and hammer to hang up photos and things without my dad's help!"

CONCLUSIONS

Embarking on learning experience design, whether a single activity in an established course, a redesign of an existing course, or the creation of something completely new is an exciting challenge. As makerspaces proliferate on college campuses, it is important to keep in mind the mission of the spaces and the institutions that house them. At a community college in California, new learning experiences are being piloted to a broad audience and yielding information that is useful to the field at large.

The primary learnings from Folsom Lake College's efforts to infuse making across the curriculum are summarized below.

- The success of integration of making activities into curriculum hinges on professional development, and the degree to which individual faculty see themselves as makers/embrace the maker mindset.
- Students are often the vector for introducing faculty to new technologies and skills.
- Ideas for class activities can come from faculty or students, and are encouraged by spending time in the makerspace. Often, new ideas for activities and courses come from faculty seeing the examples their colleagues are championing/evangelizing. Publicizing good examples can help set the culture for the whole college.
- Having faculty and students spend time in the same makerspace is invaluable. These interactions often help to extend the thinking of both faculty and students, and faculty modeling of maker mindset behaviors often leads students to become engaged with maker activity.
- Faculty begin by a) developing maker skills (professional development), b) applying those skills to a course activity (cyanotype example), c) collaborating with students in the development of maker projects, d) empowering students to use makerspace resources in the completion of class projects, e) incorporating making activities into existing courses, and e) designing courses that specifically address maker activities.
- The importance of a faculty member who is not associated with any single discipline, and who is very familiar with the mindset and tools of the makerspace, cannot be overstated.

The overarching goal for bringing making into students' curriculum is not only to help them learn discipline knowledge, but to create 21st Century thinkers and doers—makers. The power of making to this larger goal is on clear display in one student's final self-evaluation: *"The Innovation Center and the Making Social Change class gave me access to tools and information I wouldn't have anywhere else. I have been able to create projects from my imagination and build skills and knowledge that help me in my life, my education, and my career."* She connected the activities in the course to a statement of empowerment that touches many important areas of her life. And that's the whole point.

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