Library and Student Innovation Center: Makerspace!

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***Abstract*— In May 2012, Governor Mead, the State legislature, and the Wyoming Governor's Energy, Engineering, and STEM Integration Taskforce articulated a vision to propel the College of Engineering and Applied Science (CEAS) and the University of Wyoming to the realms of "excellence in instruction, research, and service." Part of this initiative included development of a network of Student Innovation Centers (SIC) on the University of Wyoming campus. The initiative began with the development of the Coe Library Student Innovation Center (CSIC) makerspace, in order to spark student innovation, creativity, and design skills. This was a cooperative effort of the College of Engineering and Applied Science together with the College of Arts and Sciences, the College of Education, and the University of Wyoming Libraries. The initiative also included development of another active learning "makerspace" in the new Engineering Education and Research Building (EERBSIC). Makerspaces employ technology along with hands-on education to spark student innovation, creativity, design, and entrepreneurship. This paper describes the importance of makerspaces to education, the step-by-step approach used to develop and launch a makerspace, lessons learned and used in the development of the EERBSIC, and a sample of programs conducted within the makerspace. This paper serves as a useful guide for other institutions that are considering setting up a makerspace.**

***Index Terms*—makerspace, active learning, STEAM, innovation, entrepreneurial, problem-based learning, constructivism, constructionism, DIY**

I. INTRODUCTION

Over the last several years, an interdisciplinary team has stood up a makerspace within the UW Library (CSIC). The team has gathered considerable information from the literature [1-39], from a variety of sources discussed in the paper, and lessons learned about developing a makerspace – information that the team believes will be valuable to other institutions pursuing this same goal. In this paper, we answer the following questions: What did we do? Why did we do it? What was our motivation? What are our goals? What is the current status of the project? Where are we heading?

II. BACKGROUND

In May 2012, Governor Mead, the State legislature, and the Wyoming Governor's Energy, Engineering, and STEM Integration Taskforce articulated a vision to propel the College of Engineering and Applied Science (CEAS) and the University of Wyoming to the realms of "excellence in instruction, research, and service." Part of this initiative included development of a network of active learning "makerspaces."

One of the primary objectives of the initiative was to develop a location for exploration of creative ideas. A makerspace provides a location for students to explore ideas, complete class projects, or pursue an entrepreneurial innovation. As a general concept, university makerspaces present both formal and informal learning opportunities to students. From an educational perspective, makerspaces espouse constructivism and constructionism as learning philosophies, incorporating collaborative and problem-based activities. Essentially, the expertise and tools provided in makerspace facilities foster a hands-on approach to learning based upon individual interests, building upon intrinsic motivation [40]. Whether a student wants to learn a new skill to improve classroom performance or participate just because it seems interesting, they can work within a makerspace to identify these opportunities. In some cases, a facility might offer regular workshops on a topic. In others, there might be a one-time event that showcases a particular expertise. The open access, drop-in approach to facility operation encourages visitors to visit at any time to tinker or explore.

There's also the notion of university-based makerspaces serving curricular needs by providing tools and resources necessary for completing class projects. An example here might be a seminar on problem-solving and design that challenges student teams to identify a problem, research existing solutions, and propose a new solution through designing, prototyping, and testing. In some cases, these experiences create entrepreneurial opportunities. In one case, a student-team used a makerspace to design a lighted-seat prototype of a child's toilet with a Bluetooth®-enabled application to help parents potty-train their toddlers. These types of projects can be entered into innovation

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competitions or used as the foundations for other business opportunities.

The maker movement had already come to campus with the opening of the College of Education Makers facility, established within the College of Education in Fall 2014, and the UW 3-D ArtScience and STEM Maker Laboratory, established in the Department of Art and Art History in Fall 2015.

To help maintain this momentum, the SIC planning committee agreed that an intermediate and more centrally located facility might assist with broader campus goals, build anticipation for the new facility, and launch a network of makerspaces on campus to maximize impact and use. Committee meeting discussions took into consideration guidance and advice learned from opening the other spaces, including an absolute need for a facility to be easily accessible and visible to students.

When innovation and maker labs are not directly in the flow of typical student traffic, they become destinations that require forethought and planning rather than open-access, inviting spaces. Additionally, windows looking into a facility provide valuable free marketing to advertise the kinds of activities and projects that happen in the space, generating curiosity and conversation. These considerations led the committee to look toward buildings on campus that featured fewer administrative offices and more spaces oriented toward student services. Early conversations with University Libraries revealed a desire to collaborate and opened up potential for available space. This collaboration presented an opportunity to begin scouting for optimal locations within the main library. Ultimately, a large (2500 square foot), mixed-use study area emerged as the most suitable space to convert into an innovation center. The area was designated the Coe Library Student Innovation Center, or CSIC.

The purpose of the CSIC is to provide experiential learning space for STEAM (science, technology, engineering, arts, and math) students. The CSIC provides a location for students to explore ideas, complete class projects, or pursue an entrepreneurial innovation. Also, the space is available to conduct classes and workshops. The space is coordinated and managed by an onsite specialist. The CSIC planning team consisted of an interdisciplinary group of faculty members and students with a common interest: hands-on, innovative learning.

With representatives from the library now on the committee, plans commenced in late 2016 with the purchase of modular walls to enclose the area and the design of a layout for new equipment and furniture [41].

During the preliminary planning stages, faculty within the CEAS were surveyed to find out how an innovation facility could fit with their current practices and future curricular plans. This survey helped inform later data-gathering efforts as the committee prepared proposals to seek internal and external funding for the SIC network effort. In terms of existing practices that could benefit from or be expanded by a makerspace, CEAS faculty highlighted activities including fabrication, prototyping, machining, programming, and design related to software, interfaces, virtual reality, and production. Responses about fabrication focused on circuit boards and related assemblies, fluid dynamics, concrete beam construction, concrete batching and testing, and structural member testing. Future curricular goals indicated a desire to expand more into 3D printing models, parts, and entire assemblies with particular emphasis on a variety of materials. Other plans selected include robotics experiments, micron-scale fabrication, and rapid prototyping. When asked about how such a facility might be used outside of formal curricula, CEAS faculty noted that the innovation centers could assist during recruiting tours, attracting students, parents, and partners. Additionally, the spaces should accommodate projects and competitions such as the Chemical Car Competition, Department of Energy (DOE) wind energy, American Society of Civil Engineers (ASCE) Concrete Canoe, ASCE Steel Bridge, robotics competitions, design competitions, and NASA design competition(s).

As construction on the CSIC began in early 2017, the decision to locate the facility in a central, visible location helped to generate interest in the facility. Some students were already familiar with these kinds of centers because of two existing makerspaces on campus, and their word-of-mouth exchanges helped to generate excitement. Students began contacting planning committee members with questions regarding new student organizations such as a blacksmithing club and a 3D design and prototyping club. Additionally, faculty members began to inquire about how to teach an entire course or schedule individual classes in the library space.

Hundreds of university-based makerspaces exist around the United States, offering a variety of facility experiences. In 2015, a review of top-ranked universities found that 40 had at least one makerspace, with the vast majority indicating that the facility was housed in a department other than Engineering and/or was open to the broader campus [42]. It is interesting to note that three of the universities hosting makerspaces listed more than one facility, indicating different emphases or contextual applications for the facility equipment. Also the review noted that the most common equipment provided in these facilities were 3D printers and textile work; e.g., sewing machines, followed by computers for design and research/collaboration. Unfortunately, the review did not explore the kinds of activities conducted in these facilities or how the institutions with multiple makerspaces viewed their individual or collective roles.

A recent special issue of the International Designs for Learning showcased the learning designed for makerspaces in cooperation with how they are designed [43]. The profiles of university makerspaces describe using the facilities to introduce students to newer technologies such as microcontrollers, circuitry equipment, 3D printing, augmented reality, videography, and 3D design. One of the universities also provided unique and specific guidance related to extracurricular design challenges rooted in realistic problems and helping students showcase their productions through visible displays and scout-style badges.

The existing makerspaces on campus, along with the profiles and reviews of other university facilities, helped guide decisions related to differentiating the CSIC. While emerging literature and popular media continued to cover the booming maker movement, most of the universities profiled operated a single large facility. By launching a third facility with the fourth under construction, the University of Wyoming inherently established a commitment to supporting student innovation through a variety of channels. The strategic approach to include the existing facility coordinators ensured a holistic plan that considered the needs of other disciplines as integrated and interdisciplinary with the CEAS. Once the initial planning and equipment ordering were completed, the committee's attention turned toward how to maximize use of the facility for both in- and out-of-class opportunities. For example, various courses within the education and engineering colleges were identified as possible candidates for scheduling in the innovation center to expose students and integrate the tools as a learning strategy. Similarly, discussion included what kinds of special events to host. One early example included a rave-like dance party in the evening, featuring collaborative demonstrations from theater, music, and electrical engineering faculty and students on set-up, sound production, and music mixing. As student interest expanded, committee members also worked to identify possible faculty sponsors for specialized student organizations to ensure regular use of and scheduled programming in the facility. In essence, the interdisciplinary and multi-faceted approach to use blended together concepts represented in other institutions.

III. Methods

In this section we provide a step-by-step, chronological listing of activities accomplished to establish the makerspace in the UW Library.

A. Formed interdisciplinary team

Starting in the summer of 2015, the CEAS and the Dean of the University of Wyoming Libraries (Libraries) first openly discussed the idea for a makerspace, or CSIC, within the UW Coe Library. The Dean of Engineering was interested in laying the groundwork for jump-starting a student innovation and entrepreneurship space that would be in the new CEAS EERB. By using space, the library could be modified to work as the interim makerspace. Equipment could be purchased and the facility could be used ahead of the actual opening of the new facility. In the fall of 2015, a Memorandum of Understanding between the CEAS and Libraries was agreed to with the understanding that the Libraries would provide and modify the space while equipment and staffing needs would be provided by the CEAS. With the completion of the new EERB building, the furniture and equipment would be assessed and anything that was still appropriate for the new space would be transferred. Ultimately, the overwhelmingly positive responses from the UW community towards the interim makerspace led to the decision to keep the CSIC space as a complementary sister facility to the EERBSIC.

The Deans approached the Associate Dean of Libraries and two librarians to start the discussions. After that initial meeting, a group was created to start the planning for the CSIC. The early planning team consisted of two librarians (heads of the Brinkerhoff Geology Library and of the Learning Resource Center) and one engineer from the Chemical Engineering Department. Members of the team were already familiar with the concept of a makerspace and were excited about helping facilitate this idea. The purpose of this team was to explore the arrangement for creating the space in the library and identifying equipment and costs appropriate for a facility within the library.

B. Investigated other makerspaces on campus

We also learned about other spaces on campus with makerspace equipment. There is a small space devoted to making in the College of Education; the Learning Resource Center has tinkering equipment, and the Art Department has some 3D printers and a vinyl cutter. With the goal of the new Coe Student Innovation Center (CSIC) to be a space for anyone to use, the team decided to bring in the individuals working on these spaces. The UW Coe Library is of course a very busy space, so foot traffic could not hurt as we looked for exposure for the space and also to advertise the future home of the SIC in the new EERB. With this in mind, the team grew with the addition of representatives from the College of Education, Department of Art, CEAS Shop Manager, and a member from the University of Wyoming Information Technology Department.

C. Detailed planning efforts

In the fall of 2016, the group started to move ahead with the planning for the CSIC and were invited to take part to help plan for the SIC space in the new EERB (EERBSIC). The planning team started meeting every other week as the floor plan for the UW Coe Library was finalized and equipment for the space was ready to be ordered. We started our efforts to hire a manager for the space in the spring of 2017, intending to hire the part-time position starting that summer.

D. Developed concept of network of makerspaces

The existing makerspaces on campus and collaboration with these personnel demonstrated the potential to leverage local, contextualized facilities within disciplines with an open access model. The makerspace housed in Education targeted preservice teachers specifically and showed how these students might use the technologies as future teachers. The makerspace in Art targeted design students learning how to create in 3D with various media for artistic expression. The planned EERBSIC would target Engineering disciplines but also provide the greatest variety of tools and feature the largest space. In designing the CSIC, it became clear that a network of facilities might help coordinate access and focus contextualized activities and expertise. Originally intended to be temporary, the CSIC space is now maintained to work alongside the EERBSIC. Ultimately, the planning team decided that both SIC facilities should complement each other – with the CSIC aimed at K-12 STEAM outreach and introductory equipment and the EERBSIC geared towards advanced use and offering a wider array of state-of-the-art equipment. A student unfamiliar with emerging technologies might start their project and gain experience in the CSIC, before being shepherded to the next appropriate campus makerspace as their creative needs and interests evolve. In concept, this idea welcomes students to whichever facility is easiest to access and/or most comfortable for them. While discussing project goals or expectations, the visitor might be referred to one of the other makerspaces based on necessary tools, upcoming programming, and/or in-house expertise. For example, a student team in an Education seminar conceptualized an idea for easily moving bales of hay manually. The students used tinkercad.com to sketch the initial handle idea and brought it to the in-college makerspace. After consulting with the work-study students on staff, the team was referred to the Art makerspace to work with one of the interns to modify the design and produce it on one of their 3D printers. This networked approach helps mitigate potential overloading issues that are sometimes experienced in single facilities and helps reinforce the interdisciplinary approach embedded in the maker movement.

E. Visited other spaces to adopt best practices and lessons learned

The Pikes Peak Library District (PPLD) in Colorado Springs, Colorado has an outstanding makerspace at Library 21c. The Creative Computer Commons (C3) portion of PPLD has two makerspaces available for public use. These makerspaces are well established and well run. The development team took a fieldtrip to PPLD to learn more about the day-to-day operations of a makerspace [44].

F. Developed extensive equipment list for CSIC and EERBSIC

The development team constructed a list of equipment for both the CSIC and the EERBSIC based on the expertise of team members, recommendations from the PPLD C3 visit, and CEAS shop expertise. The list of desired equipment for the CSIC is provided in Table 1.

G. Established fund-raising goals

To fund the equipment for the CSIC, approximately $180,000 was required. The Dean of CEAS pledged the first $60,000 of equipment money. To raise the remaining funds, the development team approached two other groups on campus:

- The College of Engineering and Applied Science University of Wyoming Engineering Fund for Enrichment (UWEFE), and
- The University of Wyoming University Central Student Technology Committee.

These two student managed groups provided the balance of required remaining startup funding.

H. Hired director

In July 2017, the CSIC planning committee hired Mr. Tyler Kerr, a University of Wyoming graduate program alumnus, to oversee and direct the day-to-day operations of the makerspace. In his role as director of the makerspace, Mr. Kerr is responsible for managing employees, maintaining equipment, hardware, and software, and planning and implementing community and educational outreach. Mr. Kerr became the full time CSIC Director on July 1, 2018

Table 1. CSIC Startup Equipment List

Item	Description	Cost
LEGO® Wall	Variety of LEGO® creative material	$4300
LEGO® MINESTORMS®	EV3 core set with charger (5), EVS expansion kit (5), Pneumatics add-on set (5), EV3 cable pack (2)	$4400
little Bits® Pro Library	Collection of the Bits and accessories	$5000
Zortrax 3D printer	Desktop 3D printer	$3800
Vinyl Cutter	US Cutter MH 34in bundle	$300
Computers	Hewlett Packard Workstations (2) Hewlett Packard laptops (10) and security cabinet	$4000 $13400
Large Format Scanner	Epson Graphic Arts	$2200
Electronics Bench	Soldering station: Weller WLC100 40W soldering iron, safety glasses, magnifying light, 3D hands, solder sucker, other soldering paraphernalia Work Bench: Agilent 33120A Arbitrary Waveform Generator, Agilent E3631A triple output power supply, Agilent 34401A digital multimeter, Tektronix MSO 2024B mixed signal oscilloscope, National Instruments myDaQ with LabView , Rigol DSA815YTG Spectrum Analyzer (1.5 GHz)	$11000
3D scanner	ARTEC Eva	$16000
Arduino® startup package	Arduino UNO R3, Dagu Magician robots, Sharp IR sensors (20 kits)	$2900
Furniture	24 roll about tables, 48 chairs	$42000
Big screen	LG 65” big screen with touch overlay and Ergotran cart	$5785
consumables		$5000
	Total	**$120,085**

I. Established day-to-day operations

The CSIC makerspace is open to students from Monday to Friday and is staffed by one full-time staff member (the makerspace director) and seven students (makerspace educators). Typical day-to-day activities include short tours and demonstrations for curious students, printing objects for visitors, and brief tutorials on 3D printing. Presently, the CSIC caters predominantly to individuals and small groups interested in 3D printing. The makerspace staff also receive requests to 3D scan objects using the CSIC’s Artec Eva structured light scanner. At the same time, there are requests for tours – usually lasting one hour – from educators interested in demonstrating the capabilities of emergent technologies that can benefit a wide range of STEAM disciplines.

J. Staffing

The CSIC is staffed by seven student employees. Students hired were those who expressed a passion for emergent technologies, innovation, discovery, and creative design, and who had an interest in DIY projects. Experience with emergent technologies was not a job requirement. The CSIC Director developed rigorous in-house training programs during the first semester to fill any gaps in the student educators' knowledge of makerspace trends and to ensure that they were well-versed in the makerspace's equipment, hardware, and software. All CSIC staff members, including the Director, are expected to 1) monitor and maintain the center's hardware and software for optimal performance; 2) interact, assist, and engage effectively with a diverse population of K-12 educators, UW students, faculty, staff, and members of the local community; 3) develop and deliver brief onsite lessons, modules, or workshops for K-12, college and general audiences; and 4) respond to evolving community requests for new technologies or equipment.

K. Hours

Initially, the CSIC was open Monday through Thursday from 12pm to 8pm MT and Friday from 12pm to 7pm MT in order to accommodate visitors after work and school. The hours of operation were adjusted for the Spring 2018 semester to better suit morning visitors, since the CSIC received few visitors in the evening. Currently, the CSIC operates from 10am to 6pm MT.

L. Grand opening and ribbon cutting

The CSIC facility opened in the fall semester of 2017 with the grand opening during homecoming weekend October of 2017.

IV. RESULTS

Even without large-scale advertising campaigns, the CSIC has attracted plenty of attention thanks to word-of-mouth mentions. The center has welcomed 8,224 visitors since it started counting use statistics in September 2017. There have been approximately 374 visitors a month, of whom approximately 75% are drops-ins with interests in using equipment, and the remainder are tour groups wishing to engage in directed activities. On a given day, the CSIC sees an average of 12 unique visitors. Following a series of campus and community advertisements and workshops planned for the Spring 2018 semester, the CSIC saw usage dramatically increased. Information booths hosted in high traffic areas on campus attracted 990 student visitors across eight days, with the highest growth rate in usage (285% from September 2017 to 2018) directly following the four most popular information booth dates (567 total student visitors at the four information booths in late August and early September).

Equipment use leans overwhelmingly toward the 3D printers, followed by a few monthly requests for 3D scans of objects. Open houses and tours are requested most often by K-12 educators and youth organizations (e.g., Boy Scouts, Girl Scouts). Efforts to engage extracurricular collegiate groups, college classes, and campus student-led academic organizations will be addressed through more frequent advertising campaigns and informational hands-on open houses.

Crucial to the tracking of usage statistics is a recent initiative to digitize attendance and equipment use. The SIC team has recently established an event and equipment reservation system tracked through LibCal software. This system enables the team to get accurate counts of visitors, and also generates valuable data about equipment and space usage – which in turn provides an accurate metric with which to determine future needs for new equipment, workshops, or open houses in the space.

At present, one recognized student organization (RSO) meets weekly in the makerspace. The Association of Wyoming Student Makers (AWSM) is a 25-member group that uses the resources of the CSIC to design, create, and collaborate with like-minded peers and to champion a greater maker community within the student body. A primary and ongoing goal of the CSIC is to promote use of the space to as many additional student organizations as possible.

Two or three open houses or equipment demonstrations are typical each month. These events serve several purposes, such as: 1) fostering youth interest in the wide-ranging academic and hobbyist applications that a makerspace provides; 2) encouraging faculty and staff to consider how the space might be used in their curricula or in academic research projects; and 3) motivating community members to consider how the space might be used for personal, research, or hobbyist projects.

It is common for the CSIC to host three or four tours per month, largely for K-12 or young adult organizations. School tours often include a 30-minute tour of all the available technologies followed by interaction with specific equipment at the request of the organizer for the remainder of the period. Due to time constraints, the hour-long tours do not often include a 3D printing component. Most popular among young adults is a 30-minute introductory 3D modeling lesson using the user-friendly Sculptris program. At present, the CSIC has hosted over 240 events in the makerspace.

Several special events have been hosted at the CSIC. During the UW Impact Weekend (an event for high-performing high school students), the center held technology demonstrations for 125 visitors. The CSIC also hosted an activity for the UW Latina Youth Conference, at which 119 young women were encouraged to use the engineering design process and equipment at the CSIC to imagine, plan, construct, and test catapults for distance, accuracy, and precision using household materials. Furthermore, during the Wyoming State Science

Fair, the CSIC hosted an activity for 91 middle school students who had been challenged to think through the engineering design process and come up with creative solutions for buoyant, wind-powered, weight-bearing "cargo ships" made of Lego.

In June 2018, the course "Robots! - Introduction to Engineering and Computer Science," was taught as part of the UW Summer High School Institute in the CSIC. This course is designed to be an intensive, hands-on, motivational experience. Each student builds and programs their own robot. Along the way students learn about different engineering fields and also the basics of computer programming. The students take their completed robots home to continue with their exploration of this exciting topic. The course instructors found the reconfigurable space in the CSIC friendly and easy to use.

As yet, no college courses have been hosted in the makerspace. However, several faculty members have utilized the space to develop hands-on components for their coursework, including haptic feedback devices for hearing or sight-impaired individuals, chemical engineering petri dish supports, brain slice teaching reproductions, 3D printed cetacean skulls, and 3D printed woodwind reeds. The CSIC team is optimistic that the center will become an active hub for hosting courses. Both the CSIC and the EERBSIC are exploring the option of hosting a cooperative first-year seminar to introduce freshmen students to the capabilities of the makerspace network on campus.

V. DISCUSSION

Although the CSIC is not the first makerspace on the University of Wyoming campus, it is the first large-scale, multidisciplinary facility at the University to provide substantial, accessible, dedicated space for students to create, collaborate, and innovate. As such, the first semester of operation at the CSIC was met with many new challenges, such as: 1) finding ways to actively engage visitors; 2) ensuring print quality and overall quality control; and 3) promoting underutilized equipment in the space. Each challenge merits a closer look:

- **Finding ways to actively engage visitors.** Bearing in mind that the overarching goal of the makerspace is to provide a location for students to explore ideas, complete class projects, or pursue an entrepreneurial innovation, the CSIC team focused on meeting those first-semester challenges to the best of their ability. The early operational focus was primarily on space development, staff training, and visitor feedback in order to determine what resources, instruction, or workshops visitors would wish to see in upcoming semesters. Less focus was spent on campus-wide advertising, and any publicity was largely through word-of-mouth. During the second semester of operation, with staff trained and equipment operating well, the focus turned to the hosting monthly instructional workshops for faculty, staff, and students as well as to awareness campaigns such increased campus advertising (both print and online), as well as highly-successful information booths. University faculty and staff who might wish to host classes and conduct research using the space's facilities remain a challenge for the SIC staff to effectively engage. The main issue is one of timing: when the makerspace officially opened its doors in October 2017, faculty, educators, and researchers had already developed their curricula or research plans for the semester. Therefore, during the second semester, the CSIC team spent more time and resources raising awareness among faculty, staff, and graduate students using large-scale campus poster advertisements, email campaigns, and hosting faculty and staff open houses. Of the 240 events subsequently hosted, 92 have been informational tours or open houses geared towards increased engagement of specific groups. The team expects positive results from these ongoing efforts to be reflected in even greater faculty and staff participation in the academic year ahead.
- **Ensuring print quality and overall quality control.** 3D printers are the most popular technology housed in the space, and consequently the machines used most often. As a result, regular maintenance is required to ensure acceptable print quality. In the first semester of operation few visitors knew how to use the software necessary to 3D print objects. Because of this, most 3D printing, including prints for visitors, was completed by staff members. This proved to be challenging for the staff for two reasons: 1) print preferences and personal settings varied considerably; and 2) the first printers were largely unreliable and inconsistent over time. Care was taken to ensure consistency in use among staff members so that print quality and cost would remain constant over time. The CSIC set out to keep almost all services free and accessible to encourage frequent student use. Any charges, such as the $1.50 per hour to use the 3D printers, was implemented only to recoup the costs of consumable materials, a practice which is consistent with other 3D printing price models on campus. The issue of cost, however, does play a role in the larger issue of quality control, since different settings influence the timing of a print. To combat this, individual use profiles (low resolution, high resolution, fast draft) were created around each machine and each machine's known printing issues. This was coupled with extensive logs for each print which included time, estimated cost, machine used, filament color used, and staff member. Thus in theory, a user could print the same object months apart at the same quality and cost.
- **Promoting underutilized equipment in the space.** In addition to the 3D printers, the CSIC now houses littleBits® circuitry kits, LEGO®, LEGO® MINDSTORMS® robotics, Makey Makey® circuitry kits, Arduino® kits, a VR station, a 3D scanner, a suite of different modeling and CAD software, a vinyl cutter, a large-format poster plotter, a fully-equipped repair bench, and five sewing machines. Because some of these machines, kits, and tools are less visible than the 3D printers, they are largely underutilized. For the future, the CSIC team plans to host lively and more detailed information campaigns (campus event booths, community advertisements, active community engagement during community events, free workshops) to further engage the center's target users and promote its underutilized equipment.

As part of the ongoing efforts to raise awareness about the facility, the CSIC team envisioned hosting workshops of interest to the broader campus community. It should be noted that the University of Wyoming also houses a K-8 laboratory school (UW Lab School) in cooperation with the local school district. Classes at the UW Lab School often benefit from access to university resources on campus such as the Art Museum and Libraries. Thus, the CSIC represents an additional venue through which these younger learners might experience new learning opportunities, and workshops hosted in the CSIC can provide access to diverse expertise.

An example of such an event includes the Cardboard Pinball Workshop hosted in the CSIC in May 2018 for 4th graders enrolled at the UW Lab School. The learning goal of the workshop was for students to demonstrate applied introductory physics concepts in the creation of a game. This workshop was led by a teacher education faculty member who specializes in science education, technology integration, and developing creativity. Two workshops, two hours in length each, allowed these young learners to engage with the faculty expert, preservice teachers completing practicum course requirements, and CSIC staff, including the director and three student workers. The workshop schedule included:

1. CSIC welcome
2. Introduction and safety overview
3. Activity instructions
4. Team selection
5. Free build
6. Share & play
7. Clean-up

During the brief welcome, the 4th graders were introduced to the CSIC staff and visiting faculty member. Students took the opportunity to ask questions about the space, including equipment and activities, and learned that they were welcome to visit outside of school with parental guidance. The introduction component incorporated clips from the *Caine's Arcade* documentary about a young man who built an entire arcade of games from cardboard and everyday objects and encouraged the students to discuss what they saw. This approach follows recommended instructional design practices to gain learners' attention, inform learners about the objective, and stimulate recall of prior learning [45]. The introduction discussion also included a safety overview in which the students were cautioned against running with any of the tools, asking for assistance with using certain tools (such as the hot glue gun or cutting cardboard), and respecting peers. During the activity instructions, the visiting faculty member displayed the various supplies available to construct their pinball game, including:

Cardboard pizza boxes donated by a national chain restaurant	Pool noodles
Chenille stems	Wooden sticks & skewers
Cotton poms	Duct tape
Googly eyes	Hot glue
Scissors	Pencils
Rubberbands	Markers
Marbles	Paints
Springs	Cardboard scraps

Further instruction included displaying a looping video of pinball machine design ideas, theming the game design, and a brief overview of physical science concepts related to forces and motion. Teams of two were quickly formed for the purpose of sharing supplies and facilitating collaborative design, and teams were allowed up to 75 minutes for the free build portion of the workshop. During the actual pinball construction, students worked diligently designing their pinball creation with some students going so far as to incorporate obstacles with planned point values to truly create a game experience. In some cases, teams also interacted to test their designs and determine playability. This later activity became a focal point during the share and play time towards the end of the workshop. As teams shared their finished cardboard pinball game, they were asked to talk about thematic design, if present, and describe design inspiration. The final phase of the workshop, clean-up, required the students to take responsibility for their learning space, cleaning up all trash, returning unused materials to the supply table, and wiping down the tables to remove any marks from paint or glue.

STEM educators looking to adapt this activity for implementation should note that the informal setting did not emphasize disciplinary core learning, but more direct instruction could easily align with Next Generation Science Standards related to multiple Physical Science standards for different grade levels. Further, other variations of this workshop might include:

- Expanded timing for all day learning and building
- Collaboration with undergraduate and graduate students
- Integrated content with mathematics for precise measurement and calculations
- Competition-based assessment on game play and/or design

VI. Conclusion

We are pleased by the early success of the CSIC over the last two years. We will continue to look for ways to publicize and expand its use. The lessons learned in standing up the CSIC will directly be applied to the development of the EERBSIC. We hope this paper will be useful to others considering starting a makerspace.

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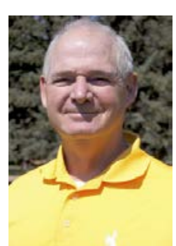
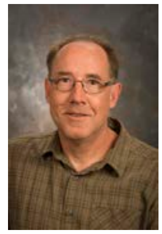


Steven F. Barrett, Ph.D., P.E. Dr. Steven F. Barrett, P.E., received the B.S. in Electronic Engineering Technology from the University of Nebraska at Omaha in 1979, the M.E.E.E. from the University of Idaho at Moscow in 1986, and the Ph.D. from the University of Texas at Austin in 1993. He was formally an active duty faculty member and professor at the United States Air Force Academy, Colorado and is now professor of Electrical and Computer Engineering and associate dean for Academic Programs, College of Engineering and Applied

Science, University of Wyoming. He is a senior member of IEEE and chief faculty advisor of Tau Beta Pi. His research interests include digital and analog image processing, computer-assisted laser surgery, and embedded control systems. He is a registered professional engineer in Wyoming and Colorado. He authored/co-authored several textbooks on microcontrollers and embedded systems. His book, “A Little Book on Teaching,” was published by Morgan and Claypool Publishers in 2012. In 2004, Barrett was named “Wyoming Professor of the Year” by the Carnegie Foundation for Advancement of Teaching and in 2008 was the recipient of the National Society of Professional Engineers (NSPE) Professional Engineers in Higher Education, Engineering Education Excellence Award.

Tonia Dousay, Ph.D. Dr. Tonia A. Dousay received a B.S. in Agricultural Science and M.S. in Agricultural Education from Texas A&M University in 1999 and 2000 respectively. Her Ph.D. in Learning, Design, & Technology was awarded from the University of Georgia in 2013. With 20 years of K20 teaching and instructional design experience, Dousay worked as an instructional designer for the Texas A&M Engineering Extension Service and later led online course development as the eLearning Manager for the agency. She has designed and taught courses in technology integration, message design, communication, instructional design, and multimedia development for multiple universities, including Blinn College, University of Georgia, James Madison University, University of Wyoming, and Abilene Christian University. Tonia is an assistant professor of Learning Sciences and researcher for the Doceo Center for Innovation + Learning at the University of Idaho. She is a co-author of the Survey of Instructional Design Models and two-time past recipient of the Information Age Publishers/Association for Educational Communications & Technology Distance Education (AECT) Best Practices Award as well as the 2016 International Society for Technology in Education (ISTE) Award for Advocacy.

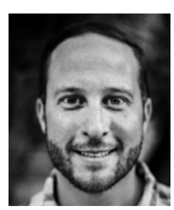
Tyler J. Kerr, B.A. Tyler Kerr received a B.A. in Geology from Franklin & Marshall College in Lancaster, PA in 2011, and an M.S. in Geology (Paleontology) from the University of Wyoming in 2017. His background in paleontology and interest in emergent technology has led him to pursue a career 3D scanning, rendering, and digitizing museum collections. In addition to his digitization work, he serves as director of the University of Wyoming's Coe Student Innovation Center (CSIC), the university's newest educational STEAM-oriented campus makerspace for students, faculty, and staff.



Lawrence Schmidt. Larry Schmidt (Head of the Brinkerhoff Geology Library). Larry arrived at the University of Wyoming in July 2002 and started working in the UW Libraries - Science Library. He holds a Master of Library Science from Emporia State University, MS in Environmental Engineering from Montana State University and BS degrees also at Montana State in Chemistry and Botany. As a science librarian Larry has collaborated on a number of interdisciplinary projects related to information literacy in the sciences and engineering disciplines. He recently co-taught ChE 5150-01 Research Data Management to graduate students in Chemical and Civil Engineering. Larry is also collaborating with Associate Dean of Engineering and the Head of Student IT Services along with faculty in education and the arts to create and coordinate innovation centers and makerspaces across the UW campus.

Larry’s passion and most significant work continues to be in the digitization of natural history collections both specimens and related publications. He collaborates with librarians, managers, curators and museum directors on multiple projects including digitizing National Park Service herbarium specimens, BLM specimens and other related collections. He is currently working with both federal and state agencies to digitize multiple herbarium collections in Wyoming and the surrounding states. These collections are available on the Rocky Mountain Region Digital Herbarium on the UW Libraries website as the work is finished. He has participated and presented at iDigBio workshops in support of collaboration between libraries and museums to digitize/database natural history collections.

His current interests continue to build on digitization of natural history collections, data management and innovative ways to utilize library spaces. In working with natural history collections databases he has taken an interest in working on managing research data in other disciplines especially as funding agencies such as NSF require data management plans and open access to research data. He participated in the E-science Institute supported by Academic Research Libraries, Digital Library Federation and DuraSpace to help research libraries develop a strategic agenda to support e-research. He attended the Harvard Institutes for Higher Education - Leadership Institute for Academic Librarians in 2013.



Brandon Gellis. Brandon S. Gellis is a new media artist creating work around contemporary issues of identity and place across intersections of art, science and technology. His creative practice – deeply rooted in his desire to work with my hands and a love for the mechanics of technology – visualizes relationships that exist at and across the intersections of art, science and technology. During his MFA, Brandon became fascinated with biomimicry, the steps mankind will take to advance itself by mimicking biological phenomena. For example, as people do not have gills, consider the use of scuba tanks to allow people to explore underwater environments and communities, like aquatic species

A native of Los Angeles, he received his B.A. from the University of California at Santa Cruz, and earned his M.F.A. in Emergent Digital Practices, at the University of Denver. In 2014, Brandon was an invited art-scientist at the Museum für Naturkunde, Berlin where he created works helping to advance knowledge of evolutionary and biological sciences through interactive exhibits.

In 2015, he joined the Department of Art & Art History faculty at the University of Wyoming. Brandon has been exhibiting art work and scholarly papers at juried national and international exhibitions and conferences since 2012. In 2017, he won the First-Place Juror's Choice Award at Circle Gallery's "Focal Point," a Maryland Federation of Art's Juried Exhibition, and a Juror's Choice Award at the Annapolis Maritime Museum's, "Flora or Fauna," a Maryland Federation of Art's Juried Exhibition.

Jesse Ballard, received his B.A. in Communications and Journalism from the University of Wyoming in 1998. Jesse has worked for Information Technology at the University of Wyoming since 1997 when he was hired as an entry level Computer Support Specialist. Over the years Jesse has received a succession of promotions and has led numerous technology related project implementations across campus. Jesse currently holds the title of Manger, Information Technology and oversees all Academic related technology support at the Laramie campus and all distance education locations around the state.