Making Maker Literacies: Integrating Academic Library Makerspaces into the Undergraduate Curriculum

ISAM
2017
Paper No.:
61

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INTRODUCTION

While there have been many developments in recent years establishing makerspaces on college and university campuses, much work remains to identify and measure what types of learning are taking place in those spaces. The University of Texas at Arlington Libraries are exploring opportunities for incorporating making and the UTA FabLab, an 8,000 sq. foot makerspace, into UTA's undergraduate curriculum and methods for measuring the learning that takes place within. We are developing a competencies-based learning model, with a focus on high-level, transdisciplinary competencies relevant to all undergraduate students, such as communication, teamwork, project management, tools and materials sensibilities, intellectual property knowledge, safety, and knowledge management and sharing.

Academic library makerspaces are uniquely suited to fill this pedagogical gap by fostering cross-disciplinary, hands-on experiential learning opportunities that can be scaffolded into the undergraduate curriculum. For years, libraries have advocated for a place at the pedagogical table, often successfully making room for the integration of information literacy into curricula. Although discussions of active and problem-based learning have become ubiquitous in library instruction circles, much of the focus in libraries has been on students as consumers of information rather than as creators of new knowledge. And yet, whether we look to *ACRL's Information Literacy Competency Standards* or the new *Framework for Information Literacy for Higher Education*, the characterization of a student as creator is clearly an expression of information literate behavior.

Academic libraries have begun to recognize the relationship between making and the transferable skills we have taught for years. Results of a 2013 survey indicated that 41% of respondent libraries currently provided maker-related activities and an additional 36% intended to begin doing so in the near future [1]. Many of these library makerspaces were created to address transferable, cross-disciplinary skills such as critical and creative thinking, research skills (beyond Google), project planning and management, professional communication, the ability to work in multidisciplinary teams, and adaptability to new contexts and circumstances. These are all skills sought after by employers [2]. NACE Job Outlook 2016 indicates that American companies seek employees with cross-disciplinary skills and lists attributes such as "ability to work in teams," "communication" (verbal and written), "problem-solving," "analytical/quantitative" reasoning, "initiative," "flexibility/adaptability," "work ethic," "organizational ability," "strategic planning," "creativity," and "entrepreneurship/risk taking" as highly-sought skills among new hires [3].

Although the number of academic makerspaces is growing, there is very little work being done to determine whether the intended goal of teaching transferable skills is being met. There have been a few explorations of the general learning that occurs in these spaces [4, 5], there has been little to no work done tying student learning in makerspaces to subject-based learning, or measuring student outcomes in these areas. A great deal of the literature on maker-based education focuses on STEAM education, and very little focusses on higher education (the literature is overwhelmingly devoted to K–12 learning). The *Children's Museum of Pittsburg* is an example of the cutting edge program development that is occurring in public and K–12 environments [6]. Within the context of academic libraries, much of the literature has focused on the process and challenges of standing up a makerspace or integrating and supporting 3D printing [7, 8, 9, 10, 11, 12, 13].

Our focus on assessment of competencies learned in makerspaces is not an arbitrary decision. Assessing the learning that takes place in makerspaces is a problem that has been documented in various case studies and the scholarly literature. Many make assessment secondary or not required at all, others state that it is impossible, not important, or that it doesn't resonate with maker culture [14, 15, 16, 17]. By assessing learning outcomes in makerspaces, academic institutions are able to prove quantitatively that these experiential learning environments contribute to student learning. UTA Libraries and the UTA FabLab aim to take up this mantle and show that assessment is important, necessary and possible.

METHODS

During Fall 2016 and Spring 2017, UTA Libraries tested maker competencies that impart transdisciplinary skills in a broad cross-section of undergraduate programs, including non-STEAM disciplines in the social sciences and humanities.

In preparation for this initiative, over the summer of 2016 a multi-disciplinary Maker Literacies Task Force was formed, with librarians, FabLab staff and faculty from five academic departments. The Task Force investigated and developed a draft set of assessable maker-based competencies (see Appendix: Draft Maker-Based Competencies) that can be mapped to existing course learning outcomes in many subjects.

Over the 2016-2017 academic year, the competencies were pilot tested in nine undergraduate courses from the departments of Art Education, Computer Science and Engineering, English, Fine Arts, Industrial Engineering, and Science Education. In each of the participating courses, faculty assigned a project that required their students to employ specific maker-based competencies if they were to successfully complete the assignment. Based on the requirements of course assignments, Libraries and FabLab staff provided instruction and support for student work.

For this first year of the program, the Task Force collaborated with subject faculty to help map their course learning outcomes to our draft maker-based competencies and assist them with curriculum development, adapting or creating different assessment models for each assignment. We met with each professor individually to discuss their course and plans for assessment, but did not insist upon specifically reviewing the actual assessment questions. In analyzing the results of this, it has become clear our data will be far more useful if future assessment methods are more standardized.

At the end of each course, faculty members compiled reports in which they outlined their learning outcomes, student assignments, instructional interventions, assessment methods, student performance. Task Force members evaluated the results of the instructors' assessment methods and offered suggestions for improvement going forward. Subject faculty and Task Force members together strategized improvements for future iterations of the courses.

RESULTS

In Fall 2016 we piloted two English courses, one Fine Arts course and one Industrial Engineering course. In Spring 2017 we piloted one Art Education course, one Computer Science & Engineering course, one Science Education course, one English course, and one Industrial Engineering course. Together they include nine distinct courses from five different academic departments. Space limitations for this paper prohibit us from including accounts of all nine of these courses, but here we will outline three courses that provide a glimpse accomplishments and challenges of the first year of the program.

ART 4392 Emerging Technology Studio

This Fine Arts course required students to learn how to use the equipment in the FabLab and incorporate new tools, techniques and materials into their practice. The course had students complete a brief self-evaluation at the beginning of the course asking them to rate on a scale from 1-5 their experience levels in several concepts that can be mapped to the maker competencies: "Sharing information/Teaching others," "Project Documentation," "Working in teams," "Time management," and "Communicating with professionals outside of the arts".

Being Fine Arts students who for the most part focused on their individual bodies of work, they were also given a major assignment requiring them to form teams and design workshops where they would teach the new skills that they acquired during the course. According to the instructor, all but one student indicated that they had never taught a workshop. The Maker Literacies Librarian provided a two-hour instruction session on Backward Design, teaching students the basics of how to design a workshop, and the Director of the FabLab instructed them on the limitations and considerations they would need to take into account for teaching in the FabLab. All teams were able to successfully accomplish their workshops. Given that teams were teaching new skills that they had recently acquired, and that only one of the students had previous teaching or workshop development experience, it was easy to see that students gained competency in "Sharing information/Teaching others," "Project Documentation," "Working in teams," "Time management," and "Communicating with professionals outside of the arts," even though we gathered no metrics with which to measure them.

The Task Force was supplied copies of each student's self-evaluation, but this alone didn't provide enough data for measurable assessment. The self-evaluation serves as a proper beginning-of-the-course self-evaluation (a 'pre-evaluation'), but without an end-of-course self-evaluation (a post-evaluation) there is no way to measure whether or not students' competencies increased. The workshops were conducted during finals week and required significantly more preparation time and guidance by the professor than had been anticipated, resulting in the planned post-evaluation surveys not being administered. This helped us realize that we should encourage professors to structure their assignments and associated assessment modules for earlier in the semester when time is not at such a premium. Going forward, we will be sure to include a post-evaluation in this course.

ENGL 2303 Afrofuturism

This English course required students to read writings from and about the African Diaspora, to engage in a Wiki that represents a futuristic world thematically aligned with problems of the African Diaspora in the future, and to design and 3D print an object that visually represents a solution to one of those hypothetical future problems.

The learning outcomes listed by the instructor for the 3D modeling and printing assignment were a straightforward mapping of the sub-categories of the "Applied design praxis" maker competency, which in total encompass the entire design process. Students had never engaged in the design process prior to taking this course, and were admittedly surprised to find that they would be required to do so in a literature course. 19 of 22 students successfully completed the design project.

Like the ART 4392 course, this professor utilized a self-assessment, but in this case it was an end-of-semester self-assessment and instead of students rating their competencies, they were asked open-ended questions about their experience with the course. Questions asked were only tangential to the maker competencies, for example, asking students how they felt about using 3D design and printing to create visual components to a fictional story. While we received some really great student reflections on the course and the 3D printing assignment, we were unable to measure student success using this method.

Since the professor is already utilizing a student self-assessment, we will create additional questions for each maker competency that we wish to measure in future iterations of this course. For example, a question about "problem identification" could be modeled as such:

> This assignment has helped me understand how to better identify problems and issues of concern that disproportionately impact the African Diaspora in some negative way. (circle one)
>
> 1 Completely agree
> 2 Somewhat agree
> 3 Neither agree nor disagree
> 4 Somewhat disagree
> 5 Completely disagree

In addition to self-assessment data, we will also create rubrics for evaluation of the competencies. Professor-supplied assessment data will provide an additional data point for determining whether or not students completed the course with the listed maker competencies without relying solely on student self-assessment. Following the example above, we could develop a rubric for measuring competency in "problem identification" using something along the lines of what is shown in Table 1.

Table 1 Grading Rubric for Assessing "Problem Identification"

Criteria	**Needs Work (1-3 points)**	**Satisfactory (4-7 points)**	**Exceeds expectations (8-10 points)**
Defines the problem	Student did not identify a problem, or did not sufficiently define and articulate the problem with examples, data, or citations.	Student sufficiently defined and articulated the problem and provided ample data, citations and/or examples.	Student defined and articulated the problem sufficiently and went beyond expectations by conducting interviews, surveys, visited historical archives, or some other activity beyond internet/literature searching.

IE 1205 Introduction to Industrial Engineering

The previously mentioned courses each had their unique problems with regard to assessment of maker competencies. We did have one course that, even in its simplicity, provided useful assessment measures that will not require too much tweaking in future iterations. We provide that here as an example of "what went right".

This entry-level Industrial Engineering course required students to learn the DMAIC design process (Define, Measure, Analyze, Improve, Control) by conducting real-life process engineering projects in the FabLab. Students were to design simple training processes for new employees to learn how to use equipment. Students were required to learn a piece of equipment, then develop a training manual using a template. While the course covered the entire DMAIC process, the FabLab-specific assignment only took them through the first three parts, Define, Measure and Analyze.

Several of the steps in the "DMA" segments were mapped directly to sub-topics in the "Applies design praxis" maker competencies, and each of those were transformed into multiple choice questions that were included verbatim on both on pre- and post-tests. For each question, the professor counted how many students answered the questions correctly at the beginning of the semester and at the end, as shown in Table 2. This way we were able to easily see that at the end of the course, students had a much better grasp of the "DMA" concepts (she did the same for the "IC" segments, but since those were not part of the FabLab projects, we didn't use them in our evaluation of competency acquisition).

Table 2 Learning Outcomes for IE 1205

Competency	**Pre Test**	**Post Test**
Defines the problem (Define)	19 (students answered correctly)	25 (students answered correctly)
Specifies project requirements (Define)	9	26
Identifies and works effectively within project constraints, be they financial, temporal, proximal, or material (Measure)	26	29
Analyzes the problem and breaks it into component parts acquires reliable and relevant background information identifies stakeholders (Analyze)	14	27

DISCUSSION

Assessment of maker competencies gained in the UTA FabLab is the primary goal of our maker literacies program. However, during the first year of the program the Task Force was focused mostly on drafting the maker competencies, recruiting faculty to pilot their courses in the program, and assisting them with curriculum development. The second year of the program we will place much more scrutiny on the assessment practices of program faculty. Ultimately we want to have assessment methods and tools that allow us to see and articulate tangible results of what learning takes place in makerspaces.

In general, assessment of our maker literacy courses has shown successful student achievement in a variety of the maker competencies, including teamwork, time management, communication, design thinking, problem solving, and knowledge sharing. Upon evaluation of the assessment data and methods, the Task Force found that most of the learning outcomes were assessed by anecdotal and largely subjective criteria. This is not necessarily bad, and may be perfect for the instructors' own needs, but we wish to take assessment to the next level to show that students are gaining these transdisciplinary competencies by working on projects in the FabLab.

Faculty buy-in has been outstanding. All but one of our instructors has expressed satisfaction with the maker literacies program and wish to continue participating in the 2017-2018 academic year. In their reports, they have identified areas for improvement, and the Task Force is currently evaluating assessment results and making recommendations for improvement, several of which have been discussed in the results section above. The Task Force has six more potential courses lined up in addition to the eight that will be returning next academic year.

Some examples of assessment challenges are incomplete or missing assessment data, inadequate or inappropriate assessment tools and measures, and most of all, miscommunication about the importance of assessment between the Task Force and teaching faculty.

Now that we have a better understanding of what to expect, we also have a better idea of what types of assessment measures to put in place. We realize that requiring additional assessment data from our teaching faculty will place additional work on them, and add another layer of complexity to their assessment regimes, but we also believe that by providing our expertise that they and their students will benefit. We are pivoting our marketing strategy to include "become an assessment expert by participating in the maker literacies program" in addition to other already-lucrative selling points that the FabLab itself embodies.

Due to the success of our local accomplishments, we have been awarded a $49,800 Institute of Museum and Library Services (IMLS) National Library Leadership Award planning grant that will allow us to expand this program to four other selected universities in the spring of 2018. This grant will allow us to test the beta competencies in diverse academic library environments and ultimately refine the competencies and develop best practices for integration of making into course curricula. Upon the successful completion of this work, we will formalize our findings, finalize our set of maker-based competencies, and create a clearinghouse of creative-commons licensed curriculum materials developed by us and our pilot partners. We are working to establishing UTA Libraries as the leader in the field for maker-based literacies.

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APPENDIX: DRAFT MAKER-BASED COMPETENCIES

The "Maker-Literate" student:

1. Identifies the need to invent, design, fabricate, build, repurpose or repair some "thing" in order to express an idea or emotion, or to solve a problem
   - recognizes unmet needs that may be filled by making
   - expresses curiosity about how things are made and how they work
   - "hacks" and "tinkers" to learn how things are made and how they work
   - evaluates the costs & benefits of making as an alternative to buying or hiring
2. Applies design praxis
   - defines the problem
   - analyses the problem and breaks it into component parts
   - acquires reliable and relevant background information
   - identifies stakeholders
   - specifies project requirements
   - identifies and works effectively within project constraints, be they financial, temporal, proximal, or material
   - brainstorms for a variety of solutions & chooses the best one
   - evaluates the costs & benefits of using off-the-shelf parts or kits as opposed to making from scratch
   - creates and tests prototypes
   - revises and modifies prototype design over multiple iterations
   - takes intelligent risks and learns from failures
3. Demonstrates time management best-practices
   - outlines project milestones and identifies dependencies
   - constructs critical paths
   - builds in extra time to allow for multiple prototype iterations
4. Assembles effective teams
   - recognizes opportunities to collaborate with others
   - evaluates the costs & benefits of "Doing-it-Together" (DIT) vs. "Doing-it-Yourself" (DIY)
   - seeks team members with skills appropriate for specific project requirements
   - joins a team where his/her skills are sought and valued
   - solicits advice, knowledge and specific skills succinctly from experts
5. Employs effective knowledge management practices
   - communicates clearly with team members and stakeholders
   - restates technical and "maker" jargon in plain English
   - documents work clearly
   - uses version control to manage project outputs and documentation
   - preserves project outputs and documentation for long-term access
6. Assesses the availability of tools
   - selects the best tools for the job
   - acquires the necessary tools or revises project to conform to tool availability
   - seeks alternate tools when a required tool is not available
   - creates necessary tools that can't be acquired or when an alternate is not an option
7. Assesses the availability of materials
   - selects the best materials for the job
   - acquires the necessary materials or revises project to conform to materials availability
   - seeks alternate materials when a required material is not available
8. Demonstrates understanding of digital fabrication process
   - recognizes additive and subtractive fabrication techniques
   - applies 3D modeling principles
   - creates 3D models using appropriate software
9. Understands many of the ethical, legal and socio-economic issues surrounding making
   - demonstrates an understanding of intellectual property rights and protections
   - identifies project outputs that may be protectable by trade secret, patent, trademark or copyright
   - compares the costs & benefits of seeking intellectual property protections v. making project outputs open and freely available to others
   - evaluates the costs & benefits of open source and proprietary systems
   - recognizes and respects the intellectual property rights of other makers
10. Employs safety precautions
    - seeks training for dangerous equipment and materials
    - wears personal protective gear when appropriate
    - teaches safety precautions to others
11. Transfers knowledge gained into workforce, community, and real-world situations
    - teaches what he/she knows to less experienced makers