Maker Competencies and the Undergraduate Curriculum

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INTRODUCTION

The University of Texas at Arlington (UTA) Libraries was awarded $50,000 by the Institute of Museum and Library Services (IMLS) for FY 2017-2018. This grant allowed us to develop a proof-of-concept for course integration of academic library makerspaces into the undergraduate curriculum (Wallace, 2017a). A minimum of two pilot courses at each of four selected partner sites (University of Nevada, Reno, UMass Amherst, Boise State University, and UNC Chapel Hill), as well as UTA, are currently under evaluation. Each represents a unique undergraduate course, faculty member, curricula, and group of students. Coordinators at each partner site identified faculty who were not only willing to integrate making into their courses, but who were also willing to include assessment of student learning over a range of competencies believed to be acquired when students complete project-based assignments in makerspaces. Participating faculty come from a wide variety of disciplines including Architecture, Art, Biology, Civil Engineering, Computer Science, Education, English, Geology, History, Industrial Engineering, Mathematics, Philosophy, and Public Administration. At the time of this writing, these courses have concluded and faculty have provided the grant team ample feedback about the assigned projects, the learning that took place, and how they assessed that learning. The grant team will spend the summer of 2018 analyzing faculty feedback and student assessment data as we prepare a final report for IMLS. This paper provides an overview of the program, a case study from one partner site, preliminary analysis of data, and our plan for moving forward.

Successful completion of this pilot program will situate us to apply for a larger IMLS project grant, with which we hope to more thoroughly delve into techniques that measure student learning, including by means of the method described herein, and to provide professional development opportunities for interested maker-librarians who wish to implement similar programs at their institutions.

LITERATURE REVIEW

Hira, Joslyn & Hynes (2014) provide a concise and current review of the history of makerspaces in education, theoretical foundations, implications for pedagogy, and relevance of makerspaces to national science standards. Andrews (2017) provides an exhaustive literature review on the state of the art in "Making Literacies," and Rosenbaum & Hartmann (2017) provide a meta-analysis that distills recent literature on educational makerspaces into discrete areas of research.

The literature reveals an interest in, and the need for, exploring the impact of makerspaces on student learning outcomes (SLOs), but, as Rosenbaum & Hartmann are quick to point out, few universities are actively engaged in this type of research. As Koh & Abbas (2014) proclaim, the current literature focuses mainly on 1) history and models of makerspaces; 2) case studies or informal reports of how specific makerspaces were founded; 3) advice and resources for how to start a makerspace; 4) suggested technology and sample projects; and 5) issues related to funding, staffing and programming. Some studies on measuring impact on SLOs are beginning to emerge. The following are a few examples of related research taking place. Each consists of integrating a maker-based assignment into the curriculum and assessing what learning takes place; all but the first example focus on undergraduates. We include the K-12 example because it represents a good model of course integration and assessment that is highly relevant and similar to the work we're doing with our undergraduates.

Blikstein, Kabayadondo, Martin, & Fields (2017) are engaged in research surrounding K-12 makerspace-course integration and assessment, developing a regime for integrating what they call "Exploration and Fabrication Technologies" (EFTs) into school curriculum and developing a statistically validated instrument for measuring skills attainment of these technologies. EFTs are a distinct class of technologies, separate from general computing and information and communication technologies (ICT). While Blikstein et al. focus on technology literacy among K-12 students, our program focusses on interdisciplinary, transferable competencies among college undergraduates. While these domains clearly intersect and overlap in various ways, our work centers around high-level competencies such as team building, communication, design thinking, and project management, and the makerspace serves as laboratory for acquiring these competencies.

Saorín, Melian-Díaz, Bonnet, Carbonell Carrera, Meier, & De La Torre-Cantero (2017), using pre- and post- Abreaction Tests for Evaluation of Creativity, found that integration of 3D scanning, 3D modeling software, and 3D printing into a first-year engineering graphics course improved students' creative competence. This study analyzed the work of 44 students; results were found to be reliably statistically significant by calculating their Cronbach alpha coefficient.

Nagel, Ludwig, & Lewis (2017) found that the multidisciplinary experience and use of maker technologies in a Community Health Innovation course at James Madison University

enhanced student learning and engagement, fostered teamwork and interdisciplinary skills, and increased student's ability to innovate. This study involved 48 engineering, biology and pre-nursing students (24 students per semester for two semesters). The researchers used objective assessment data for course measures of student learning. Desired level of attainment was met (or was a near miss) for all but one of their course learning outcomes, namely, students underperformed in the category of ethical, legal and practical implications of applying novel technologies. Learning outcomes for other categories, such as being able to describe the innovation process, far exceeded instructors' expectations.

Morocz et al. (2015, 2016) are conducting a four-year longitudinal study of how makerspaces influence at-risk student retention, impact students' idea generation abilities and design self-efficacy, and positively influence females and minorities to broaden their participation in engineering. At the conclusion of the first year of the study, using a validated instrument for engineering design self-efficacy (Carberry, Lee, & Ohland, 2010), the researchers found that students with higher participation in their makerspace were more motivated and less anxious to perform engineering design related tasks. This early phase of the study consisted of 498 first-year undergraduate engineering students.

Lastly, a University of Ottawa study reports an increase in confidence in communication and teamwork skills (80%), engineering and problem solving skills (60%), and design skills (90%). 75% reported that the makerspace helped them finalize their design projects by demonstrating limitations/restrictions of manufacturing methods, and by offering accessibility to equipment, tools, and guidance (Galaleldin, 2017). This study relied on a survey of only 28 self-selected users of the L'Abbe makerspace who identified as engineering majors.

PARTNER SELECTION

During the early conceptual phase of our work, before the grant proposal was written, University of Nevada, Reno (UNR) Libraries was identified as an ideal partner for this type of work due to their own exploration of maker literacies and their stated desire to measure the impact of makerspaces on learning. Tara Radniecki at UNR's DeLaMare Library was invited and joined our grant team to help write the proposal. The proposal sought funding to visit five academic library makerspaces, and from those five select three additional partner sites to collaborate with UTA and UNR (Wallace, 2017a).

Of primary importance was to determine which makerspaces to visit as potential partners. To do this, the grant team first decided to narrow our scope to only academic library makerspaces, an appropriate factor for a funding agency specifically addressing challenges and opportunities for libraries and archives.

Next we defined the minimum makerspace equipment standards for inclusion:

- must have more than just 3D printing;
- must not be primarily "arts and crafts" but offer some digital fabrication and prototyping capabilities;
- must be able to provide for at least two modalities of making; for example: fully support fabrics/textiles projects AND fully support woodworking projects;
- the more equipment that a makerspace has, the more indicative of the support its staff can offer.

Grant personnel then began researching academic library makerspaces and populating a rubric, scoring them on the above standards and attempting to answer the following questions about each:

- Is the school public or private?
- What is the size and/or capacity of the makerspace?
- Is the institution a land grant college or university?
- What geographic region is the school located within?
- What are the student demographics of the school?
- Does the library serve a specific discipline?
- Is the makerspace exclusively for specific disciplines?
- What is the staffing model of the makerspace?
- What are the hours of the makerspace?
- What equipment does the makerspace offer?
- How many years has the makerspace been open?
- Is the makerspace already being embedded into the curriculum?

It was significant to the grant team that the five sites selected for site visits, and ultimately the three sites selected as partners, represented a diverse subset of all the institutions researched; we wanted to test the applicability and feasibility of maker literacies across spaces that were geographically disparate, served a variety of student populations, and were both large and small, newer and more well established, and staffed with varying degrees of technical acumen.

Research was conducted first using information available on the internet, including their own websites, third-party websites that aggregate information about makerspaces, and scholarly literature published by and about academic makerspaces. A review of academic makerspaces by Barrett et al. (2015) was instrumental in this process. In total, we identified 18 academic library makerspaces to consider for inclusion.

We then used the scoring rubric to rank them, and we reached out to the top ten to gauge their interest and ask them to complete a questionnaire designed to clarify information that we could not gather from the internet. Of those ten, only one declined participation, and the other nine enthusiastically completed the questionnaire. Finally, we adjusted scores on the rubric based on the questionnaires, re-ranked them, and discovered the top five sites to visit: UMass Amherst, Boise State University, Carnegie Mellon University, Lawrence University, and UNC Chapel Hill.

Grant team members visited each institution between September and October of 2017. The intent of these visits was to gauge their interest in, and capacity for, successfully participating in the program. During the visits, the grant team met with the makerspace-librarians who served as our primary contacts and site coordinators, potential faculty partners, and

makerspace staff members to review the intent and requirements of the grant and answer their questions. We also toured the makerspace facilities. These visits served as wonderful opportunities to share knowledge and practices, and to form relationships with these institutions, regardless of whether or not they were selected for inclusion. It was a difficult decision to make, but we ultimately selected UMass Amherst, Boise State University, and UNC Chapel Hill to join us.

COURSE INTEGRATION

Once our partnerships were solidified, our primary contacts at each partner site set about identifying faculty to participate in the program. In all but a few cases, there were already interested faculty waiting to be contacted due to communications from their librarians before, during and after our site visits. Several of the sites had an abundance of interested faculty and in fact had to turn some away to keep our scope manageable, and the necessity to include a diverse disciplinary cross-section—it was mostly engineering faculty who were left out in order to bring in the more inimitable courses such as English, History, Philosophy, Public Administration, and others.

Participating faculty members were asked to map their student learning outcomes, either from the course or their assignment, to the beta list of maker based competencies drafted by UTA Libraries in spring 2016. [See Wallace, 2017b, for the complete list of competencies.] Most of them adopted two or three the competencies from the list; collectively, faculty found relevance in a broad range of competencies, including:

- 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;
- applies design praxis;
- demonstrates time management best-practices;
- assembles effective teams;
- demonstrates understanding of digital fabrication process;
- understands many of the ethical, legal and socio-economic issues surrounding making; and,
- transfers knowledge gained into workforce, community, and real-world situations.

All faculty participants were offered the services of curriculum, instruction and assessment consultants at UTA to help align their assignments with the maker competencies. Most chose to complete this work independently or in consultation with their home site's curriculum assessment experts.

Upon the conclusion of the Spring 2018 pilot, we asked all participating faculty, site coordinators and makerspace staff who were involved to complete an extensive exit survey providing their insights. We gathered feedback about the competencies themselves, the ability to map and integrate them as SLOs for a makerspace assignment, and how they assessed the SLOs in their courses. These data will be used to revise the beta list of maker competencies and to develop best practices for course integration.

MEASURING LEARNING

While the IMLS grant proposal did not specifically require measurement of student learning, the grant team did not want to pass up this opportunity to begin exploring assessment methods. We left this aspect open-ended and encouraged participating faculty to design their own assessment tools and methods. However, we also wanted to have one standardized tool to apply to all participating courses for comparison of competencies across courses and disciplines. This materialized in the form of a simple pre- and post-self-assessment survey combination which we asked each participating faculty member to administer with their students.

Upon selection of maker competencies for each course, the grant team developed pre-assessment surveys that all students enrolled in the courses would be asked to complete. The surveys were customized to the competencies chosen for each course, but the individual questions were drawn from a standardized question bank that we created. The pre-self-assessments asked students to rate and/or reflect on their self-identified knowledge, comfort, and expertise with demonstrated behaviors associated with the maker competencies. The questions utilized a combination of Likert scale and open short answer formats. Students completed the pre-self-assessment prior to any classroom engagement with their makerspace, maker-based course content, or technologies related to making. Adhering to IRB guidelines, students were given the option to opt-out of the study.

Upon the completion of their makerspace assignments, all students who opted-in to participate in the study were asked to complete a post-self-assessment survey, again asking them to rate and/or reflect on their self-identified knowledge, comfort, and expertise with demonstrated behaviors associated with the maker competencies. They were also asked to reflect on how and why their self-assessment had changed after completing the maker assignment. Again, while surveys were customized for each course, the questions in the surveys were drawn from our standardized question bank.

Because we used a set of standardized questions, with a subset of questions for each of our eleven competencies, we are now able to compare results across courses and disciplines. For example, the UNR partner site piloted a Geology course and an Art course. Both instructors chose the "design praxis" competencies for their SLOs. Upon aggregation with other Geology and Art courses, we will be able to see differences between these two disciplines in design praxis competencies attainment. When viewing these numbers in context with the actual makerspace assignment and activities, we can use the impact comparisons to help faculty make data-backed decisions about which assignments and activities foster the greatest impact on student learning.

At the time of this writing, the grant team has aggregated all data and has begun analysis of pre- and post-self-assessment results. Unfortunately, we have not had time to review the data in-depth in time for this paper deadline, but we anticipate having all results and analysis available on our Website by the end of September for the IMLS reporting deadline. We discuss this more in the Conclusions & Future Work section, below.

PARTNER SITE EXPERIENCE

The University of Nevada, Reno's DeLaMare Science & Engineering Library participated in the IMLS grant project as a site partner. As a site partner, one of their first responsibilities was to identify two courses in which to integrate one or two maker competencies. Two faculty members who regularly utilize the library were invited to participate; an Art professor, who had previously incorporated the makerspace into class assignments, and a Geology professor, who regularly included library instruction into her courses and had just begun work on a grant project utilizing one of the library's 3D scanners.

After the goals of the grant project were described, both faculty members were eager to participate. Both identified courses they would like to incorporate specific maker competencies into and worked with the site librarian for an initial draft of what the corresponding assignment would look like. After the initial discussions, the grant team's curriculum, instruction and assessment experts at UTA were consulted to help the faculty members further flesh out their assignments in a way that would address the chosen competencies and could also be reliably assessed.

The grant provided for up to $600 worth of consumable materials at each partner site, in order to offset student costs. The Art course chosen for participation required no outside materials, as the department already had a method for providing needed materials and chose not to utilize grant funds. The faculty member chose to integrate parts of the design praxis competency and the competency addressing ethical and legal issues surrounding making into an existing project where students design and create lamps on the library's laser cutter. The faculty member did all instruction addressing the design praxis competency via an assignment utilizing the makerspace's laser cutter and did not require any additional assistance from the library beyond providing routine assistance to students utilizing the machine in the library. The site librarian presented a 60-minute instruction session on copyright, trademarks, and patents and issues surrounding them in the art and making world. The integration of maker competencies into the Art course proved relatively seamless as both issues were being address in less formal ways in the course or in discussion between the librarian and faculty member about the course already.

The Geology faculty member selected a historical Geology course to integrate the following competencies into; identifying a need to make something and assessing the available tools. This course required a substantial amount of time in planning and implementing by both the faculty member and librarian. The faculty member wanted students to utilize the makerspace to create a physical or digital representation of a fossil that could further one's research and/or learning of it. The librarian worked with the faculty member and course TA to explain the capability of various technologies in the makerspace and how students might utilize them in order to complete the assignment. Tours of the space were given to all the course's students and those students then booked appointments with the library's makerspace student employees to brainstorm ideas and carry out their assignment. Each student was allotted a portion of the grant-supplied materials fund and placed their orders through the site librarian. While Art students are very familiar with assignments requiring physical fabrication, it was the first time working in the makerspace for many of the Geology students. The impact on library staff was greater as students required in-depth consultations on both project design and equipment operation.

Preliminary analysis of the student pre- and post-self-assessment surveys distributed by the grant team showed varying success, but faculty and student feedback on the experience was positive for both courses. Feedback from the Art faculty member included the usefulness of the competencies in identifying and bridging knowledge gaps in her project and helped push it into a more dynamic space. The in-class project assessment and discussions with students showed a firmer grasp of the maker competency concepts than prior to the project.

Feedback from both the Geology faculty member and course participants was also positive. At the final class presentations students expressed gratitude for being exposed to technologies and resources they would not otherwise be in their disciplines. The project allowed them to learn about technologies they can use in other course (or outside academia altogether) and also encouraged them to think critically and creatively in developing a helpful visualization for their project.

The DeLaMare Science & Engineering Library looks forward to contributing to the further development of the maker competencies and experimenting with other assessment tools in order to better track the transdisciplinary skills being acquired in the library makerspace. The success of their pilot program has shown that the makerspace can provide an engaging learning environment for students beyond the engineering disciplines and they plan to collaborate more with subject liaisons in other disciplines to continue this work.

IMPLICATIONS FOR MAKERSPACE STAFF

As mentioned, our partner institutions were selected largely based on the twin capacities of the physical space and the ability of staff to accommodate the extra load of working with students assigned to complete a project in the makerspace. A critical component of partner institution capacities is something well beyond fire marshal occupancy ratings; the culture within the space is the primary concern regarding adaptability to the Maker Literacies initiative.

The typical student who frequents a makerspace is internally driven by their own curiosity to seek out the learning opportunities afforded by making. Assigning students to do coursework in the makerspace inherently changes the social dynamic of the space, as it introduces students who have not self-selected their presence in the makerspace or even necessarily the parameters of the project they are engaged with. This effect is especially acute when assigning students from traditionally non-maker-oriented disciplines to engage with digital fabrication systems, requiring attentive preparations by makerspace staff to facilitate positive learning experiences.

In our work at UTA leading up to and throughout the IMLS planning grant period, we have worked closely with professors to determine the nature of their desired SLOs and en-

gaged in collaborative brainstorming to creatively apply makerspace technologies towards those goals. Such interactions can be generally categorized into two streams, with a tertiary offshoot that points promisingly towards collaborative educational systems. The most common pre-course curriculum development conversations with faculty are either calming down wild fantasies of what they want their students to accomplish in the allotted time (i.e. undergraduate history students learning 3D modeling for the first time and recreating a VR-optimized historical site with additional information pop-ups upon interacting with objects, in addition to the regularly assigned tests and term paper) or working to expand professors' thinking about what is possible in a makerspace (i.e. having each student download the same .stl file from an online repository and simply print it in their chosen color of plastic), with the majority being far more nuanced deliberations.

A good number of these conversations are as much about the details of equipment capabilities as they are about makerspace policies, with the goal that realistic expectations are communicated to the students in the class. It has been our experience that the process of integrating a class can also be a spur to action for makerspace staff to refine workflows in preparation for expected consistent use, especially use by students that may not be as familiar with the process. This can take the form of writing out or revising procedural documents, providing or reinforcing training for student staff, and/or policy modifications to align with the ultimate goal of equitably supporting the research needs of the university.

When the academic term begins and we begin directly supporting the students assigned to work in our makerspace, we often start with a makerspace tour and an instructional session to familiarize students with some of the software useful for CAD/CAM, especially if the professor is not already well-versed in these skillsets. This work has been led by makerspace staff and "maker librarians," and can also include classroom visits to observe student presentations at various stages of project completion to offer feedback on potential strategies and critical engagement with the learning objectives, as well as being available during class periods scheduled for student work in the makerspace to help problem solve along the way.

During these introductory tours and instructional sessions, it is imperative to customize the presentation of the information with an empathetic sense of what the student will be able to relate to so they can gain a toehold of familiarity. Again, this is especially important for the courses that come from outside the traditional maker disciplines of engineering, architecture, and studio art.

CONCLUSIONS & FUTURE WORK

In total, over 350 students, enrolled in 17 different courses spread across five campuses, representing 13 distinct disciplines all completed a project in their academic library makerspaces during Spring 2018. 328 of these students consented and participated in the pre- post-self-assessments, providing valuable data about their comfort and knowledge with eleven defined maker-based competencies. From participating faculty, we've secured 11 unique makerspace assignments licensed for re-use by anyone in the world, and invaluable feedback for improving our list of maker-based competencies and integration as SLOs for curriculum planning. As you can imagine, we have a lot of data, but we have not had a chance for in-depth analysis at the time of this writing. However, some preliminary conclusions can be drawn from a first-pass review of the data.

First, we received rich responses from participating faculty about the competencies themselves. Feedback included suggestions for making them more inclusive and transdisciplinary, suggestions for improving or building upon the existing competencies, and suggestions for adding competencies not in the beta list.

Second, in-class assessments done by faculty members seemed to be more successful when incorporating a self-reflection aspect. Faculty who required students to keep journals, or added a self-reflection component to their presentations were able to directly observe growth in their students. They were also able to provide deeper analysis of the learning that took place in their courses than instructors who did not implement a self-reflection component.

Third, some librarians did not feel comfortable assisting with curriculum development, and those who did were not consulted as true partners in curriculum development. Both of these aspects point to the need to develop librarians as experts and leaders in curriculum planning in order to foster better partnerships with their faculty members.

Lastly, there is much room to improve our data collection methods and validating our data for reliability. For example, with Likert scale questions, it is unknown if student took the time to read and understand the questions and answer them honestly. We intend to improve upon the pre- and post-self-assessment surveys by re-wording questions and experimenting with various response option configurations (Barnette, 2000; Maeda, 2015). We plan to explore statistical methods to determine the data's validity as exemplified in Bilkstein et al. (2017) and Saorín et al. (2017) by use of Cronbach's alpha and/or Cohen's kappa tests.

Our program team will continue working with these and other faculty for makerspace-course integration and we aim to continue collecting data about student learning and the competencies gained when completing projects in makerspaces. The results of this pilot program will be available on the UTA Libraries' website, https://library.uta.edu, by the end of September 2018, and will be continually updated with new information about additional courses brought into the program. Along with project reports, data, and analysis, we will provide curriculum materials from participating faculty under a Creative Commons license, for instructors who wish to re-use these course materials.

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REFERENCES

Andrews, C. (2017, September). Learning and teaching in library makerspaces: A literature review on making literacies. Paper presented at the International Symposium on Academic Makerspaces (ISAM) 2017, Cleveland, OH. Retreived from https://drive.google.com/file/d/0B4ZIatyug-WjJdmU3YVNHelhiMWc/view

Barnette, J. J. (2000). Effects of stem and likert response option reversals on survey internal consistency: If you feel the need, there is a better alternative to using those negatively worded stems. *Educational and Psychological Measurement, 60*(3), 361-370. https://dx.doi.org/10.1177/00131640021970592

Barrett, T. W., Pizzico, M. C., Levy, B., Nagel, R. L., Linsey, J. S., Talley, K. G., . . . Newstetter, W. C. (2015, June). A review of university maker spaces. Paper presented at the 122nd ASEE Annual Conference and Exposition, Seattle, WA. https://dx.doi.org/10.18260/p.23442

Blikstein, P., Kabayadondo, Z., Martin, A., & Fields, D. (2017). An assessment instrument of technological literacies in makerspaces and FabLabs. *Journal of Engineering Education, 106*(1), 149-175. https://dx.doi.org/10.1002/jee.20156

Carberry, A. R., Lee, H., & Ohland, M. W. (2010). Measuring engineering design self-efficacy. *Journal of Engineering Education, 99*(1), 71-79. https://dx.doi.org/10.1002/j.2168-9830.2010.tb01043.x

Galaleldin, M., Bouchard, F., Anis, H., & Lague, C. (2017, June). The impact of makerspaces on engineering education. Paper presented at the Canadian Engineering Education Association's Annual Conference - CEEA2017, Halifax, NS. Retrieved from https://www.researchgate.net/publication/315974582

Hira, A., Joslyn, C. H., & Hynes, M. M. (2014, October). Classroom makerspaces: Identifying the opportunities and challenges. Paper presented at the 2014 IEEE Frontiers in Education Conference (FIE), Madrid, Spain. https://dx.doi.org/10.1109/FIE.2014.7044263

Koh, K., & Abbas, J. (2015). Competencies for information professionals in learning labs and makerspaces. *Journal of Education for Library and Information Science Online, 56*(3), 114-129. Retreived from https://search.proquest.com/docview/1708167894/

Maeda, H. (2015). Response option configuration of online administered Likert scales. *International Journal of Social Research Methodology, 18*(1), 15-26. https://dx.doi.org/10.1080/13645579.2014.885159

Morocz, R. J., Levy, B. D., Forest, C. R., Nagel, R. L., Newstetter, W. C., Talley, K. G., & Linsey, J. S. (2015, June). University maker spaces: Discovery, optimization and measurement of impacts. Paper presented at the 122nd ASEE Annual Conference and Exposition, Seattle, WA. https://dx.doi.org/10.18260/p.24967

Morocz, R. J., Levy, B., Forest, C., Nagel, R. L., Newstetter, W. C., Talley, K. G., & Linsey, J. S. (2016, June). Relating student participation in university maker spaces to their engineering design self-efficacy. Paper presented at the 123rd ASEE Annual Conference and Exposition, New Orleans, LA. https://dx.doi.org/10.18260/p.26070

Nagel, J. K., Ludwig, P. M., & Lewis, E. J. (2017, June). Community health innovation through an interprofessional course. Paper presented at the 124th ASEE Annual Conference and Exposition, Columbus, OH. Retrieved from https://peer.asee.org/28051

Rosenbaum, L. F., & Hartmann, B. (2017, September). Where be dragons? Charting the known (and not so known) areas of research on academic makerspaces. Paper presented at the International Symposium on Academic Makerspaces (ISAM) 2017, Cleveland, OH. Retreived from https://drive.google.com/file/d/0B4ZIatyug-WjJY1ZjOXhIVGRzSFU/view

Saorín, J. L., Melian-Díaz, D., Bonnet, A., Carbonell Carrera, C., Meier, C., & De La Torre-Cantero, J. (2017). Makerspace teaching-learning environment to enhance creative competence in engineering students. *Thinking Skills and Creativity, 23*, 188-198. https://dx.doi.org/10.1016/j.tsc.2017.01.004

Wallace, M. (2017a). Maker competencies and the undergraduate curriculum. National Leadership Grants for Libraries LG-97-17-0010-17, sponsored by Institute of Museum and Library Services (IMLS). Retrieved from https://www.imls.gov/grants/awarded/lg-97-17-0010-17

Wallace, M. (2017b). Maker literacies: Competencies. Retrieved from http://libguides.uta.edu/makerlit/competencies