Incorporating Maker-centered Learning into Preservice STEM Teacher Education: A Model from UTeach Maker

A WHITE PAPER PRESENTED BY THE UTEACH MAKER CONSORTIUM

February 2019

Over the past decade, there has been a growing interest in how both formal and informal educational environments can benefit from the tools and practices of "making." Popularized by the publication of *Make:* magazine and the worldwide success of Maker Faires, the terms "maker" and "making" have become part of the modern-day lexicon and expanded to the global phenomenon known as the *maker movement*. Harking back to its do-it-yourself (DIY) origins, the maker movement stems from "the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and products with others" (Halverson & Sheridan, 2014, p. 496). The success and growth of this movement is highlighted by Maker Faires, which are public gatherings where makers can showcase their own creations and be inspired by the projects of others. As of 2018, there are 212 Maker Faires of various size taking place annually in 44 countries worldwide (Miller, 2018). The momentum of the maker movement and its ability to connect educators, industry, entrepreneurs, and cultural institutions has grown from its local community-based roots to being part of a broader national conversation.

Existing at the intersection of the arts, crafts, engineering, mathematics, science, and technology, making is made visible through the breadth and depth of what makers create (Marshall & Harron, 2018). Making may include no-, low-, and high-tech applications of science, technology, engineering, and mathematics (STEM) tools and skills such as metal and wood working, sewing, knitting, weaving, computer programming, 3-D printing, digital recordings, and other creative endeavors. Most importantly, the making of personally meaningful artifacts within education and elsewhere allows makers to form community connections, develop agency, find support, and build the foundations to imagine, make, and iterate.

The UTeach Maker Consortium is a collaborative of representatives from The University of Texas at Austin, Boise State University, The University of Houston, West Virginia University, as well as partners from Maker Ed (the Maker Education Initiative) and stakeholders from maker-centered organizations in each community. Through a generous grant from The Infosys Foundation USA, this group was brought together to outline a model for rigorous, sustained professional learning that could be used to support maker-centered learning in teacher preparation programs nationwide. The consortium offers this white paper to: a) describe the need for school-based maker-centered learning and teacher training; b) outline a mechanism for micro-credentialing maker educators; c) articulate elements of success for a robust maker professional development program for preservice teachers; and d) describe best practices and strategies for building partnerships between formal and informal education spaces in order to support making.

Making in Education

Making has manifested in libraries, museums, classrooms, afterschool programs, and other community spaces within the K-12 age range over the past decade. It connects in-school and out-of-school content in authentic ways and, within education, it has contributed to the

conversation of teachers and administrators who are actively rethinking their practices and approaches. A similar swell of effort and thought is also occurring in institutions of higher education, where more emphasis is being placed on experiential learning through both authentic contexts and projects.

There is rarely a one-size-fits-all approach to maker-centered learning since it can be explored, valued, and implemented in many ways. Educational spaces and programs may identify as maker education programs and makerspaces; or they may orient themselves towards valuing creativity, innovation, and invention with a focus on STEM or Career and Technical Education (often known as CTE and including skills such as wood and metalworking, automotive technologies, cosmetology, and family and consumer sciences). Since making is a student-centered, hands-on approach, it can be seamlessly integrated into any subject or topic area, including but not limited to science, mathematics, language arts, social studies, the fine arts, or athletics. Some maker educators introduce this type of learning and teaching through tinkering and play; others bridge to cultural, historical, and/or family experiences, such as textiles and food; others leverage design thinking and project-based approaches. No matter the content, making can bring together technical skills, content learning, and development of dispositions into a cohesive learning experience for all students.

In the educational context, making can be seen as a bridge between disciplines and also as a vehicle to enact student-centered instructional philosophies and tools for learning. Maker-centered learning is rooted in contextualized experiences, where students act in the moment to apply ideas to pertinent questions or problems as they build and create. In the literature, key themes are surfacing for why this type of learning is important. These themes include a connection to lifelong learning (Resnick, 2017), considerations of equity and inclusion (Vossoughi, Hooper, & Escudé, 2016), attention to career and workforce development (NSF,

2017), and the promotion of technology and skill development (Martin, 2015). Thus, making in the classroom is emerging as a viable pedagogical approach (Clapp, Ross, Ryan, & Tishman, 2016; Peppler, Halverson, & Kafai, 2016).

While making and maker-center instruction in the STEM classroom show promise for promoting creativity, student choice, and exploration, there is a need to do more to prepare future educators to maximize making as an instructional method. According to a 2017 national survey, only half of undergraduate teacher preparation programs in the United States gave participants an opportunity to learn about maker-education and maker technologies, and only 17% had a makerspace available (Cohen, 2017). These survey results suggest that few STEM educators are being exposed to professional learning experiences related to making. Research shows that STEM teachers' more readily uptake and implement the inquiry-based practices with which they have personal experience (Windschitl, 2003) and that those new to making need substantial onboarding and support in order to incorporate making in their own classroom practice (Blikstein & Worsley, 2017). Thus, a lack of exposure to maker-centered instructional practices during teacher preparation means that many future educators will remain unaware of the potential benefits of making for their students and may be reluctant to add making to their curriculum.

In order to address the need for school-based maker-centered learning and teacher training we have developed UTeach Maker, a micro-credentialing program for educators who are interested in bringing the philosophy, practices, and mindset of making into their classroom. UTeach Maker is intended to provide long term, high quality maker professional development and learning experiences for the students in the program. In the section below, we describe UTeach Maker as a model for what a micro-credentialing program for teachers could look like.

UTeach Maker: A Model for Micro-credentialing Maker Educators

UTeach Maker is an embedded micro-credentialing program within the UTeach secondary STEM licensure pathway at The University of Texas, Austin. It supports preservice teachers who express interest in integrating making into STEM classrooms and/or promoting learning within K–12 makerspace environments. As micro-credentials for teachers are competency-based forms of certification, the UTeach Maker micro-credential program supports developing educators' knowledge and skills around elements of making. The program also provides preservice teachers an opportunity to develop an extra skillset, which not only makes the preservice teachers more appealing to potential employers, but ultimately improves their professional practice in the classroom.

Through intentionally embedding maker-centered philosophies, practices, and experiences into preservice STEM teacher preparation, teachers can learn to confidently use "making" as a mode for facilitating and fostering authentic learning. Maker-centered learning, as defined by UTeach Maker, focuses on making and learning as "an iterative process of tinkering and problem solving that draws on a DIY mindset" that "allows students to collaborate and express themselves through the creation of something that is personally meaningful." By incorporating maker-centered learning into preservice STEM teacher education, there is potential to reshape what preservice education programs look like and how they engage and influence the communities around them.

During their time in UTeach Maker, each preservice teacher is paired with a mentor who works alongside them as they develop a website which serves as a public-facing online portfolio - called the UTeach Maker Showcase. Additional support is provided through monthly cohort meetings, workshops, internships, and special Maker events. While some experiences are completed independently, the program director and Maker mentors help candidates meet their

goals. The Maker Showcase serves as the framework for organizing the whole program and is ultimately presented to and viewed by professionals and peers in the community (see Figure 1). Graduates earn the title of UTeach Maker Teaching Fellow and are micro-credentialed, indicating that they have completed the process and developed key skills, thereby enhancing their resumes.

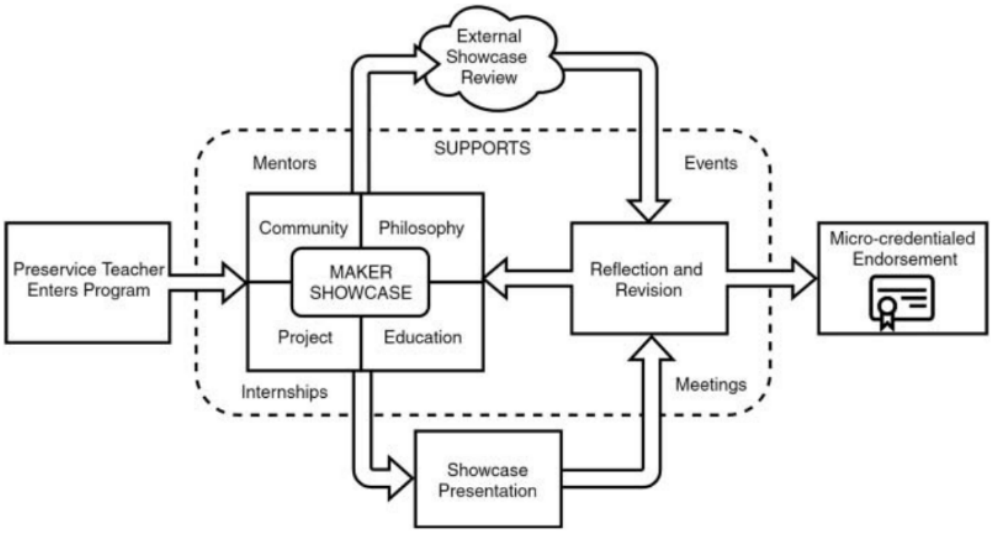

Figure 1. The pathway for the UTeach Maker micro-credentialing process (Rodriguez, Harron, & DeGraff, 2018, p.9)

Elements of Success for a Robust Maker Professional Development Program

The section below discusses several factors that have contributed to the success of UTeach Maker as well as a supporting rationale. This section outlines the role of open portfolios as a platform to showcase teacher growth, the importance of building community, the value of the public review and presentation of work, and the ongoing work of developing teacher leaders.

UTeach Maker Showcase

The UTeach Maker Showcase is an open portfolio that serves to highlight each participant's growth as a maker-centered educator. This portfolio is a publicly accessible, openly

networked platform that allows participants to capture, curate, and share work. It shows the creator's unique voice, abilities, and interests. Evidence of accomplishments may include photos, reflections, coursework, and artifacts that represent progress. Once complete, the Showcase is submitted to a national leader in maker education for feedback using a rubric. Each participant also presents their Showcase publicly. The micro-credential is issued once the presentation and rubric criteria are met. Each Maker Showcase has four sections that highlights specific areas listed below.

1. *Maker Philosophy*—This serves to encourage preservice teachers to develop an understanding of the philosophical and pedagogical roots that are expressed via maker-centered learning. Having an understanding of student-centered educational models, such as constructionism, allows preservice teachers to connect theory to practice through contextualized application of STEM content knowledge.
2. *Maker Project*—Personal experiences as a maker are highlighted in this section of the portfolio. Through the creation of a personally meaningful project, preservice teachers document and reflect upon their process and identity as a maker. This provides opportunities to experience the playful, growth-oriented, and collaborative nature of making.
3. *Maker Community*—In this section of the Showcase, preservice teachers are asked to provide documentation of engagement with the broader maker community, such as monthly cohort meetings, attending a Maker Faire, or engaging with online maker groups. These communities provide support and connections to the larger social context of the maker movement and multiple pathways for learning. This affords preservice teachers an opportunity to broaden their definition of making through exposure to a wide and diverse array of people, places, and perspectives.

4. *Maker Education*—This section highlights the connections between making as a personal endeavor and the broader arena of maker-centered learning, specifically as it applies to STEM classrooms and K–12 makerspaces. Topics ranging from issues of equity and access, using rubrics for support, connections to curriculum standards, and classroom management strategies are discussed in this section. Through the practical application of maker pedagogy, preservice teachers develop and enact a maker-centered lesson. This provides real-world experience for reflection and growth as a maker-centered educator.

Building Community

UTeach Maker provides a forum where participants can build and participate in a maker-centered community. Building community in the UTeach Maker program is supported by assigning each participant a Maker Mentor, requiring participation in monthly cohort meetings, and providing additional opportunities to build and create at optional weekend workshops.

Maker Mentors. A Maker Mentor is an experienced local maker educator who has access to their own resources, including a combination of tools, materials, and space. Each Maker Mentor works with a team of up to four preservice teachers. The Maker Mentors attend monthly cohort meetings with their small team and shepherd them throughout the year. A major role of the Maker Mentor is to support their preservice teachers in developing their Maker Showcase by setting goals, developing timelines, periodically checking-in on progress, troubleshooting technical issues, and offering feedback. Mentors also have a role in helping the preservice teachers respond to the feedback provided through the external review and the public presentation of the Showcase.

Maker Mentors are an important resource for the preservice teachers as they provide a real-world connection to making in various contexts such as the classroom, science centers, and

museums. Mentors provide advice on classroom management, using maker tools and technologies, assessing students, and integrating making into schools. They are also active members in many local and national maker communities. The mentors help to keep the UTeach Maker program, and thus the preservice teachers, connected and involved in relevant communities and events.

Cohort meetings. Monthly cohort meetings provide additional opportunities to build community within teams and the cohort as a whole. These meetings typically occur on the first Tuesday of the month at the university campus, local spaces, and community venues. These cohort meetings provide time to engage in shared maker-centered experiences, develop a sense of camaraderie, and provide ongoing support.

The first half of these meetings provide a casual atmosphere to enjoy a provided dinner and engage in informal conversations. This is an opportunity for mentors and their teams to check-in and update each other on the progress, challenges, and successes related to their maker experiences and development of their Showcase. The second part of the meeting is focused on maker-centered professional development. This work includes experience with project-based learning, elements of design and engineering education, techniques for supporting students in long-term projects, and the use of a wide variety of maker tools such as 3-D printing, laser cutting, woodworking, and more. Meetings conclude with time set aside for reflection.

Weekend workshops. UTeach Maker supports an on-going community by offering optional weekend workshops each month. These workshops range from three-to-five hours and embody a *Design, Make, Take* philosophy where participants can customize their own *design*, are provided materials to *make* their project, and are able to *take* it home with them at the end of the workshop. These workshops are typically run by Maker Mentors or other members of the local maker community.

Workshops may include topics such as creating and editing Scalable Vector Graphics (SVG) which can be used to cut materials on a variety of digital fabrication tools (e.g. CNC machines, laser cutters, and vinyl cutters), programing single-board microcontrollers to create light-up snow globes, or learning and applying the mathematics behind Japanese bookbinding techniques. These workshops aim to provide participants of the UTeach Maker program with additional opportunities to make, while also helping them develop skills that they can connect back to the K-12 STEM classroom.

Public Review and Presentation of Work

At the end of their UTeach Maker experience, all preservice teachers must publicly present the body of work they have documented in their Maker Showcase. This provides an outlet for students to highlight their progress as a maker educator, gives them an opportunity to articulate their accomplishments, and encourages the development of a high-quality portfolio. Prior to the presentation, preservice teachers are given the option of a formative Showcase review. For this process, a Maker Mentor or one of the other program staff uses the Maker Showcase rubric to provide feedback and help the preservice teacher identify elements that need to be strengthened.

For the final review, UTeach Maker has partnered with Maker Ed staff and other nationally recognized makers to serve as reviewers. These reviewers evaluate the submission and provide feedback thereby ensuring that the work of the preservice teachers is high quality. The Maker Showcase is an iterative work that participants are encouraged to continuously develop throughout their professional careers. It has proven valuable in showing employers what participants know and are able to do. Furthermore, the participant experience of creating a Maker Showcase models the ways in which open portfolios might be used with their own STEM students.

Developing Teacher Leaders

The program provides resources and differentiated guidance as UTeach Maker Teaching Fellows transition into the classroom. Showcase maker lessons are published on the public facing UTeach Maker website and a new mini-grant award provides the financial resources needed to plan and carry out maker-centered lessons. Fellows are encouraged to write about their classroom making experiences and, with support from UTeach Maker faculty, submit these lessons to journals that reach a broad practitioner audience. In addition, fellows are supported in taking on outreach activities such as presenting at conferences, establishing their own school maker faire, or developing a maker summer camp experience aimed at reaching students from underrepresented neighborhoods. These are valuable opportunities for Maker Fellows to share the role making can play inside the classroom while at the same time, giving them the chance to utilize their own maker skill set to consider issues of equity and access within the broader maker community. Experiences like these are part of ongoing program support. They encourage Teaching Fellows to develop an aptitude for leadership that will translate to their work with colleagues and their role as advocates of maker education in their schools and districts.

Best Practices and Strategies for Building Partnerships

The previous sections described UTeach Maker as a model for the micro-credentialing of preservice STEM teachers and articulated the elements of success for a robust maker professional development program, including the importance of working with and in the community. The section below discusses some best practices and strategies for building community partnerships and supporting connections between formal and informal learning spaces to support making.

A Shared Vision

An important lesson learned as a program working with multiple stakeholders is the need for a shared language and common framework that articulates a joint vision of making. In some ways, making by its nature defies singular characterization but for program cohesiveness it is important to establish a program definition. After several semesters of exploring the literature, consulting with experienced makers, and engaging in multiple rounds of revision, the UTeach Maker advisory board settled on this statement: "Making is an iterative process of tinkering and problem solving that draws on a DIY mindset. Making allows students to collaborate and express themselves through the creation of something that is personally meaningful." Over time, it became clear that, the participants in UTeach Maker needed additional clarity about what it meant to 'make' in STEM classrooms. Thus, using the UTeach Maker advisory board statement along with our own experience supporting novice maker educators, we developed a framework for classroom-based making called *Elements of Making* (Rodriguez, Harron, Fletcher, & Spock, 2018). It suggests that learners as makers:

- create an original, personally meaningful product,
- engage in iterative design and fabrication,
- demonstrate characteristics of a maker mindset,
- collaborate and connect with community,
- present their work publicly, and
- utilize science and engineering practices.

The development of the *Elements of Making* framework was a turning point for our program. It gave our makers, their mentors, and our community partners a common language for discussing making, planning lessons, and evaluating outcomes. It has helped explain to schools and administrators what is meant when they are asked to try maker-based lessons in classrooms and

it has given program graduates a vocabulary to use when explaining making to others and highlighting various aspects of their showcase to employers. Finally, the *Elements of Making* is a framework that has become the foundation of the maker lesson planning tools and the published lessons that UTeach Maker has produced.

Community Resources

Another emergent best practice is the use and integration of shared resources at both the university and off-site locations. UTeach Maker draws on existing community connections and on new partners brought in by the Maker Mentors to establish productive relationships.

Makerspaces. Despite a focus on maker-centered learning, UTeach Maker does not have its own makerspace. Although this may seem counterintuitive, partnering with others in the community provides a valuable vehicle for partnerships that support participants to engage in authentic maker-centered experiences. In doing so, UTeach resources that would be needed to sustain a makerspace, including space, time, people, and money, are instead devoted to maintaining, locating, and sustaining community partnerships. As such, participants can have access to maker equipment such as 3-D printers, CNC machines, and woodworking tools for both maker-centered lessons and projects. The UTeach Maker preservice teachers have used makerspaces in the engineering department, the fine arts library, and local K-12 public and private schools, as well as community makerspaces, to complete their work. The benefit of this model is that it encourages teachers to search for and utilize resources available in their community even if they are outside of their department or school campus. Unlike spaces connected directly with a university, many of these spaces will continue to be available to the preservice teachers long after their UTeach Maker experience.

Local venues and events. UTeach Maker also benefits by being situated within a vibrant community that is supported by both professional and amateur makers who host numerous local

events. As with much of the community support, the Maker Mentors are key in helping the program to identify potential locations and events of interest. These community events occur outside of the monthly cohort meetings and are an optional part of the program. Some examples of outside events include attending local maker meet-ups, visiting annual professional conventions, touring local design studios, and volunteering to work at the regional Maker Faire. These events provide a wide visibility for the UTeach Maker program and, most importantly, they provide inspiration and connect our preservice teachers to a wide and diverse world of making.

A Win/Win

Another best practice for the collaboration between formal and informal education spaces is ensuring that both parties benefit from working together. One way that UTeach Maker does this is through internships. UTeach offers paid internship opportunities for student participants to work in STEM-focused organizations, local schools, museums, and other informal spaces featuring a focus on maker education. Interns gain valuable field experience while bringing innovative and effective STEM teaching methods to K–12 students, especially in underserved areas of the community. UTeach Maker has also been proactive in placing preservice teachers into schools that have established or are in the process of establishing makerspaces. This situation benefits both parties since the expertise and manpower needed to run a successful makerspace is often in short supply. UTeach Maker also provides volunteers to support local maker meet-ups, school-based maker fairs, STEM nights, and the like. Thus, by working in the community, program participants provide manpower to local maker partners, bring skills in making to schools, and pilot innovative lessons that utilize maker pedagogies.

Ongoing Communication

Finally, ongoing communication is critical to any productive collaboration. Thus, the UTeach Maker team is in active contact with both formal and informal education partners on a regular basis. Most of our partners have representatives serving on the UTeach Maker advisory board which meets twice a year. At this time, board members are provided with updates and asked for feedback on the latest program initiatives. Partners also stay connected through active participation in the local maker ecosystem in Austin. We see each other at events, promote each other's activities, and stay in communication through social media. Finally, we view each other as part of a collective whose goal is to promote maker education in Austin and beyond. To this end, we often collaborate on grants and outreach efforts both locally and nationally. These joint endeavors are the thread that keeps this close-knit group together.

Discussion

UTeach Maker is an example of how a micro-credentialing program can be used to incorporate maker-centered learning into preservice STEM teacher education. The purpose of this paper has been to provide a model for rigorous, sustained maker-focused professional learning and describe the ways in which the model could be used to support maker-centered learning in teacher preparation programs more broadly. We have endeavored to describe the need for teacher training in the area of making, put forth a mechanism for micro-credentialing maker educators, outline elements of success for maker professional development, and highlight best practices for building partnerships between formal and informal education spaces to support making. We hope that the program aspects portrayed in this paper will be useful to others who are interested in implementing a robust maker professional development program.

UTeach Maker has successfully translated and applied making to the important arena of STEM teaching and teacher preparation. The UTeach Maker model weaves together the

university program, local schools, and the wider community. The model also builds on a strong backbone and network of UTeach programs across the nation, leveraging existing infrastructure, support, and resources to deepen STEM teacher preparation. It has potential for substantial scale while maintaining key connections and characteristics unique to each community and campus. Through personal learning experiences and hands-on projects, UTeach students are able to explore, practice, and model maker skills in their respective classrooms. Those facilitation practices are key for designing an environment and experience that allows for student engagement while simultaneously providing structure and support at critical learning moments. Integrating maker approaches into preservice teaching programs sets the stage for a far reaching and significant impact on educational institutions and ultimately, the student learning experience.

Acknowledgement: This article was developed in connection with the UTeach Maker program at The University of Texas, Austin. UTeach Maker is funded in part by a Robert Noyce Teacher Scholarship grant from the National Science Foundation (1557155). Opinions expressed in this submission are those of the authors and do not necessarily reflect the views of The National Science Foundation. Contributors to this paper are: Patrick Benfield, Magellan International School Innovation Lab; Hannah Brooks, UTeach Maker; Sharon Cardenas, Northern Arizona University (NAUTeach); Stephanie Chang, Maker Ed Initative; Erica Compton, Idaho STEM Action Center; Mike DeGraff, UTeach Austin; Paige Evans, The University of Houston (teachHouston); Sarah Hagenah, Boise State University (IDoTeach); Jason Harron, UTeach Maker; Amy Moreland, UTeach Institute; Brent Richardson, Baker Ripley Fablab; Shelly Rodriguez, UTeach Maker; Jakki Spicer, Maker Ed Initative; and Gay Stewart, West Virginia University (WVUteach).

References

Blikstein, P., & Worsley, M. (2016). Children are not hackers: Building a culture of powerful ideas, deep learning, and equity in the Maker Movement. In K. Peppler, E. R. Halverson, & Y. B. Kafai (Eds.), *Makeology: Makerspaces as learning environments* (Vol. 1, pp. 64–79). New York, NY: Routledge.

Clapp, E. P., Ross, J., Ryan, J. O., & Tishman, S. (2016). *Maker-centered learning: Empowering young people to shape their worlds*. San Francisco, CA: Jossey-Bass.

Cohen, J. (2017) Maker principles and technologies in teacher education: A national survey. *Journal of Technology in Teacher Education, 25*(1), 5-30. Retrieved from https://www.learntechlib.org/primary/p/172304/

Halverson, E. R., & Sheridan, K. M. (2014). The maker movement in education. *Harvard Educational Review, 84*(4), 495–504. doi:10.17763/haer.84.4.34j1g68140382063.

Marshall, J. & Harron, J. R. (2018). Making learners: A framework for evaluating making in STEM education. *Interdisciplinary Journal of Problem-based Learning 12*(2). doi:10.7771/1541-5015.1749

Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research, 5*(1), 30–39. doi:10.7771/2157-9288.1099.

Miller, M. J. (2018, September 5). World Maker Faire: The evolution of making. *PCMag*. Retrieved from https://www.pcmag.com/news/363966/world-maker-faire-the-evolution-of-making

National Science Foundation (NSF). (2017). The National Science Foundation and making. Retrieved from https://www.nsf.gov/news/news_summ.jsp?cntn_id=131770

Peppler, K., Halverson, E., & Kafai, Y. B. (2016). *Makeology: Makerspaces as learning environments (Vol. 1)*. New York, NY: Routledge.

Resnick, M. (2017). *Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play.* Cambridge, MA: The MIT Press.

Rodriguez, S. R., Harron, J. R., & DeGraff, M. W. (2018). UTeach Maker: A micro-credentialing program for preservice teachers. *Journal of Digital Learning in Teacher Education, 34*(1), 6-17. doi:10.1080/21532974.2017.1387830

Vossoughi, S., Hooper, P. K., & Escudé, M. (2016). Making through the lens of culture and power: Toward transformative visions for educational equity. *Harvard Educational Review, 86*(2), 206-232.

Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice?. *Science Education, 87*(1), 112-143. doi:10.1002/sce.10044.