International Journal of Designs for Learning

2021 | Volume 12, Issue 1 | Pages 77-100

PLAY, DESIGN, CREATE, FAIL, TEACH, AND REPEAT: A DESIGN CASE OF DESIGNING A MAKER EDUCATION COURSE FOR PRESERVICE TEACHERS

Yi Jin, Kennesaw State University

This design case shows a course designed for teaching preservice teachers about how to design literacy-infused STEAM learning experiences that involve both making and the use of educational technology at a large Midwestern land-grant university in the U.S. This course emphasizes the high-tech making activities in PK-12 formal education that offers students richer, more engaging, and potentially more meaningful learning experiences. The course expects to equip the preservice teachers with the understanding and skills they need to be ready to transform existing curricula in PK-12 education, incorporate curricula that cultivate creativity, design thinking, and problem-solving, and provide students authentic instructions and the opportunities to be the creators and owners of their learning. The current design case highlights design decisions during the design process.

Yi Jin is an assistant professor of instructional technology at the School of Instructional Technology and Innovation of the Bagwell College of Education at Kennesaw State University. Her research explores technology integration in PK-20 education, focusing on maker education, computational thinking, and the TPACK framework.

Copyright © 2021 by the International Journal of Designs for Learning, a publication of the Association of Educational Communications and Technology. (AECT). Permission to make digital or hard copies of portions of this work for personal or classroom use is granted without fee provided that the copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page in print or the first screen in digital media. Copyrights for components of this work owned by others than IJDL or AECT must be honored. Abstracting with credit is permitted.

https://doi.org/10.14434/ijdl.v12i1.25857

INTRODUCTION

In this article, I will discuss a design case of creating a course for teaching preservice teachers about how to design literacy-infused STEAM learning experiences that involve both making and the use of educational technology in a maker lab of technology (Cohen, 2017). This design is firmly rooted in my attention to several research strands, which are outlined below to give readers a clear picture of the perspective from which this design was created.

A *makerspace* is a physical space where individuals gather to create, invent, innovate, and learn while using 3D printers, software programs, electronics, and tools and supplies (Forest et al., 2014). The definition of a makerspace is broad and loose because no two makerspaces are the same or serve the same purposes.

Makers are people who engage in 1. Making creative physical artifacts using traditional and technological tools, and 2. Sharing their making processes and artifacts with a broader community using modern technology (Martin, 2015). Two characteristics that distinguish making from other creative activities are 1. The utilization of digital technologies, and 2. A maker mindset/ethos of open-resource sharing with the help of modern technology (Martin, 2015).

"Making" with the help of technology brings endless possibilities for essential 21st-century skill development and significant content area alignment in PK-12 education (Kurti et al., 2014). Learning activities that involve making bridge the digital and physical worlds and facilitate students' skill development in academic content areas and technology skills. The two characteristics of making highlight the necessity of having content area knowledge and knowing how to apply those to interdisciplinary projects, as well as mastering new literacies skills to successfully communicate with a community of makers. This skill set aligns with the Next Generation Science Standards and Common Core State Standards. Three benefits were reported in students' learning outcomes: 1. Fostering and supporting students' participation in science environments, 2. Supporting academic/ disciplinary development, and 3. Creating communities of learners (Vossoughi & Bevan, 2014).

Preservice teachers are an indispensable part of the maker movement because they must enter schools understanding the possibilities of this innovative and creative learning space, along with the active learning pedagogies that should be used in it (Peppler & Bender, 2013). However, as emerging technologies newly introduced to education, these topics have only been briefly mentioned in education courses. Cohen (2017) sent out a national survey to 741 member-institutions of the American Association of Colleges for Teacher Education (AACTE) who have teacher education programs in the U.S. Among these institutions, only 123 responded. Cohen found that half of the respondents provided some opportunities to undergraduates and graduates to learn about teaching and learning with maker principles and technologies through a unit or module of instruction at the least. The other half of the programs at least had some limited interest in offering a course within the next three years. Our immediate priority as teacher educators is to prepare preservice teachers to be ready and knowledgeable about using making pedagogies and technologies to transform student learning. Therefore, teaching about how to design learning experiences that involve making and technology is an essential component of teacher preparation.

Maker education has a close and natural connection to STEAM education in PK-12 schools. Furthermore, maker education brings unique opportunities for literacy education in PK-12 schools, which is less discussed in the literature. For this design case, I designed the projects to be literacy-infused STEAM activities that involve making and technology. Meanwhile, I ask preservice teachers to create similar learning experiences for their lesson ideas for a few reasons. First, the definition of being literate changes, especially in the 21st century. Multimodality such as image, gaze, gesture, movement, music, speech, using sound-effect, and digital technologies are essential components in the current times. New literacies that incorporate traditional text literacy, digital literacies, and the new ethos become the standard for 21st-century students (Gee, 1996; Lankshear & Knobel, 2006; New London Group, 1996). Second, in the current economy, computer and information technologies are essential tools. Students need to achieve universal computational literacy and information literacy as a mechanism for providing access to powerful ideas (DiSessa, 2000; Jacob & Warschauer, 2018; Papert, 1980). Third, maker education utilizes a wide variety of emerging technologies and information technologies. A lot of these technologies need beginner to advanced computational thinking and programming skills. Connecting computational thinking and programming to new literacies practices provide students more authentic learning experiences that facilitate literacy instruction (Jin & Zha, 2020). This combination provides space for students to use problem-solving skills for self-expression and share those in

an online community (Jacob & Warschauer, 2018). By giving students choice and voice, reluctant readers and writers might be more motivated to read, construct narratives, and share their works with others. Finally, with digital tools that facilitate multimodality, educators need to recognize that literacy is a material and social practice (Baroutsis & Woods, 2018). Educators should consider how to utilize digital technologies to encourage student collaboration in writing by producing multimodal texts between students of various confidence and proficiency levels (Baroutsis & Woods, 2018). Research found that students developed critical thinking and a range of 21st-century literacy skills through making (Jenkins et al., 2009; Santo, 2011, 2013).

CONTEXT

The Learning Technologies Minor Program

The current design case was developed for the Learning Technologies Minor Program of an Educator Preparation Program in a School of Education at a large Midwestern land-grant university in the U.S. This university is a research-intensive institution with around 36,000 students. The educator preparation program attracts national and international students. These preservice teachers observe, assist, and student teach within and out of the state. Graduates teach in various states and overseas with state licensures.

The minor program is an optional addition to the degrees offered. About ¼ preservice teachers in the educator preparation program enroll in the minor program. The stated mission of the minor is to prepare preservice teachers to fully achieve the five technology standards for teachers identified by the International Society for Technology in Education (ISTE, 2008). Preservice teachers need to take 16 credits to fulfill this goal. In these courses, students learn about a wide range of pedagogies and educational technology tools. One component is a series of electives on the Emerging Topics in Digital Learning. Each course in this series has a compressed format, which is a one-credit course lasting four weeks. Preservice teachers need to take three courses in this set after consulting faculty members and advisors. These courses could be taken any time after they enroll in the minor program. Students taking the current maker education course usually finished the majority of their coursework and are about to begin student teaching, so they have already learned various pedagogies and educational technology tools that could be used for student learning and engagement.

Initial Impetus

Because of the nature of the electives in the Emerging Topics in Digital Learning series, we consistently review the topics every year to add emerging topics or delete those that have become common sense or were placed in other courses. We consult the NMC/CoSN Horizon Report K-12 edition, National Education Technology Plan and related policies, new publications in the field, and discussions with teacher educators at academic conferences. A list of emerging topics is generated every year and prioritized according to their fit to the program and the mission of the school and university. In 2016, several new topics were introduced, including Digital Citizenship, Google Tools, Game-Based Learning, and Maker Education in PK-12 Schools. Meanwhile, 1:1 initiative, GPS, and Technology for ELL topics were deleted, for those topics were incorporated into the general educational technology course, science, and English as a second language endorsement.

I proposed the Maker Education in PK-12 Schools course due to several reasons. First, over the years, during my conversations with preservice teachers about their practicums and student teaching, especially those in the minor, I got to know that most of the schools they worked at had or planned to create a makerspace or STEM lab. For these minor students, they were frequently requested to work with a STEM teacher or a librarian in a makerspace or STEM lab. Occasionally, preservice teachers were invited to design and model making/ STEM learning activities in the local schools. These students expressed their interest in learning more about the maker and STEM education. Through communication with school district administrators, we were informed that administrators prefer to hire graduates who acquired sufficient preparation and training to maintain such active learning spaces, design corresponding standard-based learning experiences, and incorporate elements of making into their curricula. Although there was a strong need, I was also told by preservice teachers that they felt underprepared for managing and design learning experiences in makerspaces in PK-12 schools due to the lack of preparation. The non-existence of such a course in the program became an issue that we needed to address to provide better training to preservice teachers. Meanwhile, such a course would help us build a stronger partnership with local school districts.

Second, the School of Education received funding to renovate the building. Stakeholders of the Center for Technology in Teaching and Learning (CTLT) decided to renovate the center as a part of this renovation and create a maker lab of technology. The maker lab would provide opportunities for preparing preservice teachers for maker education, offering project-based learning curricula, and eliciting collaborative learning. After the renovation, CTLT was redesigned as a maker lab of technology, which became an ideal physical space for the course. The center was called a maker lab of technology to distinguish it from a makerspace that provides open access to everyone or a maker classroom that imitates the operation of a classroom (Cohen, 2018). A maker lab of technology is an open area that has maker technologies. However, users need to work with the lab personnel to be able to use the materials and technologies, for those are either stored away or require log-ins. The renovation of the

center was a collective effort of faculty, staff, and students, who contributed ideas to the redesign. Most faculty, staff, and students believed maker education was important to PK-12 education and making principles and pedagogies would not only support but also transform teaching and learning. With grants brought by the faculty and funding provided by the school and university, the center was equipped with a variety of educational technologies that could be used for making activities. The maker lab was designed to be flexible, so the furniture and equipment could be easily moved and rearranged. The maker lab is available most of the days during the week, with staff members and student assistants working to help faculty and students. Therefore, students have easy access to the lab, materials, and tools.

Third, as a learner myself, I learn from creating and making. Design thinking is a powerful tool for my learning (see Figure 1). My vivid memories of learning from my childhood always involved creating projects and making artifacts physically or digitally. I firmly believe in the possibilities of hands-on learning experiences and the potentials maker education could bring to PK-12 students, especially those students who learn more from making and those who are not challenged enough. My own learning experiences and teaching beliefs fueled my interest in teaching and learning with preservice teachers.

In my teaching beliefs, the actual goal of Maker Education teacher training is to prepare preservice teachers to be confident in teaching making to all students, engaging them in purposeful project-based learning experiences, and cultivating their maker mindset (Chu et al., 2015; Regalla, 2016). With the new technological tools in makerspaces, teachers could combine technology tools and design thinking to create a transdisciplinary, project-based learning environment for ALL students, which will provide unique learning opportunities. Teachers could also use maker education to build students'



FIGURE 1. The Design Thinking Process.

of maker education should emphasize design thinking and designing learning experiences for students, instead of solely focusing on introducing emerging technological tools. My long-term vision of maker education in teacher education is to prepare preservice teachers to learn how to design literacy-infused STEAM learning experiences that involve

social and emotional competencies and help them begin to

teacher educators should build capacity in preservice teach-

ers to appreciate the failures in making and the commitment

conduct critical making (Ratto & Boler, 2014). Furthermore,

to learn new technology tools. To sum up, the preparation

literacy-infused STEAM learning experiences that involve making and technologies in makerspaces or similar environments. Furthermore, I hope by infusing preservice teachers with these active learning pedagogies, they will change their teaching beliefs and enter the teaching profession ready to transform current curricula. Proposing, designing, and teaching this one-credit course is the first step towards these goals. I plan to develop a four credits course later, expanding on the topics, adding more low-tech and high-tech literacy-infused STEAM making experiences with a one-credit practicum.

Course Design and Consultants

I took the primary responsibilities for the design and implementation. I was a doctoral student in Curriculum Instructional Technology and Literacy Education and was finishing up my doctoral studies during this process. I have been working as an instructor and an instructional designer at the same university. I taught various courses in the program and designed and developed eighteen online and blended courses for the university.

Besides me as the instructor of record, two other faculty and staff members served as consultants. One consultant is a faculty member and the Director of the Center for Technology in Teaching and Learning (CTLT), who has a Ph. D. degree in Curriculum Instructional Technology. The other consultant is the instructional support staff at CTLT, who has an M.S. degree in Curriculum Instructional Technology. During the initial design phase, they shared resources and information and participated in the initial ideation of the course. We brainstormed major topics that should be covered with considerations of the availability of resources. Other faculty members also provided me with consultations and resources, focusing on the content area and pedagogical knowledge particular to STEAM. Staff members in the center not only offering me suggestions and inspirations to come up with ideas and solutions but also helped me with the logistics of arranging spaces and checking out technologies. For example, staff members showed me the inventories of materials and tools that could be used with robotics. They brainstormed with me the activities I could do with the available materials and tools.

Learners

This course was offered in spring 2016 to twenty-five preservice teachers who were enrolled in the Learning Technologies Minor. Most students were juniors and seniors who had some teaching experiences in their practicums. Some were about to enter student teaching or were student teaching during the semester. Because all of them were enrolled in the Learning Technologies Minor, they all had more training on technology integration into the curriculum compared to students who were not enrolled in the minor. Some preservice teachers had part-time jobs in local daycares and schools, while others worked as technology interns in school districts.

In the past, I taught several courses for the program and established a close relationship with these preservice teachers. Before designing the course, I talked to them about their interest and suggestions for this course. They commented that they witnessed more school districts created makerspaces and designed STEM activities that could be taught in the makerspaces. Thus, they aspired to be prepared for maker education and learn how to design learning experiences that could fully utilize the features of those spaces. They also expected to learn how to use the innovative educational technologies we had in our center to design learning experiences that focused on hands-on activities involving both making and emerging technology tools. Preservice teachers' interest coincided with and justified my rationale for creating this course.

Maker Lab of Technology and Educational Technologies

Before the renovation, CTLT was a designated space for faculty and students to check out educational technology tools and books. It resembled a traditional technology/media library. Staff members and student assistants operated the center with an electronic system for check-ins and outs. The center updated the equipment and added new tools yearly. For the renovation, we wanted to transform the physical layout of the center to encourage collaborative work. Mediascapes and furniture were set up for teamwork. We also reorganized the storage rooms and updated the inventories of our equipment and tools. Because the operation of the center was well-established previously, the daily running remained the same. The center is run under the leadership of its Director. Faculty members of instructional technology, staff members, and student assistants in the center also contribute to making the center a state-of-the-art learning environment and resource center that continually demonstrates powerful applications of technology that improve student learning. The staff members and student assistants checked out tools and books, delivered technology and materials to classrooms, and assisted faculty and students with their technology integration needs.









FIGURE 2. The Design of CTLT.

With these efforts, the center develops a good reputation in the school and college. Thus, faculty members and students view the center as an excellent learning environment with instructional leadership and a great resource with instructional technology tools and support readily available. Other faculty members and students in the school frequents the center to work with the instructional technology team on their research, teaching, and projects. Faculty members in the content areas often work with the center to determine the educational technology tools they will use in their courses. The center coordinates with these needs, delivers the technology tools needed to the classrooms, or downloads and installs apps and tools on the center's devices. For example, faculty members of science education bring their students to the center for STEM activities. Undergraduate and graduate students come to the center to use the space and tools for their research and projects. For example, undergraduate students come to the center to design and 3D print their artifacts as a project in their math method course.

After the renovation, the flexibility of the setup and the availability of emerging educational technologies made

the center the ideal place for the course. The course itself demonstrates the strong need to learn about maker education from the students. The course projects done in the center could lead to potential cross-pollination in the school.

Because the physical space was critical to this design case, I showcased the center's design in the figures below. Figure 2 provided an overview of the design of the center. This center was designed as a maker lab of technology. There were both PC and Mac desktops set up as in a traditional computer lab. Ample space was set up for collaborative learning. The furniture could be moved around for different kinds of active and collaborative learning. There are more than five spaces with tables, chairs, and sofas that are ideal for low-tech and high-tech making and group work. Students could bring their materials or check out materials and tools from the center to work on their making projects. For this course, we used those tables for team-based making projects with a rolling cart full of bins that contained materials and tools. Figure 3 showcased the four sets of mediascapes. These mediascapes have connectors to the main screens, and students could







FIGURE 3. Four Sets of Mediascapes.

use the cables and connectors to display their screens to the entire group.

Figure 4 (next page) showcased the digital tools available in the center. These tools are available for students to use. Some of them ask for a small amount of material fee.

Besides the physical spaces and educational technologies shown in these figures, the center had several rooms for storing low-tech materials and other educational technology tools, such as laptops with educational software, recording devices, robotics, games, etc., which were available for checkout. The center also has a mobile green screen and a green screen recording room readily available.

DESIGN OF THE MAKER EDUCATION COURSE

Learning Theories and Pedagogies

Both constructivism and constructionism paradigms guided the design as the theoretical frameworks. Constructivism posits the active and constructive learning processes that are influenced by people's experiences and emotional, biological, and mental stages of development (Piaget, 2013). Constructionism emphasizes that people construct knowledge by manipulating objects and creating projects (Papert, 1980). Both learning theories stress that instead of being a passive recipient of knowledge, learners should proactively create their subjective representations of the objective reality, which is built upon their prior knowledge, perceptions, and experiences (Ertmer & Newby, 1993). These two theories align with the essence of maker education that learners learn through making, failing, and sharing.

My teaching philosophies are also aligned with Vygotsky's Social Development Theory, especially the three core concepts, that 1. Students should play an active role in the learning contexts through active social interaction with family, friends, teachers, and peers, 2. Learning from the more knowledgeable others (MKO), and 3. Deploying the Zone of Proximal Development (ZPD) (Crawford, 1996; Moll, 2013; Vygotsky, 1978, 1980).

The hands-on nature of maker education calls for a bridge between behaviorist and cognitive learning because learners experience the continuous reciprocal interaction between cognitive, behavioral, and environmental influences (Bandura, 1997). Hence, Bandura's Social Learning Theory that stresses the importance of learning from each other via observation, imitation, and modeling also guided the design. This theory is closely connected to Vygotsky's Social Development Theory, and both highlight learning through social interactions. Further, Bandura's Social Learning Theory connects social and cognitive learning by highlighting attention, memory, and motivation, which were important factors to consider during the design (Bandura, 1986). Thus, the course followed these guidelines and encouraged making, failing, sharing, and learning from others.



















FIGURE 4. Digital Tools.

Multimodality Theory undergirded the design of the online course page and students' final products, which should communicate and interact with the audience through multiple modes, such as touch, visual forms, movements, sound, light, etc. (Kress, 2000, 2009). To model this kind of communication and presentation, I intentionally selected the course materials that encompassed text, videos, images, etc. I designed the assessments in the same way and required students to present their projects in different modes. Guided by these learning theories, I adopted the discovery learning approach to designing the course with particular attention to the efficient use of multimodality (Bruner, 1961, 2009; Kress, 2000, 2009). Table 1 provides a list of how these learning theories were implemented in the course.

Problem-based learning (Ellen et al., 2011) and project-based learning (Bell, 2010) pedagogies were used for providing modeling to preservice teachers on what pedagogies could be utilized in designing active learning experiences that involve making and technology. Problem-based learning is a student-centered teaching approach that designs the learning experience to focus on the process of working toward understanding or solving a problem (Gandhi & Dass, 2019). Project-based learning is also an active learning approach that engages students in experiential learning experiences (Chen & Yang, 2019). Projects in this course were designed using either of these pedagogies for its suitability. For example, real-life problems were presented for the 3D digital fabrication projects. Students were required to create

LEARNING THEORIES	EXAMPLES	
Constructivism	Reflection paper: students write reflection papers and construct meaning through the process.	
Constructionism	Hands-on activities: students work on hands-on activities and learn through making and creating projects.	
Social Development Theory & Social Learning Theory	Hands-on activities: students work in teams on projects and learn from the interactions with the instructor and peers. They were asked to observe others. Encouragements were given frequently for them to try different approaches together or individually for building their self-efficacy.	
Multimodality	Design of the online components: pages were designed according to the multimodality theory. Assessment: students were required to submit work with text, videos, images, artifacts, etc.	

TABLE 1. Utilization of the Underlying Learning Theories.



FIGURE 5. Vision board.

a solution and prototype of their products. All projects followed the guidelines of project-based learning.

Course Design Process

I followed the Backward Design Model during the course design process (Wiggins & McTighe, 2011). This model has a three-step process: 1. Identify desired outcomes, 2. Identify acceptable evidence, and 3, Plan learning experience and instruction. I also adopted the Rapid Prototyping Model, which has a spiral cycle of prototype, review, and refine (Tripp & Bichelmeyer, 1990). The Backward Design Model provided me the necessary structure to design, and the Rapid Prototyping Model was flexible, fast, and effective in enhancing communication between my colleagues, students, and me. During the design process, I first followed the tasks outlined by the Backward Design Model. Then at each stage, I created prototypes, asked colleagues to review and provide comments. Based on the suggestions I received, I further refined the design. First, I drafted the central topic and goal of the course. Then, I went to the two consultants to elicit feedback. The feedback was mostly on wordings, so I edited and finalized it. The central topic was *literacy-infused* STEAM learning activities that involve making and technology (Bowler, 2014).

Second, I drew a vision board to envision the learning outcomes of the course (see Figure 5). In summary, I expected students to construct their understanding of maker education through playing, designing, acting, creating with trials and errors, failures, and frustrations. Students would grow through thinking, learning, reflecting, sharing, and revising. There would be no unified way for students to achieve the learning outcomes, and grades should not be the goal.

Being cognizant of these guidelines, I wrote the learning outcomes and showed them to my two consultants. They suggested changing the order of the outcomes to highlight the progression of learning. I followed their suggestion, and the outcomes were: As a result of completing this course, preservice teachers will be able to:

- 1. Use emerging technology tools commonly found and used in an educational makerspace.
- 2. Identify and evaluate the affordances and limitations of maker education.
- 3. Design literacy-infused STEAM learning experiences that involve making and technology that promote students' skills in design thinking, problem-solving, and creativity.

After, I designed the assessments that would measure students' understanding and mastery. Each module's primary assessments were a multimodal representation of their making projects, lesson idea, and discussion posts on various topics. A final reflection paper with writing prompts was designed to be the last assessment that required preservice teachers to reflect on their experiences, teaching beliefs, plans, and needs for professional development.

Ren	nembering Understa	nding Applying Anal	yzing	Evaluating Creating	
Prior Knowleds	Novice	Advanced		Specialist	
	What is Innovation?	★ National Standards	★ Where	e is it fit in the curriculum?	What is Makerspaces?
	 What is Engineering Design? What is Makerspace? Makerspaces in Education Context of the Institution 	* Their Connections to Makerspaces in Education Professional Reasoning		ORationale of Teaching and Learning in Makerspaces to administrators, teachers, students, parents and other stakeholders	
	 Physical Programming (concepts, examples, tips, etc.) LittleBits (what is, examples, educator case studies) 	 * Project 1 - LittleBits * Other Possibilities- Explore Other Technologies and Projects 	Design Thinking	 OPhysical Programming Plan Ideas that Covers Standards in Several Subject Areas Evaluations of Other Possibilities and Practical and Creative Lesson Plan Ideas 	Physical Programming
	©Computer Programming(concepts, examples, ips, etc.) © Why and How to Teach Coding? © Sphero (what is, examples,	 * Project 2 - Sphero * Project 3 - Hour of Code * Other Possibilities- Explore Other Technologies and Projects 		Computer Programming Lesson Plan Ideas that Covers Standards in Several Subject Areas Evaluations of Other Possibilities and Practical and Creative Lesson Plan Ideas	
	educator case studies) Digital Fabrication, (concepts, examples, tips, etc.) Design-based Learning 2D and 3D Printing (what is, examples, educator case studies)	 * Project 4 – 2D Printing * Project 5 – 3D Printing * Other Possibilities- Explore Other Technologies and Projects 		 Digital Fabrication Lesson Plan Ideas that Covers Standards in Several Subject Areas Evaluations of Other Possibilities and Practical and Creative Lesson Plan Ideas 	
	 Multimedia Creation, (concepts, examples, tips, etc.) Multimedia Creation Technologies What is the future? 	 Project 6 – Multimedia Creation Other Possibilities- Explore Other Technologies and Projects 		 Multimedia Creation Lesson Plan Ideas that Covers Standards in Several Subject Areas Evaluations of Other Possibilities and Practical and Creative Lesson Plan Ideas 	Final Reflection

FIGURE 6. Course map.

Next, I listed all the potential topics and evaluated each topic based on seven criteria:

- 1. Connections to PK-12 curricula.
- 2. Connections to maker education.
- 3. Links to emerging educational technologies.
- 4. Potentials for literacy-infused STEAM learning experiences.
- 5. Availability and accessibility of educational technologies.
- 6. Physical spaces, resources, materials, and time required for the projects.
- 7. Preservice teachers' interests.

I evaluated the list and had conversations with the consultants who had more information on criteria 5 and 6. For example, fashion design was deleted because of the availability of e-textile and fabric printers, as well as the time and skills required. I also discussed with preservice teachers, and they felt excited about the topics. In the end, four topics were chosen for their fulfillment of all the criteria, as well as an overview module, Design Thinking and Makerspaces in Education, and an ending module, Envisioning the Future of Education. The four central topics were Physical Programming, Computer Programming, Digital Fabrication, and Multimedia Creation.

Third, I drew and created a course map to visualize each component and its connection to the course (see Figure 6). I drew multiple versions on paper, storyboards, and online, and discussed them with colleagues. My colleagues commented on the sequence of the topics. So, I evaluated the complexity of the four primary topics. I decided to begin with Physical Programming because it was the easiest to understand and work on. It also laid a solid foundation for Computer Programming, which required prior knowledge and experiences, as well as abstract computational thinking skills. Digital Fabrication was placed as the third for its high requirements for design thinking and programming skills. I intentionally put the Multimedia Creation last due to its need for time, resources, and skills.

I chose the educational technology tools for each topic, also based on the seven criteria listed. For example, LittleBits and Spheros are tools developed for educational purposes. They are relatively low cost and have a lot of potential uses in the classrooms. They have a well-developed content-specific curriculum guide and professional development for teachers. In local school districts, many schools already have these kits ready to be used. For instance, LittleBits could be used in math and science content areas helping students understanding electricity and circuits, which are topics in the standards. The course projects required preservice teachers to design making learning experiences that were connected to the content. The multimodal representation required them to fully explain their lesson idea and how they would teach content using these tools.

MODELS	ASSIGNMENTS		
Module 0 Makespace in Education	 Rationale and Professional Reasoning for Integrating Maker Education in the Curricula (0 pt.) 		
Module 1 Physical Programming	 Project 1 LittleBits (5 pts.) Physical Programming Lesson Ideas (10 pts.) Explore Other Possibilities of Physical Programming (5 pts.) Project 2: Sphero (5 pts.) Computer Programming Lesson Ideas (10 pts.) Explore Hour of Code (5 pts.) 		
Module 2 Computer Programming			
Module 3 Digital Fabrication	 Project 3: 2D Printing (5 pts.) 2D Printing Lesson Ideas (5 pts.) Project 4: 3D Printing (5 pts.) 3D Printing Lesson Ideas (5 pts.) 		
Module 4 Multimedia Creation	 Project 5: Multimedia Creation (10 pts.) Multimedia Creation Lesson Ideas (10 pts.) 		
Module N What is the Future?	• Final Reflection (20 pts.)		

TABLE 2. Course assessments.

I decided to introduce the content before hands-on projects using flipped classroom pedagogy (Velegol et al., 2015). Flipped classroom pedagogy reverses the activities done in and after class. Students learn content online before class and participate in activities and projects in class. I decided to choose this pedagogy because it saved class time but made sure students had prior knowledge and were prepared to participate in class activities and projects. It also gave students the flexibility to learn the content at their own time and pace.

Meanwhile, my two consultants provided me some resources. I designed each module as prototypes, sought continuous reviews and feedback, and refined the designs. The design challenge lay in finding the right balance for a one-credit course. My two consultants provided me feedback on the amount of content in each module. Then I carefully calculated the time needed to learn the content in each module and only kept the core content. Through these cyclical processes, these online components were developed.

We had four two-hour face-to-face class sessions scheduled on Wednesday nights when the center was less occupied. I considered the seven criteria to select hands-on activities. The course projects were designed in a way that students needed to continuously do, make, fail, and learn. Then, I discussed with the consultants based on these criteria and practicality. For example, after discussing with my consultants, a Sphero-powered boat design activity was dropped because it was challenging to find a pool or transport a large body of water to the maker lab. The consultants also suggested deleting the Sphero painting activities because of the carpeting in the lab.

Assessments

The major assessments were weekly making projects, discussion board posts, lesson ideas, and the final reflection paper. Table 2 provides an overview.

I created these assessments for students to continually construct their understanding through hands-on activities, observations of others' projects, reflections on the learning process, comments on each other's projects, and practice content alignment and professional reasoning for the integration of maker education in the K-12 curricula.

For the making projects, students first learned from working on different making projects in a group or individually. A learning environment was provided to the preservice teachers to experience the design thinking process and then reflect on their design process and challenges. I predetermined a pool of possible making projects for each module in considerations of the seven criteria and practicality. Appendix A illustrated projects selected by students in each module with sample students' artifacts (also see Figure 8). For the first three projects, I graded based on completion and whether the designs worked properly. For Project 4 and 5, I graded the artifacts based on the creativity, design, and final look. For the last project, I evaluated the artifacts based on the video's creativity, quality of the audio, video editing, content, and research.

Students shared their projects in the discussion forums. Each post consisted of a video and images showcasing the making project and the design process, a brief reflection on the design process, and the core standards it covered. Students also posted their lesson ideas with the standards covered. the rationale for content area alignment, and professional reasoning (Heitink et al., 2016). They were required to read their peers' posts and reply to at least two other posts. In this way, they got comments, feedback, and critiques on their projects and lesson ideas from their peers. Then students kept working on their posts and provided more professional reasoning or made revisions based on the reviews. This process corresponded with the design thinking process I used and advocated in the course (see Figure 1). A sample of a literacy-infused STEAM lesson idea is shared (see Appendix B). For the reflection part of the post, I expected students to reflect on their design thinking process from a student's perspective. Then, they should think about practical and innovative ideas for designing learning experiences from a teacher's perspective.



FIGURE 7. Adapted DEAL Model for Critical Reflection. Adapted from Kolb's Model of Learning and the DEAL Model for Critical Reflection (Ash & Clayton, 2009; Kolb, 2014).



FIGURE 8. Project map.

Note: Each letter in the pin represents one student. From Project 1 to Project 5, students formed their teams or chose to work individually. No students stayed in the same team in two projects.

The use of discussion forums made the course content and design consistent and coherent, as well as providing more structure for students to think about design thinking, content alignment, and professional reasoning. I created rubrics to grade these discussion posts based on the "fit" of the content and instructional technology with the lesson idea, the maker elements and making principles used, and professional reasoning. I incorporated Harris and colleagues' (2010) Technology Integration Assessment Rubric to evaluate whether the making project and technology chosen was a good fit for the lesson ideas and standards it covered.

I designed the final reflection paper following Kolb's Model of Learning Framework, which encompassed three categories of what, so what, and now what (Kolb, 2014). I followed the DEAL Model for Critical Reflection to create reflection questions (Ash & Clayton, 2009). The DEAL Model offers a critical reflection approach oriented toward well-articulated learning outcomes and experiences, which generate, deepen, and document student learning in applied learning (Ash & Clayton, 2009).

Furthermore, the writing prompts in each category "provide the guidance necessary for students to engage in the oftentimes counter-normative activity of developing their own learning rather than reproducing what their instructors have taught them" (Ash & Clayton, 2009, p. 42). The DEAL model includes three sequential steps (see Figure 7 for its adaptation for this course):

- 1. *Description* of experiences in an objective and detailed manner.
- 2. *Examination* of those experiences in light of specific learning goals or objectives.
- 3. Articulation of Learning, including goals for future action that can then be taken forward into the next experience for improved practice and further refinement of learning. (Ash & Clayton, p. 41)

I designed reflection questions under each category (what, so what, now what) to guide students through their thinking and reflection process. For example, under the so what section, three components were highlighted: personal growth and learning, academic enhancement, design thinking, and professional reasoning. Questions were developed for students to reflect on each of the components. I chose to use the DEAL Model because it provided a guided structure for professional reflection and academic writing (Ash & Clayton, 2004; Ash et al., 2005; Ash & Clayton, 2009). Moreover, practicing this guided reflection facilitates the cultivation of preservice teachers as reflective practitioners.

A rubric was designed to evaluate the quality of each writing components and the overall writing conventions. I gave students the freedom to post their final reflections in the discussion forum so they could learn from others' learning experiences. In this way, we built a professional learning community by sharing and learning from each other (Lave et al., 1991). This design element also valued the possibilities brought by the transparency of sharing on both students' learning experiences and possible improvement of the course design and development.

CREATING, FAILING, COLLABORATING, AND SHARING

During the implementation, preservice teachers formed a community of practice and learned through creating, failing, collaborating, and sharing (Britton, 2012). Students commented in their final reflection paper and course evaluation that they learned how to design making experiences and use emerging tools in the course. They enjoyed the course and wanted to have more preparation for maker education. I also did not get push-back from the administration. Instead, the administration fully supported the course as it was a highly requested topic from the school districts. After the implementation, I reflected on my design decisions and made an action plan for development. This section discusses the challenges and lessons learned that impacted the course design and students' learning.

Course Logistics

Because the making projects require continuous hands-on design and construction, course logistics play a prominent role during the implementation. The time needed for the design, trials and errors, and creation of the projects, the physical space, resources, and materials are factors instructors should pay particular attention to.

From conversations with students and their final reflection papers, I realized that the amount of time required for faceto-face meetings and the design and creation of the making projects was not what students expected before enrolling in the course. Students thought the expectations were higher compared to other one-credit electives in the Learning Technology Minor program. This inconsistency resulted in some confusion about the course requirements. Although they regarded the course as beneficial, they indicated that they would have preferred more clarification on the course requirements displayed on the course schedule webpage. Clearly communicating the course requirements will help students better plan and allocate time for their design projects.

Students' misunderstanding of the course expectations also indicated that they were not familiar with maker education, especially productive failure (Kapur, 2008). Productive failure is a crucial part of learning and making, and I plan to add more course materials and discussions on this topic. I want to help preservice teachers build the capacity to appreciate productive failures in making, which is key to maker education.

Students appreciated the flipped classroom pedagogy. They expected the instructor to work with them on the design and creation of the projects and provide just-in-time targeted feedback. Students also mentioned that going through peers' posts to look at the images and videos of the design and creation of the projects required a considerable amount of time and did not do the projects justice. They wanted to collaborate more with their peers and have the sharing and commenting activities in a face-to-face format. A gallery walk similar to those critique sessions in a studio setting will be added in the face-to-face sessions.

The physical space of the maker lab worked well for this course. The flexibility of the structure made it easy to reset the physical space to whatever format we needed. However, because the center was a public space, I did not have a space to store all the materials. To solve this issue, I found a wheeled cart to transport all the bins every time I had classes. This approach mimicked PK-12 teachers who had a maker cart if the school did not have a makerspace. Students said it was more practical for their future classrooms than a dedicated, well-designed, and furnished makerspace. I plan to brainstorm ways for storage and organization.

Because CTLT is an ideal place to work and collaborate, students frequent it to work and socialize. Thus, sometimes it was challenging to find space, schedule equipment, and work together as a whole class. For some classes, I had to use my office or reserve another classroom in the building so we could have uninterrupted time. We plan to set up a maker classroom designated for maker education.

For the projects, students faced some challenges of using the space and equipment in CTLT. Working hours and the availability of resources and materials were some major challenges. For example, we had three Makerbots in the maker lab. During the 3D printing project, students had to wait in line to use the Makerbots since each project took several hours to print. Students also needed to plan ahead to make sure the printing hours were within the working hours of the maker lab. Students who were not enrolled in this course used the Makerbots as well, making the line longer. We needed more 3D printers so students could have easier access. I plan to think about how to fully utilize the maker lab and the resources and materials we have. One solution is to purchase more equipment and materials. Although we had a fair amount of various equipment, we needed more for a class of students who wanted to use them simultaneously. I have begun to work on a grant application for this cause. This issue implied that the design and management of the center needed to be revisited, especially on how the design and management support public making activities and a

maker education course. Accessibility, flexibility, and availability are important topics.

Changes During the Course

Because I used a rapid prototyping approach, feedback from faculty, staff, and students were already included in the design of the online modules during the design phase. The online components of this course did not change much during the implementation.

Most changes occurred during the design process of making projects. As I mentioned before, I created a list of potential making activities for students to choose from. Moreover, students could propose their projects. Due to this open-ended nature of the course, I had to adjust my instruction, support continually, and keep learning the knowledge and skills needed for different projects. The complexity and trials and errors of the making projects required me to make rapid changes in my instruction throughout the course. For example, for the 2D and 3D digital fabrication projects, students created a large number of projects. I had to adapt my instruction to support them. The nature of making determines the constant changes during the course. Other designers and instructors should be aware of these needed changes.

More Targeted Instruction

One of the biggest challenges during the implementation was the lack of control. I designed the course to be as open as possible for students to explore different technology tools and materials to create their individualized making projects. However, due to the

variety of the projects. I could not provide every student the needed instruction and support for each of their projects (25 students * 6 projects = 150 projects). There were various instructional materials in the learning management system, but students commented that they preferred to work with me during the design thinking and problem-solving processes. They highly regarded the conversations and feedback with their teammates and me, which not only helped them solve the problems timely but also gave them more inspiration for improving their designs. This approach imitated a studio pedagogy.

I communicated with CTLT staff and student assistants so they could assist students with their projects. They helped me with this aspect, but they lacked knowledge in what we were designing and creating. In the future, I will need to



FIGURE 9. A Collection of Makerspace Projects.

better inform them about the projects we are doing or hire teaching assistants and find volunteers to assist.

During the course, I worked in my office every weekday from eight to six so students could work with me on their projects. However, students had a significant number of responsibilities (coursework, practicum, work, family, etc.), and some of them could not come until after seven. For example, for multimedia creation, some students felt frustrated about using the green screen and video editing programs. I was able to work with some students on recording and editing. However, I could not afford the time to work with every single student due to the difficulties in scheduling. I plan to keep brainstorming ways of providing more targeted and just-in-time instruction and support to students. Some of my ideas are Google Hangout with students and work with them virtually, creating more instructional materials online, finding teaching assistants and volunteers to support, and so on. It would be helpful to schedule more face-to-face weekly lab and studio sessions, which would allow us to meet for a longer time to work on projects.

Further Developing Grading Rubrics

I gave a significant amount of written feedback to students and replied to every post on the discussion boards. Students appreciated the comments and communicated their satisfaction through the final reflection paper and course evaluation. However, from the instructor's perspective, this grading approach was time-consuming, and the fairness of grading could not be guaranteed. Further developing the grading rubrics for different projects is a top priority for the course development. I plan to conduct a thorough literature review and create grading rubrics that measure key competencies.

More Making Projects

I plan to incorporate more low-tech making projects at the beginning of the course. I want to further clarify the notion of "making" to students that we do not necessarily need technologies for designing and creating making projects. Incorporating some low-tech making projects will help me open the conversation with students.

I expect to add a few more innovative educational technologies. With grants and funding available, we were able to purchase more educational technologies during the academic year. Adding a variety of emerging educational technologies while remaining the primary topics will help me better prepare preservice teachers and provide them with more experiences with different tools. Funding is a significant issue for a PK-12 makerspace, so it is crucial for preservice teachers to give professional reasoning and make sound judgments on the purchases of different tools and materials. Another emphasis for the next iteration is for preservice teachers to master the evaluation of more tools and their possibilities for a makerspace.

The amount of making projects and their complexity were more than the workload in a one-credit course. If the course continued to be a one-credit course, certain projects have to be cut to reflect the workload. A few well-curated making projects will help students get more in-depth with their projects.

Meanwhile, during the planning phase, I brainstormed and designed a few more long-term making projects. Due to the fact that the course was a one-credit course, I could not develop more elaborate making projects. In the final reflection papers, students recommended that the credits of some other courses in the minor could be reduced, and this course could be expanded into a three-credit course. A program review might be needed. It would be ideal for expanding the course into a full-semester four-credit course so students could have more time to work on more elaborate projects and conduct practicums in schools.

Graduate Student Being the Designer and Instructor

When I designed and taught this course, I was a Ph.D. student finishing up my doctoral studies. This identity gave me both opportunities and constraints.

On one side, as a graduate student, I was able to work with a large number of faculty, staff, and students. I had conversations with them and sought feedback on the design and implementation.

On the other side, although I contributed to the design of the maker lab before the renovation by providing feedback, the decisions were made by faculty and staff members. There was not a lot of storage space for maker education materials. Finding storage solutions for materials and tools is needed.

Due to limited funding, I could not have all the resources, materials, and tools I would like to include in the course. I would like to add some e-textile materials and tools, as well as Raspberry Pi toolkits. However, when the course was designed and offered, we were not able to purchase those. My students also needed to pay for usage and materials for the 2D and 3D projects. With the funding I got, I advocated for students and reimbursed some of the fees. However, students still had to pay for some of their projects.

Although materials and tools were regularly stocked and maintained by the staff members and student assistants, accessibility is somewhat affected by the operating hours and checkout system of the center. Though I had access to the maker lab with my ID card, I could not open the center for students to work on their projects outside the typical working hours. Continuous conversations and collaborations among the stakeholders might help facilitate the use of maker labs.

CONCLUSION

If we expected preservice teachers to be fully prepared for their teaching profession, preparing them to be able to design literacy-infused STEAM learning experiences that involve making and technology is needed. This design case shared how I designed and implemented such a course. Overall, the course design and implementation experiences were fruitful, with students excelling in the learning outcomes. I hope that this design case could serve as a precedent for other instructors working on similar topics.

ACKNOWLEDGMENTS

The author would like to thank Dr. Denise Schmidt-Crawford, Dr. Kristina Tank, Dennis Culver, Shelly Johnson, Tera Lawson, and countless colleagues and students for their reviews, feedback, and support.

REFERENCES

Allen, D. E., Donham, R. S., & Bernhardt, S. A. (2011). Problem-based learning. *New Directions for Teaching and Learning, (128),* 21–29. https://doi.org/10.1002/tl.465

Ash, S. L., & Clayton, P. H. (2004). The articulated learning: An approach to guided reflection and assessment. *Innovative Higher Education*, *29*(2), 137–154. <u>https://doi.org/10.1023/</u> B:IHIE.0000048795.84634.4a

Ash, S. L., Clayton, P. H., & Atkinson, M. P. (2005). Integrating reflection and assessment to capture and improve student learning. *Michigan Journal of Community Service Learning*, *11*(2), 49–60. <u>http://hdl.handle.net/2027/spo.3239521.0011.204</u>

Ash, S. L., & Clayton, P. H. (2009). Generating, deepening, and documenting learning: The power of critical reflection in applied learning. *Journal of Applied Learning in Higher Education*, *1*, 25–48. http://hdl.handle.net/1805/4579

Bandura, A. (1986). Social Foundations of Thought and Action. Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The Exercise of Control.* New York: W.H. Freeman.

Baroutsis, A., & Woods, A. (2018). Materialities, multiliteracies, and makerspaces: Design-based experiments in teacher/researcher collaborations. In N. Kucirkova, J. Rowsell & G. Falloon (Eds), *The Routledge International Handbook of Learning with Technology in Early Childhood*. Routledge.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House*, *83*(2), 39–43.

Britton, L. (2012). A fabulous laboratory: The makerspace at Fayetteville Free Library. *Public Libraries*, *51*(4), 30–33.

Bowler, L. (2014). Creativity through "maker" experiences and design thinking in the education of librarians. *Knowledge Quest, 42*(5), 58–61. <u>http://www.ala.org/aasl/kq/v42no5</u>

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, *31*, 21–32.

Bruner, J. S. (2009). The process of education. Harvard University Press.

Chen, C. H., & Yang, Y. C. (2019). Revisiting the effects of projectbased learning on students' academic achievement: A metaanalysis investigating moderators. *Educational Research Review, 26*, 71–81. <u>http://dx.doi.org/10.1016/j.edurev.2018.11.001</u>

Chu, S. L., Quek, F., Bhangaonkar, S., Ging, A. B., & Sridharamurthy, K. (2015). Making the maker: A Means-to-an-Ends approach to nurturing the maker mindset in elementary-aged children. *International Journal of Child-Computer Interaction*, *5*, 11–19. <u>https://doi.org/10.1016/j.ijcci.2015.08.002</u>

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

Crawford, K. (1996). Vygotskian approaches in human development in the information era. *Educational Studies in Mathematics, 31*(1-2), 43–62.

DiSessa, A. (2000). *Changing minds: Computers, learning and literacy*. Cambridge, MA: MIT Press.

Ertmer, P. A., & Newby, T. J. (1993). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly,* 6(4), 50–72. https://doi.org/10.1111/j.1937-8327.1993.tb00605.x

Forest, C. R., Moore, R. A., Jariwala, A. S., Fasse, B. B., Linsey, J., Newstetter, W., Ngo, P., & Quintero, C. (2014). The Invention Studio: A university maker space and culture. *Advances in Engineering Education*, 4(2), 1–32.

Gandhi, S., & Dass, D. P. (2019). A study to evaluate the effectiveness of Problem Based Learning (PBL) module on knowledge and attitude among nursing students. *International Journal of Nursing Education*, *11*(3), 101–106.

Gee, J. P. (1996). Social linguistics and literacies: Ideology in discourse. London, UK: Taylor & Francis.

Harris, J., Grandgenett, N., & Hofer, M. J. (2010). Testing a TPACKbased technology integration assessment rubric. In *Research Highlights in Technology and Teacher Education* (pp. 3833–3840). Society for Information Technology & Teacher Education International Conference. Association for the Advancement of Computing in Education (AACE). Retrieved from: <u>https://</u> <u>digitalcommons.unomaha.edu/tedfacproc/18</u>

Heitink, M., Voogt, J., Verplanken, L., van Braak, J., & Fisser, P. (2016). Teachers' professional reasoning about their pedagogical use of technology. *Computers & Education, 101*, 70–83. <u>https://doi. org/10.1016/j.compedu.2016.05.009</u>

ISTE (2008). NETS for Teachers. Retrieved from <u>https://www.iste.org/</u> docs/pdfs/20-14_ISTE_Standards-T_PDF.pdf

Jacob, S. R., & Warschauer, M. (2018). Computational thinking and literacy. *Journal of Computer Science Integration*, 1(1), 1–19.

Jenkins, H., Purushotma, R., Weigel, M., Clinton, K., & Robison, A. J. (2009). Confronting the challenges of participatory culture: Media education for the 21st century. MIT Press.

Jin, Y., & Zha, S. (2020). Weave coding into K-5 curricula as new literacies. *Information Discovery and Delivery*, 48(2), 49–66. https://doi.org/10.1108/IDD-09-2019-0069

Kapur, M. (2008). Productive failure. *Cognition and instruction, 26*(3), 379–424.

Kress, G. (2000). Multimodality: Challenges to thinking about language. *TESOL Quarterly, 34*(2), 337–340.

Kress, G. (2009). Assessment in the perspective of a social semiotic theory of multimodal teaching and learning. In *Educational assessment in the 21st century* (pp. 19–41). Springer, Dordrecht.

Kolb, D. A. (2014). Experiential learning: Experience as the source of learning and development. FT Press.

Kurti, R. S., Kurti, D. L., & Fleming, L. (2014). The philosophy of educational makerspaces part 1 of making an educational makerspace. *Teacher Librarian*, *41*(5), 8–11.

Lankshear, C., & Knobel, M. (2006). *New literacies: Everyday practices and classroom learning*. Open University Press.

Lave, J., Wenger, E., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation* (Vol. 521423740). Cambridge: Cambridge university press.

Martin, L. (2015). The promise of the Maker Movement for education. *Journal of Pre-College Engineering Education Research*, *5*(1), 30–39.

Moll, L. C. (2013). LS Vygotsky and education. Routledge.

New London Group (1996). A pedagogy of multiliteracies: Designing social futures. *Harvard Educational Review*, 66(1), 60–92.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc.

Peppler, K., & Bender, S. (2013). Maker movement spreads innovation one project at a time. *Phi Delta Kappan*, 95(3), 22–27.

Piaget, J. (2013). *The construction of reality in the child* (Vol. 82). Routledge.

Ratto, M., & Boler, M. (Eds.). (2014). *DIY citizenship: Critical making and social media*. MIT press.

Regalla, L. (2016). Developing a maker mindset. In K. Peppler, E. R. Halverson, & Y. B. Kafai (Eds.) *Makeology: Makerspaces as learning environments* (Vol. 1), 257–272.

Santo, R. (2011). Hacker literacies: Synthesizing critical and participatory media literacy frameworks. *International Journal of Learning and Media*, *3*(3), 1–5.

Santo, R. (2013). Hacker literacies: User-generated resistance and reconfiguration of networked publics. *Critical Digital Literacies as Social Praxis: Intersections and Challenges*, 197–218.

Tripp, S. D., & Bichelmeyer, B. (1990). Rapid Prototyping: An alternative instructional design strategy. *Educational Technology Research and Development*, *38*(1), 31–44.

Velegol, S. B., Zappe, S. E., & Mahoney, E. (2015). The evolution of a flipped classroom: Evidence-Based recommendations. *Advances in Engineering Education*, 4(3), 1–37.

Vossoughi, S., & Bevan, B. (2014). Making and tinkering: A review of the literature. *National Research Council Committee on Out of School Time STEM*, 1–55.

Vygotsky, L. S. (1978). Interaction between learning and development. *Readings on the development of children, 23*(3), 34–41.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wiggins, G., & McTighe, J. (2011). What is backward design? *Understanding by design*, 7–19.

APPENDICES

Appendix A: Course Project and Student Sample Artifacts

TOPICS	PROJECTS	SAMPLE STUDENT ARTIFACTS
Physical Programming Project 1: LittleBits	1. Box Monster	
	2. Bubble Flute	
	3. Doorbell	WELCOME
	4. Lil' Breezy	

TOPICS	PROJECTS	SAMPLE STUDENT ARTIFACTS
Computer Programming Project 2: Sphero	1. Art	
	2. Music	
	3. Obstacles	
	4. Chariot	
	5. Maze	

TOPICS	PROJECTS	SAMPLE STUDENT ARTIFACTS	
	1. Star Wars	The artifacts for this project were students' certificates after	
	2. Minecraft	finishing the Hour of Code challenges. A sample certificate was provided below.	
	3. Frozen		
	4. Flappy Code		
Computer Programming	5. Disney Infinity Play Lab	stificate of Complex.	
Project 3: Hour of Code	6. Classic Play Lab	Vi Jin for successful completion of	
	7. Artist	The Hour of Code and deconcentrating of	
	8. Angry Bird Maze	Conception of the second secon	
Digital Fabrication Project 4: 2D Printing	1. Teachers' Instructional Materials	$2(\frac{2}{2}) - \sqrt{144} + \frac{1}{17} + \frac{1}{16} $	
	2. Instructional Decorations for the Classroom		
	3. Sample Students' Work		

TOPICS	PROJECTS SAMPLE STUDENT ARTIFACTS	
Digital Fabrication Project 5: 3D Printing	1. Teachers' Instructional Materials	
	2. Supplies for the Classroom	
	3. Creative projects	REFERENCE TO THE REFERE
Multimedia Creation Project 6: Multimedia Creation	1. Tour of a Gallery or Museum	https://www.youtube.com/watch?v=JSCxhbPA-Tw by Amanda Willems

TOPICS PROJECTS SAMPLE STUDENT ARTIF		SAMPLE STUDENT ARTIFACTS	
Multimedia Creation Project 6: Multimedia Creation	2. Tour of a Makerspace or Innovative Maker Lab of Technology	3D Image: Second system Printing Image: Second system https://www.youtube.com/watch?v=zV1kuKEdFVo by Rachel Zimmerman	
		https://www.youtube.com/watch?v=0v0hx7wsFeA&fea- ture=youtu.be by Steven Burianek	
	3. Teach a Maker Education Lesson or Topic Using Emerging Technologies	Some school buildings had Makerspaces or makerspace kits in the region. Several students taught Makerspaces-related lessons during their practicums. Their co-operating teach- ers were extremely satisfied with the learning outcomes achieved in these lessons. However, to protect the privacy of the minors, the author will not provide examples for this category.	
	4. Interview an Exemplary Teacher of Maker Education	TELL ME ABOUT YOUR JOB https://www.youtube.com/watch?v=YIb9uN6HGt4 by Brooke Herren	
	5. Future of the Makerspace in Education	Only I in 4 schools teach computer programming. https://www.youtube.com/watch?v=a50YbGkvxtl by Sydnie Martinache	

Appendix B: Sample Lesson Idea

Link to the videos:

Monsters https://youtu.be/FgYm9uOVdlw

Circuit breakdown https://youtu.be/EJIbNIFO-gE

Grade Level: 1st grade

Lesson: For this lesson, the first graders will be reading the book *There was an Old Monster*. The teacher will read it out loud to the class, with all of the students sitting on the carpet around the book. The lesson objective will focus on rhyming words. The teacher will ask the students what they know about rhyming words and ask for some examples. The students will then get the chance to listen to the book being re-read by the teacher to pick out the rhyming words. The students will then get the opportunity to get to build their own monsters in small groups. The teacher will review the lesson about electricity and the circuit before the project. They will use *LittleBits* and get to program the monster correctly to where it has light-up eyes and a vibrating tongue. The students will be able to customize their monsters by adding drawings and details according to their understandings and imagination. After the small group of students has completed their monster, they will have their monster help them think of rhyming words. They will present their monster to the class by having it say (spill out) a set of rhyming words as a group.

Book to read: There was an Old Monster by Rebecca Emberley and Ed Emberley

Connections:

This lesson can be connected to literacy, science, and technology.

Possible Standards:

Speaking and Listening Standards K-5

SL.K.2

Confirm understanding of a text read aloud or information presented orally or through other media by asking and answering questions about key details and requesting clarification if something is not understood.

2. Demonstrate understanding of spoken words, syllables, and sounds phonemes). a. Recognize and produce rhyming words. b. Count, pronounce, blend, and segment syllables in spoken words. c. Blend and segment onsets and rimes of single-syllable spoken words. d. Isolate and pronounce the initial, medial vowel, and final sounds (phonemes) in three-phoneme (consonant-vowel-consonant, or CVC) words. * (This does not include CVCs ending with /l/, /r/, or /x/.) e. Add or substitute individual sounds (phonemes) in simple, one-syllable words to make new words. (RF.K.2)

Determine the meaning of words and phrases as they are used in a text, including figurative and connotative meanings; analyze the impact of rhymes and other repetitions of sounds (e.g., alliteration) on a specific verse or stanza of a poem or section of a story or drama. (RL.7.4.)

21.K-2.TL.2

Essential Concept and/or Skill: Use a variety of technology tools and media-rich resources to work collaboratively with others.

- In a collaborative workgroup, use a variety of technologies to produce a digital presentation or product in a curriculum area.
- Use technology resources for communicating and sharing ideas with others.
- Participate in learning activities with or about learners from other countries and/or cultures.

21.K-2.TL.6

Essential Concept and/or Skill: Understand basic technology hardware and software and their application.

• Choose the most appropriate technology tool for a given task.

- Demonstrate a basic knowledge of how technology is supposed to function and know when it is not working properly.
- Know when to seek adult assistance for technology problems.
- Explore new technologies using existing skills and knowledge.

How to create the circuit: Starting with the Power, connect a wire to the side, which connects to a pink roller switch. The pink roller switch has another wire on the other side which connects to the vibration motor (the monster tongue). The vibration motor is connected to a branch that has a long LED on its side.