Interdisciplinary Journal of Problem-Based Learning

Volume 12 | Issue 2 Article 3

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Recommended Citation

Marshall, J. A. , & Harron, J. R. (2018). Making Learners: A Framework for Evaluating Making in STEM Education. *Interdisciplinary Journal of Problem-Based Learning, 12*(2).
Available at: https://doi.org/10.7771/1541-5015.1749

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Cover Page Footnote

The authors gratefully acknowledge the support of National Science Foundation Project UTeach Noyce Scholarship and Stipend #1557155.

THE INTERDISCIPLINARY JOURNAL OF
PROBLEM-BASED LEARNING

SPECIAL ISSUE: TINKERING IN TECHNOLOGY-RICH DESIGN CONTEXTS

Making Learners: A Framework for Evaluating Making in STEM Education

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Abstract

The maker movement has strong connections to science, technology, engineering, and mathematics (STEM) as well as art and crafts, but the goals of making are not in perfect alignment with any of these disciplines. Within the problem-based paradigm, however, there is room to incorporate making as situated STEM learning, even in formal, standards-based educational settings. We report on a framework for making in STEM education and describe a rubric for assessing the presence of the essential elements of making within STEM instruction. We present examples of the application of the rubric in a STEM teacher education course.

Keywords: evaluation, making, problem-based learning, STEM, teacher education

Introduction

Over the last decade the maker movement and related initiatives have made significant inroads into informal and, increasingly, formal science, technology, engineering, and mathematics (STEM) education (Bevan, 2017; Blikstein, 2013). Stemming from the publication of *Make: Magazine* and the first Maker Faire in 2006, making was conceived as a platform for people to rediscover the joy and empowerment of creating artifacts for themselves and sharing them with a larger community of "makers" through digital and physical forums (Dougherty, 2012; Halverson & Sheridan, 2014). From its informal, extracurricular origins, making has been seized by the educational community as a mechanism to promote STEM learning, taking the "field by storm due to its perceived potential as a driver of creativity, excitement, and innovation" (Bevan, Gutwill, Petrich, & Wilkinson, 2015, p. 99).

There has been an enduring separation between the types of practices that are found within formal and informal learning environments (Peppler, Halverson, & Kafai, 2016). With the adoption of making practices by the formal education community comes an often unexamined shift in goals from empowering people to make, of their own volition, whatever might take their fancy, to incorporating making as part of a required curriculum to meet externally mandated learning standards. Formal education perforce has its own set of goals as articulated by national, state, and local educational institutions/organizations. Making, with its free-form, playful, and serendipitous approach to personally meaningful projects, often seems to be incompatible with the currently adopted (cognitive) STEM learning goals. Some even argue against adopting (cognitive) STEM learning goals to focus on "Maker empowerment" (Clapp, 2017). Still, the process of cultivating sensitivity to design though maker empowerment (Clapp, Ross, Ryan, & Tishman, 2016) seems just as much at home in the practices of tinkering and applied STEM. As such, further examination of the relationship between making and academic disciplines is warranted.

Relation to Academic Disciplines

Further complicating the spread to formal education is the issue of where the practices of making should be situated within the curriculum when adopted. Although connections to engineering design and technology are evident in an endeavor focused on creating "makers rather than consumers" of products, engineering is not a standard in the U.S. curriculum (National Academy of Engineering Committee on Standards in K–12 Engineering Education, 2010). Shop and home economics classes, although once a mainstay in

http://dx.doi.org/10.7771/1541-5015.1749

American schools and currently undergoing something of a resurgence as "makerspaces" and digital fabrication labs (Blikstein, 2013), are also not a required part of the academic curriculum. Art is likewise an elective in the standard American curriculum. Mathematics and science courses, required components in all state-mandated curricula, are another possibility, particularly when instruction is through problem-based learning (PBL). The connection between making and (often abstract) mathematics and science standards, however, is not always obvious, particularly to teachers in a high-stakes testing environment.

Further, there are theoretical concerns, tensions between maker projects driven by personally relevant goals and externally imposed constraints of curriculum standards of any kind. Moreover, formal education is typically a private process, where students are assessed and evaluated on individual achievement, which is also at odds with how making represents a shared/collaborative process (Cohen, Jones, Smith, & Calandra, 2017). Perhaps more importantly, there are epistemological issues to be addressed in merging making into any of these traditional school disciplines. Making has connections to art, science, crafts, and engineering, but is not comfortably contained within any of them. This relationship is illustrated in Figure 1.

Making as Craft. Making is often cited as the natural successor to tinkering, hacking, and other DIY movements, and technical skills and the use of tools are arguably central to the paradigm (Bevan, Gutwill, Petrich, & Wilkinson, 2015). Thus, making might be seen as most closely aligning with "craft." The difference here is that craft fundamentally comprises a utilitarian function, although coupled to varying degrees with artistry. The garment worker and the auto mechanic following standard designs and procedures serve a strictly utilitarian purpose. Designing one's own clothes or repurposing a gas-powered car to be electric could elevate the work beyond the utilitarian to something more akin to art. Passion drives these endeavors beyond the merely useful.

Making as Art. In contrast, the creative and fanciful nature of making would also seem to align well with the nature of art. It is possible to imagine giant flame-throwing robots (Austin Maker Faire, 2016) as art installations in a museum setting, and unicorn-headed dancers moving to techno-music (Total Unicorn) or a Tesla coil–playing band (Arc Attack) in a performing arts venue, and homemade cards and ornamental objects are staples of school art classes. However, as with the utilitarian nature of craft, art comprises a spectrum in terms of deeper meaning. In its purest form, universal

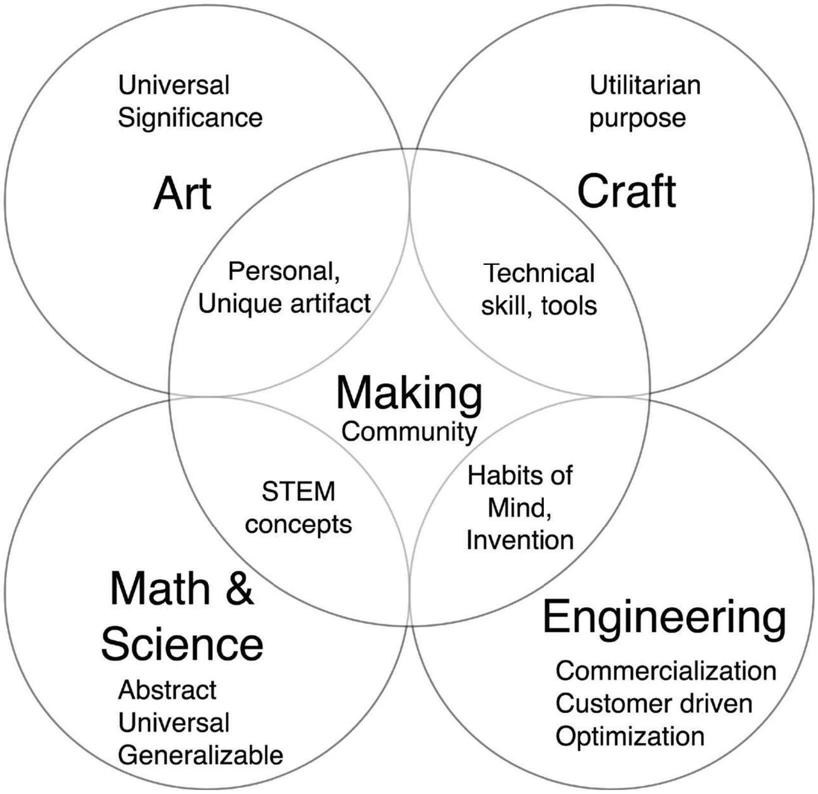


Figure 1. Representation of the relationship between making and art, craft, engineering, and math and science.

significance is essential to recognition of art, whereas no such recognition is fundamental in making.

Making as Engineering. The "maker mindset" (Dougherty, 2013; Martin, 2015) also has much in common with engineering habits of mind (NAE and NRC Committee on K–12 Engineering Education, 2009), as noted in Figure 1, and invention/innovation are central to both making and engineering, but the maker ethos is antithetical to the customer-driven nature of engineering. Creation with the client or user in mind is an essential component in engineering, but making is inherently personal. "Makers work on self-directed projects, and while both the process and product of their work is offered for public consumption, the work itself is often intended for a client base of one" (Cohen et al., 2017, p. 225). Optimization under constraints is also a central tenet in engineering. Although makers also operate under constraints of time, resources, and physical laws, the best solution is not the fastest, most durable, or most efficient in terms of resources, but rather the one that most pleases the maker. The notion of specifications is foreign to making.

Making as Science and Mathematics. Finally, as noted above, the required science and mathematics curriculum may be the most universally accessed by (or imposed on) American students, but there are significant differences in the nature of science and mathematics vs. making. Although laws of science implicitly govern the manipulation/creation of any physical object, and thus the making of any artifact, science and mathematics in essence strive for the universal and generalizable, whereas making is, again, essentially personal and idiosyncratic. The lines between science, mathematics, and making are blurred, however, as one moves toward a situated paradigm of STEM learning, found, for example, in a problem-based model of instruction (Hmelo-Silver, 2004; Savery & Duffy, 1995).

Situating Making within the Community

In the constructionist framework that underlies making (Papert, 1991), the creation of physical artifacts is privileged over the creation of (inherently unsharable) mental abstractions in promoting learning. Constructionism invokes the affordances of situated cognition inherent in authentic artifacts that will actually be used or enjoyed by students. In making, the abstraction comes from iteration, an essential feature (Cohen et al., 2017). Through the iterative process of tinkering students can develop intuition and comfort with science concepts (Petrich, Wilkinson, & Bevan, 2013). Following paradigms of learning such as PBL, making indeed can, in fact must, serve as a basis for STEM learning, where the creation of a product is central in some frameworks (Marshall, Petrosino, & Martin, 2010).

Despite differences along the dimensions of utility, universality, customer focus, and abstraction, the strong overlaps with other enterprises might lead one to question what is uniquely characteristic of making. Is making simply the intersection of art, craft, and the STEM disciplines? We argue, as in Figure 1, that it is *the maker community itself*, in a broad and grassroots sense that uniquely defines making. As argued by Dougherty (2012), "Whether it's arts and science or crafts and engineering, they seem to belong together, connected by enthusiasm and a common passion" (p. 12).

Making in Teacher Education

Despite an upsurge in research on making in education and the manifest popularity of the movement (Halverson & Sheridan, 2014), demonstration of its efficacy toward meeting any of its intended learning goals is limited. In particular, there has been little research on effective maker teacher education to date. Much of the peer-reviewed research has taken place in informal spaces, rather than in formal classrooms, or as one-time interventions.

Studies of short-term making activities with pre- and in-service teachers generally show positive results in terms of attitudes and beliefs (Jones, Smith, & Cohen, 2017). Teachers in that study considered making to be in alignment with instructional strategies, such as project-based instruction, that had been promoted by their preparation programs. They also expressed concerns about barriers to implementation, including lack of access to resources and resistance from colleagues and administrators. These are particularly salient in a high-stakes learning environment. Thus, it remains to be seen how and whether these teachers would actually incorporate making into their future instruction.

While pre- and in-service teachers who are exposed to the maker-centered education tend to have a positive attitude, there has not been a commitment to the pedagogy in most university teacher preparation programs. A national survey by Cohen and colleagues (2017) found that although about half of preservice programs have an opportunity to address some technology and principles associated with making, only 17.1% had access to a makerspace or fabrication lab. Those preservice teachers who are involved in makerspace-based projects as part of their teacher preparation often are frustrated by the learning curve of the equipment (Corbat & Quinn, 2018) or find the practices to be in conflict with their view of what learning looks like (Sator & Bullock, 2017). Furthermore, teacher candidates may be confused if preparation programs do not take the time to unpack terminology that is often associated with making (Sator & Bullock, 2017).

Papavlasopoulou, Giannakos, and Jaccheri (2017) reviewed empirical literature on the maker movement and found 43 studies meeting their inclusion criteria, the majority using qualitative methods. These studies were limited to

Table 1. Framework for Making in STEM Education.

Element	Qualities
Ownership/Empowerment	Personally meaningful Playful, enjoyable Individualized/original
Maker Habits	Failure positive Growth oriented Self-reliant
Production of an Artifact	Physical manifestation
Collaboration	Community connection Sharing of tools and products
STEM Tools	Digital tools Manufacturing tools

workshop settings and did not shed light on making in formal classrooms. They call for further investigation, particularly in classrooms, aimed at determining which aspects of making are more effective, and with which students.

Thus, there is still a need to advance understanding of making in formal STEM classrooms, its effectiveness in terms of achieving STEM learning goals, and the mechanisms by which teacher preparation programs can promote its authentic implementation.

The Purpose of the Study

The University of Texas at Austin (UT-Austin) has undertaken efforts to promote the maker community among its students, first with the establishment of the Longhorn makerspace in the engineering department, The Foundry makerspace open to all UT-Austin students in the fine arts library, and more recently with the establishment of the UTeach Maker (Rodriguez, Harron, & DeGraff, 2018) (https://maker.uteach.utexas.edu) initiative in its pre- and in-service STEM teacher communities. We are also engaged in an NSF-funded effort to investigate the affordances of making in STEM teacher education and professional development.

As a first step toward researching the value of incorporating making into teacher education, it was necessary to articulate the essential elements of making to serve as a guiding framework. This framework will serve as the basis for a rubric by which we will judge whether our pre- and in-service teachers are, in fact, engaging in making both in our program and, later, with their students.

Method

In the section below we describe the development of a framework and rubric for assessing the elements of making in preservice STEM activities and coursework.

Framework Design

The authors began with a literature review and stakeholder survey in regard to the essential elements of making. We reviewed both research-based and popular literature on making, including peer-reviewed journal articles, practitioner journal articles, and frequently cited books on the topic. Following the literature review we surveyed instructors noted for incorporating making into STEM instruction, makerspace directors, educational researchers with a focus on making, and others acknowledged as leaders in the maker education initiative. As a result of grounded coding of all these artifacts we identified five essential components of making associated with STEM education. These elements, which are presented in Table 1, include ownership/empowerment, maker habits, production of an artifact, collaboration, and STEM tools.

The use of our framework was piloted on an end-of-course making assignment from the first introductory teaching and recruitment class in the UTeach curriculum. For this assignment, students were tasked with creating a representation of their trajectory to date as teachers. The authors and two other researchers selected sample artifacts from two class sections taught by the same instructor. Based on pilot results, the framework was revised and descriptors were added for clarification. A rubric was developed to aid in assessing the degree with which projects aligned with the framework (see Table 2, next two pages). Levels in the rubric were designed to characterize work that might exhibit some making characteristics, but would be a “stretch” to classify as making, work that demonstrated the characteristic in an easily defendable way, and work that exceeded expectations for making in the classroom, with artifacts comparable to those that exemplify making in the community. The rubric was piloted first in the introductory course, reviewed by several researchers for ease and agreement

Table 2. Rubric for assessing essential elements of making.

	1 (minimal—stretch)	2 (solid evidence)	3 (clearly exceeds expectations)
Ownership/ Empowerment • Personally meaningful • Playful, enjoyable • Individualized or original	• Product shows minimal evidence of individualization. • Student used standardized product materials or kit with little customization. • The student expresses little enjoyment/fulfillment in creating the product.	• Product shows moderate individualization, moving beyond instructions (”pick a color”) but remains similar to product as described in guides or online tutorials. • The product creation engaged the student’s “head, heart, and hands.” • Student expresses enjoyment/fulfillment in making the product.	• Product shows a high level of individualization, distinct from existing product. • Product represents important aspect of student’s inner self. • Student went well beyond project requirements out of personal motivation and enjoyment. The making experience was clearly very significant for the student.
Maker Habits • Failure positive • Growth oriented • Self-reliant	• Student created product that presents limited challenges. • Student did not address challenges presented by product creation. • The student did not exhibit persistence or a willingness to learn from failure beyond creation of minimal product.	• Creation of product necessitated addressing a challenge. • Student responded to challenge by correcting errors in first version or simplifying the product. • Student shows some evidence of willingness to learn and persist.	• Product necessitated addressing a significant challenge; challenge used to modify, reconceptualize, or adapt the product. • Creation of product required significant persistence in the face of challenges or failure; more than one iteration attempted. • Student exhibited notable willingness to acquire new skills and personal growth.
Production of an Artifact • Physical manifestation	• A tangible, physical product has been created, either by following instructions verbatim or not reaching a final or working state.	• Physical product has been created and brought to final or working state. • Amateur or missing clearly needed revisions or refinements.	• Substantial or permanent physical product has been created and brought to final or working state. • Refined and publicly presentable quality.
Collaboration • Community connection • Shared tools, products	• The product indicated some use of open-source tools or other community resources. • The product was shared only within the community where created.	• The product indicated the use of open-source tools, access to community resources, and collaboration with others. • Product is shared in some way that extends beyond the classroom.	• The product indicated the use of open-source tools, access to community resources, and collaboration with others including mentors. • Public display or online documentation.

Table 2, cont'd. Rubric for assessing essential elements of making.

	1 (minimal—stretch)	2 (solid evidence)	3 (clearly exceeds expectations)
STEM tools • Digital • Manufacturing	• The student shows the ability to use STEM materials, concepts, or skills.	• Successful application of STEM tools and skills (e.g., metal or wood working, sewing, knitting, weaving, mathematical algorithms for spatial layout and part design, 3-D printers, digital recording) in a new context.	• The student has developed and documented original tools, processes, or procedures. • The student has demonstrated significant STEM expertise through the project.

of use in scoring, and then revised until consensus was reached. Descriptions of the categories in the rubric follow.

Ownership/Empowerment. With Clapp and colleagues (2016), we identify ownership and empowerment as the first/primary element of making. Making enables students to create things that they actually want to have in their lives; makers engage passionately with the objects of their creation (Dougherty, 2012). Just as almost anyone can be compelled to sing in a music class, but not everyone self-identifies as a singer, having assembled something does not automatically qualify someone as a maker. In making there must be a sense of agency, some sense of individual empowerment and choice (Cohen et al., 2017). Ownership might manifest itself simply as personalization; a choice of color, writing one's own name in lights, but in the ultimate incarnation maker projects become "like little pieces of us and seem to embody portions of our souls" (Hatch, 2014). Although ownership and empowerment seem to be universally acknowledged as central to making, more research is needed into how this element interacts with learning (Martin, 2015).

Maker Habits. Just as a sense of optimism is inherent in engineering habits of mind, optimism characterizes the maker community (Dougherty, 2012). Makers are failure-positive (view setbacks as opportunities to learn), growth oriented (believe that they can learn and do what they need to), and self-reliant. Makers are characterized as risk takers (Bevan et al., 2015). Maker habits operationalize as taking on intellectually challenging tasks, or choosing to make things that require the acquisition of new knowledge or skills, and in a willingness to engage in multiple design and construction iterations to achieve a desired product.

Production of an Artifact. Artifacts that are constructed in the maker movement are usually very personal in nature, where creators have very few limitations placed on their creativity. Making in educational environments, despite constraints, still provides students with the freedom to create something that is personally meaningful while also attempting to broaden their deeper thinking and inquiry skills. At the most basic level, products constructed can be created following a set of instructions or sometimes abandoned in an incomplete state. However, as makers develop their skills, working products can be created, improved upon, and shared with others to, in turn, inspire them to make their own creations. The practices of designing, personalizing, sharing, and reflecting are essential for learning in constructionist environments (Papert, 1991).

Collaboration. As noted above and in Figure 1, we view community as the heart of the making enterprise. The shared nature of learning is an essential element of constructionism (Papert, 1991). Dougherty (2012) highlights the origin of Maker Faires as an opportunity to come together and share. This includes both giving and receiving advice, help, and resources. The plethora of online as well as physical forums for sharing both the process and products of making provide users with very little technical background an access to making. Collaboration manifests itself in the use and repurposing of existing resources, such as open-source code routines or posted mechanical designs, in original projects, as well as the sharing of finished artifacts in a public forum.

STEM Tools. In placing STEM tools last among the essential elements of making, we acknowledge the danger of a tool-centered focus in making (Martin, 2015). The movement away from what are perceived as "women's" tools (those used in sewing, baking, quilting, knitting) and more accessible mechanical tools (hammers, saws, calculators) toward more complex digital tools lent the maker movement an exclusionary air, possibly discouraging the participation of both women (Buechley, 2013) and those who do not identify as "tech savvy." Still, we argue that incorporating making into the standard school curriculum would work against this stigma, and we have defined STEM tools broadly and explicitly to include both digital and physical manufacturing tools, in particular those such as sewing machines and knitting needles that have traditionally been associated with women. The extent to which STEM tools can be made critical in the design of maker tasks that are ultimately student-driven, however, remains to be seen.

Commonalities with Other Maker Education Frameworks

Our framework has commonalities with other published maker education frameworks. The Agency by Design framework examines maker-centered education through the lens of maker empowerment, defined as "[h]aving a sensitivity to the design of objects and systems along with the inclination and capacity to shape one's world through building, tinkering, re/designing, or hacking" (Clapp et al., 2016, p. 103). That framework also foregrounds agency, but presents the essential elements in three interacting capacities: looking closely, exploring completely, and finding opportunity. These focus much more on the process of development (as opposed to the nature of making and makers).

The Tinkering Learning Dimensions (TDL) framework (Bevan et al., 2015) consists of four learning dimensions: (a) engagement, (b) initiative and intentionality, (c) social scaffolding, and (d) development of understanding. Much as our framework recognizes the importance of developing maker habits, Bevan and colleagues (2015) recognized that the growth and persistence of the learner are important, and that social scaffolding/collaboration are important elements of learning in a community. While the TDL framework is learner focused, it serves as a tool to better evaluate free-form tinkering rather than open-ended problem-based learning, such as the design problem described below.

Participants

Using our framework and rubric as a form of evaluation, students in a preservice physics class were assigned the open-ended problem to create something of personal interest that involved electric circuits or optics, the two broad curriculum topics for the course. Following this student-centered pedagogy, the students were able to define their own project that best complemented their existing knowledge and ability level. The class had 20 students enrolled, of which 19 consented to participate in this study. Students could request supplies for their projects, such as Arduino microcontrollers, which were purchased with material funds allocated for the class. Additional technical support was provided by both the authors via email and by appointment for in-person help as needed. All projects were independently evaluated by two coders using the rubric, and differences were negotiated until agreement was reached, resulting in minor modifications to the rubric (Marshall & Harron, 2017).

Exemplars: Making and STEM Learning in a Physics Class

Examples of projects that scored at various levels of the rubric in different categories are highlighted below.

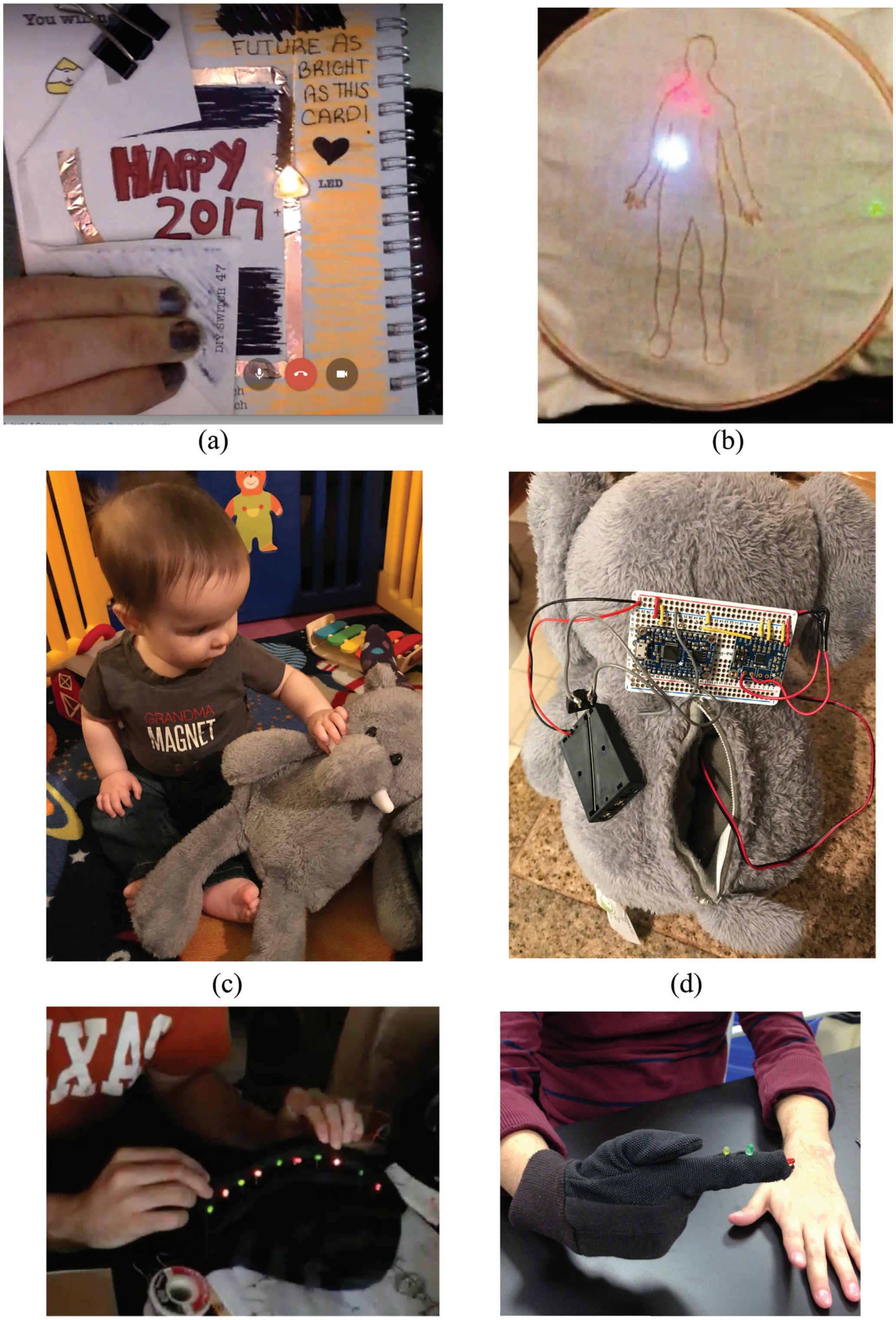
Ownership/Empowerment

On the lower end of the empowerment/ownership scale, projects that were rated as indicating only minimal ownership included a holiday card made with a Chibitronics kit (see Figure 2a, next page) and a curriculum manual for a middle school science unit using Snap Circuits (http://www.elenco.com). Although the student creating the unit was teaching middle school science and might have used it herself at some point, it was intended as a close-ended generic resource for teachers and did not capture the enjoyable/playful aspect of making. While a study by Remold, Fusco, Anderson, and Leones (2016) highlighted that there is a need for maker-centered teacher resources, this may indicate that teachers who are new to maker-centered education may confuse the act of building/constructing with commercial education kits as an authentic form of making.

On the high end of the spectrum, a future biology teacher created an embroidered model of the human circulatory system (see Figure 2b, next page), combining her first love of hand stitching with her teaching vocation. During the process the teacher had to overcome challenges such as calculating the resistance needed to illuminate different colored light-emitting diodes (LEDs) in a parallel circuit. A student teaching mathematics at the high school level created a stuffed toy with a sound module embedded that played a recording of her own heartbeat for her first child (see Figures 2c and 2d). This project was viewed as having a high degree of ownership due to the personally meaningful nature of the project, as well as empowerment, as the student needed to learn new programming skills to control the sound module.

Maker Habits

The project involving Snap Circuits also scored lower in terms of maker habits. Curriculum development was not new to the student and she also had some prior experience with Snap Circuits. Thus, creating the unit did not pose major challenges or opportunities for growth. At the other end of spectrum, the student creating the stuffed toy had never worked with an audio module (or any sort of integrated circuit) and



(a) (b)

(c) (d)

(e) (f)

Figure 2. Examples of project artifacts: (a) Chibitronics greeting card, (b) embroidered model of the human circulatory system, (c) stuffed elephant, (d) circuit inside of stuffed elephant, (e) stocking cap ornamented with flashing LEDs, and (f) "laser glove."

never used a soldering iron. Her first attempts at uploading the recording of her heartbeat to the audio module failed because only a certain type of mini-SD memory card would work with the module, a fact that she discovered by researching user posts on an online forum for makers. Working over the Thanksgiving break, she was able to assemble a working module by the end of the semester, but the sound quality was poor and the construction not robust. She continued to work after the end of the semester, rebuilding with a different audio module and an enclosed speaker system, and presented the final product to her son almost a year later.

Production of an Artifact

In contrast to the ratings in the first two categories, the Snap Circuits curriculum unit scored a solid 3 in the artifact category. Although the resulting artifact was digital (online), it was completely robust and professionally produced, and was, in fact, distributed to other teachers. All of the products reached at least the second level on the rubric (solid evidence) by creating products that worked, at least temporarily. An example is a stocking cap ornamented with flashing LEDs (Figure 2e, see previous page) that worked in the classroom, but failed while being used by the student after the classroom presentation.

Collaboration

The student who created the embroidered representation of the human circulatory systems scored in the highest category here. She created a website describing her process and product and went on to model it at maker events. The act of sharing publicly in conjunction with attending maker events demonstrated that she was becoming a member of both the online and local maker communities. On the other hand, the student who created a "laser glove" with LEDs (Figure 2f, see previous page) only worked with the instructor of the course and a graduate research assistant rather than engaging in collaboration with peers or online forums. The creator of the glove also did not share his project outside of the class presentation, and thus scored lower in this category.

STEM Tools

Almost all the projects scored in the middle category on STEM tools, with the makers having successfully learned and employed STEM tools, including soldering irons, band saws, embroidery and sewing tools, the Scratch programming environment, a Raspberry Pi microcomputer, and maker kits from Chibitronics and Lily Pad Arduino. There were no examples, however, that scored in the top category, as none of the projects were judged to involve the development and documentation of original tools, processes, or procedures, although many did develop original solutions in response to construction issues. This is the one area in which the rubric was not aligned with the full range of projects, and may indicate a need for further revision.

Discussion

As the practices related to making find their way into the STEM classroom, it is important for educators to have a means of evaluating student work that does not rely on the traditional notions of transfer of knowledge and memorization in the classroom. Our framework provides one possible method to help educators think about how making can empower students to develop positive maker habits, experience the frustration and satisfaction of developing a personally meaningful artifact, collaborate with others in both the process of constructing and sharing artifacts, and have an opportunity to explore STEM-related tools that can fuel their curiosity and creativity.

Using making as an outlet to engage in problem-based learning may seem overwhelming to educators implementing these practices for the first time. We believe the collaborative nature of making can address this issue. Further, making lends itself perfectly to problem-based pedagogy and should be explored by educators who are interested in providing students with a high degree of autonomy in the classroom.

Conclusion

To date, we have been able to use the framework and rubric described here effectively in several teacher education courses. A limitation of the work is that the rubric has only been used by a small number of researchers in one teacher preparation program. Whether the rubric as currently configured would categorize the span of work in other classes where maker education is being attempted remains to be seen.

Still, creation of the rubric and exemplars is only a first step toward researching the effect of incorporating making into STEM teacher preparation on both teachers and ultimately on their future students. Given the required resources, infrastructure (in terms of equipment and space), and teacher preparation necessary to implement making in education, whether and how it will affect student outcomes, particularly in regard to STEM learning, is important to assess. The question of whether making enables not only empowerment, but also STEM learning as measured against national, state, and local standards, remains to be addressed.

Acknowledgments

This work was supported by National Science Foundation grant NSF DUE-1557155 UTeach Noyce Scholarships and Stipends: Making Teachers.

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