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Educators' Perceptions of a Maker-Based Learning Experience

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Abstract

Purpose - The purpose of this paper is to examine a cohort of educators' perspectives of a semester-long, maker-based university course.

Design/methodology/approach - This qualitative study utilized participants' weekly and end-of-semester written reflections to illustrate participants' perceptions of a semester-long university course focused on the role of maker principles and technologies in a variety of educational contexts.

Findings - Participants' perceptions of learning following the semester-long maker experience viewed learning as a more collaborative experience, and noted the benefits of a classroom community that arose from the collaboration.

Originality/value - This study adds empirical research to the literature base on the use of maker tools and strategies in formal educational environments. While other studies have examined similar environments, they tend to focus on short-term, single experiences. This study followed the development of educators' perceptions of a maker-based learning experience over a longer duration of time. Findings of this study provide a research-based foundation for teacher educators to build upon when developing maker-based learning activities.

Keywords - Makerspaces, Maker tools, Maker culture, Collaboration, Community

Paper type - Research paper

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Introduction

While making is a fundamental human activity, there has been an increased interest recently in making activities due in part to the emergence of both advanced manufacturing technologies (e.g., 3D printers, digital die cutters, laser cutters, and digital milling machines) as well as digital communication technologies. This phenomenon has come to be known as the maker movement (Dougherty, 2012). The roots of this movement can be traced back to the creation of *Make* magazine in 2005 and the first Maker Faire in the United States in 2006 (Dougherty, 2012). The maker movement received national attention in 2014, when President Obama established a National Day of Making (Obama, 2014). This modern maker movement is unique in that current digital tools and technologies have provided individuals with more powerful means to create, as well as share creations than has been previously possible (Martin, 2015). This movement has increasingly drawn the attention of researchers and practitioners in the field of education.

Though definitions of making vary (Vossoughi and Bevan, 2014), there is general agreement that two central aspects of making are (1) the construction of some kind of artifact, whether it be digital or physical, and (2) the sharing of the process of making and/or the product created with a community of makers. Making is the central act of the maker movement, a diverse community of individuals who gather in both physical spaces (e.g., makerspaces and maker faires) and online spaces to leverage digital and analog technologies as well as the wisdom and experience of their fellow makers to produce public artifacts. What makes the maker movement distinct from previous DIY and arts-and-crafts movements is the way it leverages modern digital technologies in both the production of artifacts and in the creation and sustaining of communities of interest (Collins and Halverson, 2009). Analog tools in combination with newer digital tools, such as laser cutters, 3D printers, and microcontrollers allow makers to bridge the digital and physical worlds in ways that were available only to professionals in previous decades. Similarly, makers tend to blend their participation in physical makerspaces with digital maker communities, exponentially expanding the ability for makers to learn from, collaborate with, and become inspired by other makers.

In the last few years, researchers have sought to understand how elements of the maker movement may be employed in the service of learning (see Papavlasopoulou et al., 2017). From this body of literature several benefits for learning have been proposed. First, maker activities may align with previous learning theories such as experiential education, critical pedagogy, and problem-based learning (Blikstein, 2013; Halverson and Sheridan, 2014; Oliver, 2016). Second, research has suggested that making activities may provide a vehicle to attract students to engage in STEM (science, technology, engineering, and mathematics) subjects (Berry et al., 2010; Bevan et al., 2014; Hsu et al., 2017; Lacey, 2010; Martin, 2015). Third, several studies have pointed to a connection between maker activities and improved spatial reasoning (Katsio-Loudis and Jones, 2015; Safhalter et al., 2016). Lastly, maker activities have been identified to promote

growth mindsets, personal agency, and student empowerment (Clapp et al., 2017; Hsu et al., 2017).

Among the various features of making that are of interest to educators and educational researchers, collaboration and the development of a maker community are of particular relevance to the present study. Collaboration, and in particular the type of learning that arises from collaboration, are widely studied (Slavin, 1996) and a full review of collaboration is beyond the scope of this manuscript. However, Clapp et al. (2017) provide an overview of what collaboration looks like in a maker education environment:

> In their [maker educators'] view, it is a hallmark characteristic of maker classrooms, and it occurs in a variety of ways. For instance, often in the maker-centered classroom students collaborate on projects in which they make things or tackle a design challenge together. Sometimes students collaborate by finding and sharing resources, even if they are working independently. They often collaborate by teaching one another…. Sometimes they collaborate by giving one another feedback, or by simply giving each other a hand with whatever is needed. (p. 60)

Collaboration in maker environments exists on local levels, such as real-time physical collaboration with other makers sharing a space, and on broader levels, such as participation in Maker Faires or contributions to online maker discussions (Kuznetsov and Paulos, 2010). The pervasiveness of collaboration, occurring on multiple levels, leads, in part, to the development of maker communities. Martin (2015), borrowing from Scardamalia and Bereiter (2006) characterized these communities as knowledge-building communities, which work collectively to build and share knowledge, as opposed to "the typically competitive and replicative nature of classroom learning, where the (sometimes tacit) goal is to acquire a set of pre-existing knowledge, and to do so more effectively than one's classmates" (p. 36).

Educator perceptions

Previous research suggests that initial teacher preparation programs in the United States are beginning to increase their work in supporting teachers' ability to implement maker technologies and principles in their practice (Authors, 2017). In addition, there are several programs available to in-service teachers, such as the online course Maker Tech: Hybrid Computing and Creative Tinkering for STEAM Education offered at Boise State University, and a course focusing on establishing makerspaces in K-12 environments at the University of Wisconsin-Stout (Hsu et al., 2017). However, there is currently little empirical research to inform the development and implementation of such efforts.

While there is a growing body of research that focuses on the use of maker tools and strategies with various student populations, research examining educator training in this area is limited. Of the three studies located, one examined the experiences of four preservice teachers who facilitated a one-time making activity at a school maker faire (O'Brien et al., 2016), a

second examined 25 in-service teachers involved in a one-hour making workshop (Paganelli et al., 2016), and a third focused on 82 preservice and early-career teachers who took part in a one-time workshop exposing them to various maker tools and strategies (Authors, in press). In the first two studies, participants reported favorable perceptions towards the activities, but struggled with the open-ended, problem solving nature of the activities and assessment of the activities (O'Brien et al., 2016; Paganelli et al., 2016). In the third study, participants again reported favorable views of the activities, but were cautious about integrating these types of activities in their future classrooms due to concerns around peer and administrator support as well as lack of resources (Authors, in press).

While each of these studies has contributed to the field's understanding of educator perceptions towards integrating maker tools and activities into their instruction, each has been limited by short, one-time learning experiences. This study fills an important gap by examining the perceptions of a group of educators who have engaged in a semester long maker-based learning experience. Participants in this study reflected throughout the experience, as well as provided final reflections at the conclusion of the experience.

Purpose of study

An examination of perceptions of learning is of value because they are likely to exert some influence on the type of teaching these educators will employ (Authors, in press), and by extension, the resulting student learning (Samuelowicz and Bain, 2001). This research was guided by the following research question: How does a semester-long, maker-focused learning experience impact educators' perceptions of learning?

Methodology

Research design

Because there is not a significant body of research examining educators experiences with maker tools and strategies, the researchers employed a qualitative exploratory design (Creswell, 2012) to explore the research questions. The data were collected during the Spring 2017 semester.

Context

The study was conducted in a large university located in the Southeastern United States. The participants in the study were students in a course focused on the role of maker principles and technologies in a variety of educational contexts. The aim of the course was to provide a space in which current and future educators could explore both the technology of the maker movement and the various pedagogies and design thinking that leverage this technology.

The majority of the class time was devoted to work on project-based activities designed to allow students to experience making. These activities were done in small groups, usually

pairs. The activity briefs were open-ended, which encouraged students to think critically about each assignment and to leverage the technologies and skills they had at their disposal. One such project assignment was to design and fabricate an arcade game; the groups' resulting projects varied widely, from a low-tech fishing game created from 3D printed parts, magnets, and die cut fish to an Operation™ -style game, created using a coat hanger, laser-cut wooden pieces, and a Makey Makey, an electronic circuit board which converts physical inputs into keyboard strokes or mouse clicks. Throughout the process of making, groups maintained digital design journals, in which they recorded their making processes, from the brainstorming stage through multiple iterations and post-build reflections.

These making experiences were supplemented with more traditional supports, such as readings, individual reflections, brief lectures, presentations, and class discussions. Students were graded on their participation during the course, the completion of several individual written assignments, and the maintenance of their groups' digital design journals. The course culminated in a final project, in which students individually designed maker-centered learning experiences and reflected on changes in their own thinking about making.

The first author was the instructor of record for the course, and the second author participated in the course design and served as a teaching assistant for the course. In order to minimize any perception of coercion, the first researcher did not find out which students participated in the research until the end of the semester, and all students participated in all the research activities as part of the regular coursework, regardless of their consent status.

Participants

Research participants were students enrolled in a university course focusing on teaching and learning with maker principles and technologies. The sample was one of convenience. Twelve of the 13 students enrolled in the course participated in the research. The racial/ethnic diversity of the course reflected that of the university as a whole, with the majority of participants being students of color, and female. Three (25%) of the participants were enrolled in master's programs. Of these three, one was a curriculum designer, one was a preservice mathematics teacher, and one was an ESOL teacher who worked with adult refugees. Among the nine (75%) undergraduates, three (25%) were enrolled in formal preservice teacher preparation programs, while the other six (50%) were enrolled in an education-focused interdisciplinary studies program, designed to support students' pursuit of careers in education-related fields.

None of the participants had any previous experience in maker environments. While two of the participants had participated in a single class meeting focused on making as part of another course and another participant had used a 3D printer before, none of the participants, for instance, had ever visited a makerspace or were aware of any online maker communities.

Data collection

The four data sources which informed this research were researcher observations,

journal-style reflections (*n*=42), final essays (*n*=12), and either written or audio-recorded course reflections (*n*=8) that the students provided at the course's conclusion, collected through a learning management system. The researcher observations took the form of field notes, compiled by the second author. The journal-style reflection prompts, completed at various times throughout the semester, asked students to reflect on the previous classes' work. The final essays answered the question, "How can making be leveraged to support teaching and learning?". The post-course reflection prompt asked students to reflect on their major takeaways from the course. These data were appropriate for this particular study in that they allowed researchers to experience the nature and evolution of students' thinking about making and learning in their own words through written reflections. The observation data served to contextualize the students' words.

Data analysis

Data were analyzed using Nvivo 11, a qualitative data analysis software product. Following Miles, Huberman, and Saldaña (2014), the first two authors employed a two-cycle approach to coding. In the first cycle, researchers read the entire corpus of data and used descriptive coding to generate an inventory of topics related to making and learning. Descriptive coding is "especially helpful for ethnographies and studies with a wide variety of data forms (field notes, interview transcripts, documents, etc.)" (Miles et al., 2014, p. 74), such as the present study. In the second cycle, researchers collaboratively engaged in pattern coding in order to generate "parsimonious units of analysis" (Miles et al., 2014, p. 86), or themes. These themes then provided a framework for the subsequent and continued analysis of the data. The first cycle of coding yielded 16 codes, including "Failure and iteration," "traditional education," "creativity," and "metacognition." The second cycle of coding yielded 2 major themes, "collaboration," and "community."

Findings

In reflecting on the semester-long experience, participants noted two primary elements of a maker-based learning experience: collaboration and the development of community. While these two elements certainly support one another, participants articulated a nuanced understanding of each, and described benefits specific to each. Most surprisingly, participants were able to generalize the benefits of these elements outside of making-focused learning activities to the broader area of educational environments in general. Indeed, as evidenced in their reflections, participants demonstrated a heightened awareness of these two elements following this experience. While the popular narrative surrounding the utilization of elements from the maker movement in formal educational environments often focuses on emerging tools and technologies (Authors, in press), participants in this study focused on elements that were more pedagogical in nature.

Perceptions of collaborative learning

At the outset of the study, participants described in writing their ideal learning environment. Their responses provided insight into their conceptualizations of education, and covered a variety of domains. Despite the diversity of responses, one commonality of the responses was the almost complete lack of commentary on how collaboration can occur in an ideal learning environment. Instead, many focused on more prosaic aspects of education. For example, 5 of 12 respondents chose to focus their responses on the physical nature of the classroom, mentioning things like furniture, paint colors, room temperatures, and even room size. When participants did comment on collaboration in an ideal learning environment, their commentary was typically general in nature, such as "Students will form groups and learn through social interactions," and "all the students as well as myself could learn from each other in a safe learning environment." One participant focused on collaboration, but he did so in terms of teacher-centered co-teaching as opposed to student-centered collaboration:

> The skills and perspectives of having another person comes to mind when having coteacher. There could be times where one teacher is more knowledgeable about a subject or know a better way to deliver it. Then having that teacher lead during that subject would be beneficial in order to enrich the student's mind. It is like saying, "Two minds are better than one."

This lack of awareness of collaborative learning became conspicuous in comparison to the reflections which came later in the semester. In these later reflections, participants noted specific affordances of collaborative learning such as peer teaching and learning, and help-seeking behaviors, as well as the role of empathy in working with others.

Participants noted positive perceptions around peer teaching and learning, and suggested that maker activities facilitated these types of learning interactions. One participant, drawing from previous educational experience, stated that maker activities "support collaborative learning, or peer learning, frequently used by teachers to engage students." Another student, in discussing her personal experience in the course, noted, "to my wonderment and benefit, others in the class were eager to share their knowledge. They helped me learn and offered comfort while I dealt with my errors." Participants reported positive perceptions of helping their peers, and noted how their learning was enhanced through peer teaching. One participant articulated this perception in describing a learning activity in the course in which she assisted a peer: "She did not hear [the professor's] explanation, so this gave me an opportunity to share and teach. Together we did it. I watched as she became excited. I smiled. Not only was I learning, I was teaching." Finally, a third participant generalized these types of activities into the broader realm of education and stated, "But even in the absence of the maker lab, teachers can start facilitating space in their classrooms for fluid peer-tutoring roles." This perception of peer teaching and learning was best summarized by one participant who articulated, "The most valuable lesson was reinforced through this class was learn to teach and teach to learn."

Participants exhibited positive help-seeking behaviors as well during the course experience, and noted how maker-centered learning environments facilitated such behaviors. One observed, "Within making, you usually never solve problems on your own. You collaborate with others and with a group effort your problem gets solved." Another reflected that she had "seen and experienced how much it helps to bounce ideas off of each other… Though seeing this in action helped me start developing a more refined view of my future classroom, it was actually experiencing it in action that helped." In this quote, it is again illustrated how these participants transferred positive elements of maker-centered learning activities to the broader area of education in general. In addition, participants began to internalize subtle nuances to collaborative learning. Participants articulated the role of empathy in collaborative work (e.g., "empathy plays a huge role in making, teaching, and learning"), and noted that collaborative activities may also positively impact motivation (e.g., "I also learned that I definitely am motivated by working with others.")

In addition to the participant reflections, researcher observations provided additional data supporting the theme of collaborative learning. For example, early evidence of participants' increasing awareness of the benefits of collaboration came during the third week of the class, immediately after a guided group tour of an active makerspace on the campus of a neighboring university. This makerspace was a warren-like assembly of rooms, each focused on a particular technology or activity. Each space contained at least two students, who were actively working on various projects. In the electronics room, three students were chatting about an unrelated assignment while soldering wires to various electronics components. Through the window between the electronics room and the metal shop, participants observed two students working with a more experienced student to bend a length of steel sheeting. The 3D printing and scanning room was standing-room-only, with two students troubleshooting a 3D scan, while a fluid group of other students were co-designing 3D designs as a dozen 3D printers worked along the outside of the room. In each space, making was supported by more experienced student leaders. After the experience, one participant reflected,

> I also noticed that most of the students we saw working in the studio were doing so in pairs or teams. Perhaps this is because that's how the studio was designed, with "masters" tasked with helping those in need. But I think it underscores an important feature of the maker culture: things are better when we work together. No one can know it all, and we can do more by combining our individual expertise.

In addition, researchers observed the growing awareness and practice of collaborative learning demonstrated by the participants in the course activities. Following the makerspace field trip, participants worked in pairs to complete several assignments. However, while they voluntarily maintained their original pairings during the semester, researchers observed that pairs would engage with other pairs during particularly challenging projects. Though the class assignments formalized the paired work, informal working groups became common.

Perceptions of community

The second theme generated from the analysis of the participant reflection data centered around the concept of community. Participants consistently spoke of their experiences in the maker-centered learning course as being facilitated by a sense of community. In articulating this sense, participants moved from more personal and one-on-one collaborative aspects such as peer teaching and learning, and help-seeking to broader community aspects such as diversity of opinions, shared goals and struggles, a "safe space" to try new things and work through failures, and a move from a teacher-centered to community-centered learning environment.

Upon reflecting on their experiences observing a campus makerspace, and their own experiences in the maker-centered course, several participants noted the benefits inherent in utilizing a diversity of viewpoints. One participant articulated this by writing:

> Community involvement is a key element to a makerspace. Not only is community important for learning purposes, but also for the exchange of thoughts and ideas. Bringing in different generations can help brainstorm ideas from older generations that younger generations may not have thought of.

Another participant had a similar reflection, and noted, "Making encompasses an entire group – a collaborative community. This collective group of all ages come together to make a world of items, but more importantly, they come together to learn." In these quotes, participants recognize the diversity of viewpoints, in these cases generational, that can enhance learning environments.

Participants also conveyed that the sense of community developed through the maker-centered course provided them a support structure. One participant described participating in maker communities as one in which "Members... mentor each other and provide feedback while working toward shared goals." Another participant noted, "You can express your struggles and it can be satisfying to hear other people relate and say, 'I went through the same issue and here is how I overcame that.'" Finally, a third participant noted:

> What is interesting about this course, however, is that there was a large sense of community in the classroom. I began to realize that even if I attempted anything and it wasn't as great in comparison to what other people were doing, everyone still seemed very impressed and excited for me. That was encouraging enough to keep going through the semester. It really was a safe place to express your ideas and work through concepts with everyone. All of the criticism was very constructive, from the teachers and the class.

This quote provides an illustration of a supportive learning community, but also notable is the inclusion of both students and teachers in the description of the makeup of the community.

Participants noted that the developed community tended to be less teacher-centered and more community-centered. Participants frequently reported learning from "one another" and developing "shared experiences" often through trial-and-error. Many noted that they became more comfortable in both seeking and giving help. These findings align with previous research in this area; researchers Vossoughi and Bevan (2014) have identified this fluidity of roles as one of the many benefits of makerspaces that "has the potential to challenge deficit views and support learning and development" (p. 3). Generalizing this theme to a broader educational context, one participant noted, "Communities of education don't have to be comprised of teachers. They can be classmates in a class working together to co-construct knowledge in a particular discipline or project." Finally, another participant generalized this idea even further in considering students' future workplaces and noted that, "From school the students move into the educational community of the workplace where they become contributors and developers." Participants were also able to identify connections between the community-centered learning environment of this course with informal learning communities such as "knitting groups" and "sewing societies." In these quotes, it is evident that participants see the community-based learning environment modeled in maker-centered learning activities as beneficial to both their future practice as well as students' future formal and informal endeavours.

Overall, 10 of the 12 participants reflected on how the nature of making led to the development of a community in both the course and in classrooms in general, and the benefits thereof:

> I think the most ideal way that making can be leveraged to support teaching and learning is if the process in taking place in groups. Making in a classroom setting, in my opinion, helps create a sense of community. When you are learning things as a group you can all help each other gain an understanding because it is the first time everyone is learning about the material.

This passage in particular suggests that participants attributed the development of community, at least in part, to the nature of the maker-centered learning activities. This sentiment was echoed by another participant who wrote, "I learned that a maker space starts with the community first and foremost. Makerspaces derive from people [who like to create] things coming to create things as well as bounce ideas off of each other for their newest project."

Discussion

Collaboration

Participants in this study consistently spoke about the collaborative nature of the maker-focused learning activities. They reported favorable perceptions of interactions with their peers and noted that these types of activities could promote student engagement. These findings align with previous research suggesting that maker communities tend to be collaborative in nature

(Agency by Design, 2015; Kuznetsov and Paulos, 2010; Martin, 2015). This collaborative element may also support environments in which a wider range of abilities, disposition, and ways of knowing are valued (Barton et al., 2017; Buchholz et al., 2014; Vossoughi et al., 2016). Participants noted that the collaborative environment promoted both peer-learning and peer-teaching opportunities. The peer-learning experiences were reported as beneficial in helping participants master the content, and the peer-teaching opportunities provided participants the chance to share their knowledge as well as instilled a greater sense of agency in the classroom community.

The type of collaboration that the students in this course described relates to one of the theoretical underpinnings of collaborative learning, cognitive elaboration. From a cognitive elaboration perspective, collaborative situations can "amplify, or cognitively elaborate, the performance of basic information-processing activities such as encoding, activations of schemas, rehearsal, metacognition, and retrieval" (O'Donnell & Hmelo-Silver, 2013, p. 5). Specifically, the behaviors that the students associated with the maker activities, namely "bouncing ideas off of each other" and teaching maker processes and concepts to their peers, can serve to amplify their own cognition. The hands-on, applied nature of making in this context seemed to activate this type of collaboration, which can support cognitive constructive processing (Webb, 2013).

Community

Participants in this study perceived an increased sense of community in the learning experience. This finding aligns with previous research. In their literature review on making/tinkering in education, Vossoughi and Bevan (2014) suggested that making activities can harness the power of "a supportive community of learners that can leverage the interests and skills of each member of the group towards shared goals" (p. 25). A similar finding was reported by Agency by Design (2015) as a result of their multi-year study of making in K-12 education: "Overwhelmingly, the learning outcomes these educators describe have less to do with the development of skills, and more to do with the development of self and community" (p. 3). The community that arose due to making was perceived to be supportive by the participants, particularly with regards to shared problem solving and emotional support.

The type of community that arose in this maker-centered context could be characterized as a knowledge-building community (Scardamalia & Bereiter, 2006). A knowledge-building classroom community is one in which knowledge work "substantively advances the state of knowledge in the classroom community and situates it within the larger societal knowledge building effort" (Scardamalia & Bereiter, 2006, p. 98). The type of knowledge building that occurs in such situations is supported through the development of epistemic artifacts, which includes not only conceptual artifacts but also concrete ones, such as those produced through making. The students perceived the development of the community, and connected it to potential benefits which they could leverage in their future educational contexts.

Conclusion

This paper examined the perspectives of 12 educators involved in a semester-long university course focused on the role of maker principles and technologies in a variety of educational contexts. While other research studies have contributed to the understanding of educator perceptions towards integrating maker tools and activities into their instruction, they are often limited by short, one-time learning experiences. This study fills an important gap by examining the perceptions of a group of educators who have engaged in a semester long maker-based learning experience. Using qualitative exploratory design methods, this study utilized weekly and end-of-semester written reflections to illustrate participants' perceptions of the impacts the experience had on them both as an individual learner and as a practitioner. Participants noted several perceived affordances of maker-centered learning activities such as facilitation of participant collaboration, development of community. Findings of this study provide a research-based foundation for teacher educators to build upon when developing maker-based learning activities.

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