2017

Maker Principles and Technologies in Teacher Education: A National Survey

Jonathan Cohen
Georgia State University, jcohen@gsu.edu

Abstract

Broadly speaking, the maker movement is characterized by people who engage in the construction, deconstruction, and reconstruction of physical artifacts, and who share both the process of making and their physical products with the broader community of makers. There is growing sentiment that elements of the maker movement have the capability of positively impacting student outcomes in K-12 environments. This study reports on the extent to which teacher education programs in the United States have begun to integrate maker principles and technologies, and explores the factors which contribute to their decisions to include or not to include maker elements into their programs. Results indicate that approximately half of teacher education programs have at least some opportunities for undergraduates and graduates to learn about teaching and learning with maker technologies and principles, and there is desire among programs to increase these opportunities, as well as their maker technology infrastructure. There is less institutional-level interest in supporting research agendas related to maker education, however. Therefore, this study calls for a corresponding increase in research on the role of maker principles and technologies in teacher education.

Keywords: maker education, maker movement, teacher education, survey

Maker Principles and Technologies in Teacher Education: A National Survey

I want to encourage you to participate in programs to allow students to get a degree in science fields and a teaching certificate at the same time. I want us all to think about new and creative ways to engage young people in science and engineering, whether it's science festivals, robotics competitions, fairs that encourage young people to create and build and invent -- ***to be makers of things, not just consumers of things****.*

- President Barack Obama, addressing the National Academy of Sciences, 27 April 2009

The epigraph above, delivered to the 2009 annual meeting of the National Academy of Science (Obama, 2009), represents a call, echoed by many, to schools and other educational organizations to seize upon the principles and technologies embodied by the growing maker movement to create richer, more engaging, and potentially more meaningful learning experiences for our students. Seven years later, primary, secondary, and higher educational bodies are indeed beginning to leverage maker principles and maker technologies in both formal and informal contexts. What is less clear is the extent to which the programs designed to prepare educators have also embraced this call. In order to explore the extent to which teacher education programs are including or are planning to include making as an explicit part of their students' experiences, survey data was compiled from 123 member institutions of the American Association of Colleges for Teacher Education (AACTE; *n* = 811). Specifically, the survey data were used to answer the following questions:

1) To what extent are teacher education programs integrating maker principles and technologies into their programs?
2) What factors are impacting teacher education programs' intent either to include or not include maker technologies and principles into their programs?

Literature Review

Who Are Makers?

The maker movement is a growing group of individuals who (1) employ a combination of traditional tools and newer digital fabrication technologies in the creative production of personalized artifacts, and (2) leverage modern communication technologies to share both the processes and products of their making with the broader community of makers. Making and sharing are instincts as old as humanity itself, and to be sure the modern maker movement is "built from familiar pieces" (Martin, 2015, p. 31). What distinguishes it from traditional arts-and-crafts and do-it-yourself activities are the digital technologies leveraged by makers in the production of artifacts and an ethos of open-source sharing that, in combination with digital communication technologies, has fostered the creation of a growing community of makers (Martin, 2015).

The growth of the maker movement is generally traced to two community-building entities, *Make* magazine and Maker Faires (Brahms, 2014; Halverson & Sheridan, 2014; Martin, 2015; Vossoughi & Bevan, 2014). The makers who participate in these and in other forums are "people who design and make things on their own time because they find it intrinsically rewarding to make, tinker, problem-solve, discover, and share what they have learned" (Kalil, 2013, p. 12). In a study of the makers who contribute work to *Make* magazine, Brahms (2014) noted that makers come from and work in a variety of disciplines, though primarily these disciplines are limited to science, technology, engineering, arts, and mathematics. Though there has been criticism of the lack of diversity in the more visible aspects of the maker movement—Buechley (2013) has pointed out that a wide majority of maker depicted on the cover of *Make* are white men, and attendees of Maker Faires tend to be middle-class, middle aged males ("Attendee Study Maker Faire Bay Area 2014," 2014; Peppler, Maltese, Keune, Chang, &

Regalla, n.d.)—there is evidence that the maker movement is more demographically diverse than the broader demographics of professionals working in STEM fields, particularly among young makers (Blikstein, 2013; Peppler et al., n.d.). The diversity of young makers stands in contrast to the typically male, socioeconomically advantaged, and white or ethnically Asian who provide most of the input to the STEM pipeline (E. Anderson & Kim, 2006; Blustein et al., 2013; Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013; Wang, 2013), and provides an attractive opportunity to those interested in diversifying participation in STEM careers.

Increasingly, makers gather together in makerspaces, which are “informal sites for creative production in art, science, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products” (Sheridan et al., 2014, p. 505). In addition to traditional hand tools, makerspaces tend to include digital fabrication technologies (i.e., 3D printers, digital die cutters, and laser cutters), microcontrollers, and the software necessary to operate all the hardware. The primary function of these technologies is to bridge the digital and physical worlds. The 3D printers, for example, convert digital designs into physical objects—moving from “bits to atoms,” as some have described the process (Bell et al., 2010). The microcontrollers have the ability to digitize information from the physical world, such as sound waves, physical contacts, or gestures, which can then be manipulated by various software. And all of this crossing of the physical/digital worlds can be done with non-specialized technological knowledge or training.

Makers, then, are highly motivated, inquisitive people who develop their own and their community’s knowledge through the construction and sharing of physical artifacts. Their work is frequently interdisciplinary, applied, and it is generally the product of a combination between their own knowledge and that of others in the community. It is easy to see, then, the potential appeal of the maker movement to educators (Peppler & Bender, 2013). We explore the still-emerging literature on the role of making in K-12 contexts below.

Making and K-12 Education

It is difficult to state with any confidence the extent to which the maker movement is penetrating schools, as no large-scale, methodologically rigorous survey of the extent to which K-12 schools are adopting the principles or technologies of the maker movement has been published. However, secondary evidence does exist that making is poised to make an impact on schools, if it is not already begun (Halverson & Sheridan, 2014). The 2013 (Johnson et al., 2013) and 2015 (Johnson, Adams Becker, Estrada, & Freeman, 2015) K-12 editions of the Horizon Report describe 3D printing, a technology commonly used metonymically to represent making, as being a part of mainstream education at the time that many current preservice teachers are entering the field. These types of predictions are being reified by grant competitions, such as the U.S. Department of Education's CTE Makeover Challenge ("CTE Makeover Challenge," 2016), which aimed to provide schools the resources with which to create the infrastructure necessary to facilitate making. Additionally, various national standards value certain skills and concepts which are compatible with making the classroom. The Next Generation Science Standards (NGSS), for example, call for an increase in engineering practices, including hands-on construction, in the science curriculum (National Research Council, 2012), which aligns with the core tenets of making. The Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) emphasize the increasing need for students to be able to communicate effectively in a variety of media to increasingly diverse audiences. As a guiding principle of making is that makers communicate not only the final products of their making but also the process of making with their communities (C.

Anderson, 2012; Brahms, 2014; Hatch, 2014; Sheridan et al., 2014), a natural alignment with the Common Core ELA/Literacy standards becomes likely. The alignment with these and other individual state standards adds to the body of evidence suggesting that making will play an increasing role in schools.

The research on the potential of maker principles and technologies to support student learning and skill development focuses largely on out-of-school makerspaces, clubs, and other informal settings; research on making in formal, school contexts is only beginning to emerge (Martin, 2015; Vossoughi & Bevan, 2014). Vossoughi and Bevan (2014) undertook a critical review of the literature surrounding making and education, and identified three major categories of impacts making has had on student development: (1) fostering and supporting students' participation in science environments, (2) supporting academic/disciplinary development, and (3) creating communities of learners.

Research on the integration of technology into classrooms consistently shows that teachers are more likely to integrate new technologies and the pedagogies they support into their practice if the teachers (1) possess the relevant technological knowledge (Mueller, Wood, Willoughby, Ross, & Specht, 2008), (2) self-efficacy relative to teaching with technology (Wozny, Venkatesh, & Abrami, 2006), and (3) a belief system which values technology as a necessary ingredient to successful education (Ertmer & Ottenbreit-Leftwich, 2010; Ertmer, 2005; Kim, Kim, Lee, Spector, & DeMeester, 2013). In particular, the Technological, Pedagogical Content Knowledge framework (TPACK; Mishra & Koehler, 2006), an extension of Shulman's concept of pedagogical content knowledge (PCK; Shulman, 1986), states that the most effective technology integration—and, indeed, the most effective teaching—happens when teachers apply their understanding of the affordances of specific technologies to their PCK, allowing the technology to impact not only how they teach, but also what they are able to teach. Therefore, it becomes incumbent on teacher education programs and other types of professional development programs for in-service teachers to help teachers develop their relevant technological knowledge, self-efficacy, and belief systems. Those responsible for preparing and supporting teachers, including policymakers, administrators, and teacher educators, then, can benefit from understanding what the current status of maker education is among their peers. The research presented here focused in on teacher education programs, with the aim of understanding better the extent to which teacher education programs are including maker principles and technologies into their programs and the factors influencing decisions to include or not include them.

Methods

Participants

A list of deans, associate deans, or department chairs of colleges and universities with teacher education programs (*n* = 811) were invited to participate in this survey, of which 123 responded (see "Results" below). The list of participants was generated from a membership roster available on the AACTE public website. The researcher identified the contact at each education program through an examination of the programs' websites. For schools or colleges of education, the preferred contact was an Associate Dean for Academic Affairs, though if that role did not exist, then an assistant dean, dean, or dean of undergraduate/graduate studies was identified, depending on the individual college. For institutions in which teacher education programs are housed in a department rather than a college or school of education, the department chair was the preferred contact. When participants were invited to participate in the survey, they were given the option to forward the invitation email to another, more appropriate individual, if necessary.

Each education program was then categorized by its geographic region, and by its Carnegie Classification. Each program was sorted into one of the four U.S. Census regions (i.e., West, Midwest, South, Northeast), based on the location of the college/university's main campus. The programs were also sorted by the institutions' Carnegie classifications, the framework of which was established in 1973 to "to represent and control for institutional differences, and also in the design of research studies to ensure adequate representation of sampled institutions, students, or faculty" ("The Carnegie Classification of Institutions of Higher Education," 2016). The classifications take into account types of degrees conferred by the institutions, size and setting, and special foci. This study used the Basic Classification of four-year or higher focused institutions, which includes 17 different categories (Table 1).

Table 1

Carnegie Classifications of AACTE Member Institutions

Carnegie Classification	*n*	Percent
Associate's--Private For-profit	1	0.1
Associate's--Public 4-year Primarily Associate's	3	0.4
Associate's--Public Rural-serving Large	1	0.1
Associate's--Public Rural-serving Medium	2	0.2
Baccalaureate Colleges--Arts & Sciences	72	8.9
Baccalaureate/Associate's Colleges	7	0.9
Baccalaureate Colleges--Diverse Fields	117	14.4
Doctoral/Research Universities	58	7.2
Master's Colleges and Universities (larger programs)	252	31.1
Master's Colleges and Universities (medium programs)	92	11.3
Master's Colleges and Universities (smaller programs)	51	6.3
Research Universities (high research activity)	78	9.6
Research Universities (very high research activity)	71	8.8
Special Focus Institutions--Schools of business and management	1	0.1
Special Focus Institutions--Theological seminaries, Bible colleges, and other faith-related institutions	1	0.1
Special Focus Institutions--Other special-focus institutions	2	0.2
Tribal Colleges	2	0.2

Procedure

The survey was conducted in two stages: a pilot test and the main study. Both proceeded similarly: Participants were approached to take the survey through an emailed invitation. Taking a cue from Dillman's Tailored Design Method (Dillman, 2000), one follow-up set of emails were sent to the non-responders one week following the original emails. If participants agreed to complete in the survey, they were directed to Qualtrics, an online survey website.

Survey Instrument

The survey instrument contained a maximum of 14 questions, though some respondents would receive fewer questions depending on their responses. For example, if a respondent indicated that his or her education program did not offer undergraduate classes, then that respondent would not be given any of the follow-up questions regarding undergraduate education. The survey items were developed based on consultation with senior faculty and administration from a large teacher preparation program in the Southeastern United States. See Appendix A for the complete survey instrument.

A panel of 4 experts examined the survey instrument prior to the pilot test. The 4 panelists, 3 professors and a dean, came from 2 different universities. Each examined the instrument and suggested clarifications, which were incorporated into the pilot version of the survey instrument. It was then sent to a sub-sample (n = 40) of the main study sample. The sub-sample was chosen to reflect the diversity of the main sample with regards to geographic diversity and university classification, as determined by Carnegie classifications.

The pilot instrument included questions following each main question which probed for any potential confusion arising from either the wording or content of the items. Twenty percent (n = 8) of the sample responded. None of the respondents indicated any issues arising from the items, so the main survey instrument was distributed unchanged from the pilot version.

Results

Of the initial population of 811, 70 potential contacts were excluded. Criteria for exclusion included international programs, AACTE member institutions which do not have teacher education programs, and programs for which there were no available contact persons or information. A total of 741 colleges of education/education departments received invitations to participate in the survey, and 123 completed responses (16.6%) were received. Incomplete responses were not considered.

The response rate suggested that nonresponse bias needed to be considered in the interpretation of these data. However, a low response rate does not necessarily equal nonresponse bias (Cook, Heath, & Thompson, 2000; Rogelberg & Stanton, 2007); nonresponse bias "occurs when a significant number of people in the survey sample do not respond to the questionnaire *and* have different characteristics from those who do respond, when these characteristics are important to the study" (Dillman, 2000, p. 10). Therefore, initial analysis examined the extent to which the nonrespondents differed from the respondents.

Two Pearson correlation tests indicated high correlations between both the Carnegie classifications of the respondents and the population ($r = 0.96$, $p < .001$) and the geographic regions of the respondents and the population ($r = 0.99$, $p = .007$). Additionally, a wave analysis procedure (Leslie, 1972) was conducted, in which the researcher compared the responses of early responders to late responders. Wave analysis proceeds from the perspective that participants who respond less readily (i.e., those who respond late or need additional reminder(s) to encourage participation in the survey) are more like nonrespondents (Armstrong & Overton, 1977). To conduct this analysis, responses on the single-selection items of the first set of respondents and those of the second set of respondents were compared, using a series of independent samples *t*-tests (see Table 2).

Table 2

Wave Analysis of Single-Response Items

	Wave 1		Wave 2				
	M	*SD*	*M*	*SD*	*t*	*df*	*p*
Q1	2.03	0.57	1.95	0.38	0.59	121	0.56
Q2	1.69	0.74	1.59	0.73	0.59	118	0.56
Q3	2.17	0.84	2.05	0.79	0.63	121	0.53
Q4	2.01	0.39	2.10	0.45	-0.90	106	0.37
Q5	1.82	0.74	1.65	0.75	0.92	106	0.36
Q6	2.74	1.02	2.31	0.95	1.37	64	0.18
Q7	2.50	1.00	2.14	1.04	1.52	121	0.13
Q8	3.62	1.02	3.23	1.31	1.57	121	0.12
Q9	3.15	1.28	2.64	1.47	1.65	121	0.10
Q10	1.90	0.84	2.23	0.75	-1.68	121	0.10

No significant differences existed between the two waves of responses, indicating that further attempts to increase the response rate were not likely to alter the results reported by the respondents.

For the single-selection items, a margin of error was calculated using the formula $d = \sqrt{\frac{(1.96)^2 pq}{n}}$, where *d* is the margin of error, 1.96 is the Z score for a 95% confidence interval, *n* is the sample size, *p* is the predicted percent accuracy, and *q* is 1 – p (Lohr, 2010). Here, *p* = 0.50 because the response percentage for any of these items is unknown, so setting *p* = 0.50 gives the maximum margin of error. Given that the population surveyed was finite, this margin for error score (*d*) was then corrected by multiplying it by the Finite Population Correction Factor, $FPCF = \sqrt{\frac{(N-n)}{(N-1)}}$. The resulting calculations give an initial margin of error of *d* = 0.088, and a *FPCF* = 0.913. Multiplying the two results in a margin of error for the single-selection survey items of ±8.08%.

Maker Movement in Academics

Roughly half of teacher education programs have at least some opportunities for undergraduates and graduates to learn about teaching and learning with maker technologies and principles, with 12.7% of undergraduate programs (*n* = 14) offering an entire course on teaching and learning with maker technologies and principles, and 57.4% (*n* = 58) offering at least a unit or module on the topic. Among graduate programs, 18.8% (*n* = 19) reported offering an entire course on teaching and learning with maker technologies and principles, and 48.9% (*n* = 43) indicated that they offer a unit or module. Fewer graduate programs (7.1%; *n* = 7) focus entire courses on researching the maker movement. Of all of the programs which currently do not offer courses, 12.1% (*n* = 8) reported significant interest in offering a course within the next 3 years, 37.9% (*n* = 25) reported limited positive interest, 22.7% (*n* = 15) indicated no interest, and 27.3% (*n* = 18) were unsure.

Follow-up tests were conducted to determine the extent to which the type of institution or had any influence on the presence of courses or future plans to institute them. The small number of respondents who offer courses precluded any meaningful follow-up analysis to determine whether an interaction exists between classification and the presence of courses. The presence of either limited or significant intentions to offer courses in the future was highly correlated with the proportion of Carnegie classifications in the population ($r = .90$, $p < .001$). Therefore, it can be concluded that there is no interaction between classification and the intention to offer courses in the future.

The survey also asked about the extent to which education programs planned on establishing research centers focused on the maker movement. See Table 3 for results.

Table 3

Intention of Establishing a Research Center Focused on the Maker Movement

Interest level	*n*	Percent
Already have one	9	7.3
Significant	10	8.1
Limited	27	22
Not at all	58	47.2
Not sure	19	15.4

The small number of respondents indicating the presence of a research center, or a significant or limited desire to start one precluded a follow-up analysis to determine any potential interaction between the results and Carnegie classifications.

Maker Technology Infrastructure

This survey also aimed to determine the extent to which education programs possessed the technological infrastructure to support teaching and learning about the maker movement within their teacher education programs. In order to ascertain this information, the survey asked participant programs whether they possessed or intended to establish a makerspace or a maker laboratory[1] of technology to be used by students either as part of courses or independently. See Table 4 for results.

Table 4

Maker Technology Infrastructure Descriptive Statistics

	Makerspace or lab		Purchase maker technologies	
Interest level	*n*	Percent	*n*	Percent
Already have one	21	17.1	Not asked	Not asked
Significant	21	17.1	21	17.1
Limited	31	25.2	54	43.9
Not at all	30	24.4	22	17.9
Not sure	20	16.3	26	21.1

Certainly, maker technologies can exist in an education program outside of an organized makerspace or maker lab. However, as it was conceivable that a number of the survey's respondents (i.e., deans and department chairs) might not be aware of small or diffuse pockets of hardware within a program or college, the researcher made the determination to focus only on

[1] A maker lab here is distinguished from a makerspace in that a makerspace is open to some community of makers to use, whereas a maker lab functions more like a biology or chemistry classroom lab space, available only to students only as part of a course.

established, centralized makerspaces or labs. Therefore, the survey did not ask respondents about the presence of individual pieces of maker technologies within their programs.

Factors Driving Desire to Include Maker Elements in Future Efforts

The 84 respondents who indicated a limited or significant desire to include courses, add technology or facilities, or establish a maker research center were asked to select factors which are driving that desire. The selected-response factors were developed through conversations with senior faculty and administration of a large teacher preparation program. In order to ensure that other factors beyond those listed in the survey instrument could be expressed, respondents could select “Other” and describe any factors not listed. See Table 5 for results.

Table 5

Factors Driving Desire to Include Maker Elements

Factor	*n*	Percent*
Consistent with the college’s mission/strategic plan	47	56
Consistent with the university’s mission/strategic plan	32	38.1
Availability of research grant and/or foundation money	18	21.4
One or more of the faculty believe it to be important	65	77.4
Students have expressed interest in learning more about it	30	35.7
Schools which are hiring graduates are incorporating elements of the maker movement into their curricula	26	31
Other	15	17.9

* Note that the percentages will not equal 100%, as respondents were allowed to mark more than one response.

The researcher also examined the 15 “Other” textual responses, using an open-response item coding procedure (Ruel, Wagner, & Gillespie, 2016). Two coders read through the 15 textual responses independently and developed a list of codes, including separate codes for nonresponses and uncodeable responses (i.e., responses which do not answer the prompt). Each then compared the lists of codes and negotiated a final list of 3 codes in addition to the nonresponse and uncodeable codes. The coders then independently coded the responses using the final codes. As this was a fully-crossed design with 2 coders (Hallgren, 2012), Cohen’s *kappa* (Cohen, 1960) was used to determine if there was agreement between the two coders’ judgement on the codes for each answer. There was strong agreement between the coders' judgements, κ = 0.90, $p < .001$.

The 5 final codes were partnerships, general statements of beliefs, standards, uncodeable, and nonresponse. Four of the 15 textual responses mentioned partnerships as factors driving their desire to include maker technologies and principles into their programs, referencing both other divisions within their institutions as interested partners as well as local school districts. Three of the textual responses were general statements of belief in the potential of infusing maker technologies and principles into their programs (e.g., "sparking STEM innovation" and "we want to better prepare our teacher candidates"). One program cited incoming state science standards as a driver of their interest in exploring maker technologies and principles. Of the remainder, those not answering the question were coded as uncodeable (e.g., "The Center for Math and Science Education incorporates some of these elements"), and those responses in which "Other" was checked but no text was entered were coded as nonresponses.

Overall Impact of the Maker Movement on Teacher Education Programs

Participants were asked to rate the extent to which the maker movement is a presence in their programs (Table 6).

Table 6

Extent to Which the Maker Movement is a Presence

Presence	*n*	Percent
Strong	2	1.6
Moderate	34	27.6
Limited	44	35.8
Not at all	43	35

Respondents who indicated that the maker movement is not a presence at all (n = 43) were asked in a follow-up question to select the why it is not a presence. As in the previous section, selected responses were generated in consultation with teacher education faculty and senior administrators, and respondents could select “Other” to describe any factors not listed. See Table 7 for results.

Table 7

Explanations for Lack of Presence

Factor	*n*	Percent*
Lack of funding	20	36.7
Lack of interest from students	10	18.4
Lack of interest from faculty	21	38.6
We don’t believe the maker movement is worth addressing at this time	4	7.3
We’re not sure how principles of the maker movement can support teaching and learning	9	16.5
Other	15	27.6

* Note that the percentages will not equal 100%, as respondents were allowed to mark more than one response.

Using the same procedure outlined above, two coders also examined the 15 “Other” textual responses. Cohen’s *kappa* (Cohen, 1960) was used to determine if there was agreement between the two coders’ judgement on the codes for each answer, and again there was strong agreement between the coders’ judgements, $\kappa = 0.90$, $p < .001$. Analysis yielded 4 codes: capacity, lack of awareness, uncodeable, and nonresponse. In addition, two responses matched factors from the selection list, so these were added into the tally of selected responses and were not included into the open-response coding procedure. Three of the textual responses addressed a lack of capacity to add any elements of the maker movement into their programs, specifically referencing a lack of faculty time and a lack of space in the curriculum. In addition, three responses referenced a lack of awareness of the maker movement (e.g., “not aware of the research” and “What on earth are you talking about?”). Seven of the responses were coded as either uncodeable (e.g., “We have not yet discussed this as a group”) or nonresponses (e.g., blank responses).

Discussion

These data document the current role of maker principles and technologies in teacher education programs in the United States. Because this is the first research of its kind, it is impossible to point to any trends regarding this data over time; it cannot be inferred whether the number of programs choosing to embrace maker technologies and principles is growing, shrinking, or remaining stagnant. Moreover, the conclusions presented here are derived from a low response rate survey of a single teacher education professional association, which indicates that the conclusions should be interpreted cautiously. However, there is a historical parallel that can be drawn between the current status of the maker movement in teacher education and teacher education programs' preparation of their students to teach online. Online learning in K-12 has been steadily gaining prominence to the point that it is now established in every state nationwide (Watson, Murin, Vashaw, Gemin, & Rapp, 2013), but only a minority of teachers who teach online report receiving formalized, targeted curricula to teach online (Archambault, 2011), though doing so emphasizes particular skillsets (DiPietro, Ferdig, Black, & Preston, 2008) which warrant specialized instruction. Traditional teacher preparation programs are beginning to help their students to learn to teach online, albeit slowly (Rice, 2014). For instance, a 2012 survey (Kennedy & Archambault, 2012) of each of the AACTE and National Council for Accreditation of Teacher Education-accredited teacher education program field experience offices found that just 1.3% of those programs offered a field experience for online K-12 teaching. A sampling of the open-ended responses to a question of whether teacher education programs should offer virtual schooling field experiences (VSFE) reveal attitudes similar to some of those offered by respondents to the maker education survey. As was the case in the present study, some respondents in the Kennedy and Archambault (2012) were pro-VSFE, viewing them as necessary steps for keeping pace with a growing segment of K-12 education. However, others indicated a lack of knowledge or awareness of online K-12 education and the need to prepare teachers for that environment, and some even expressed extreme reservations about online K-12 education, for example asserting that "Good teaching must happen in person," and "Our students need to be able to interact with people/students and not machines" (Kennedy & Archambault, 2012, p. 195). Given the similarities between the research in these two areas, it is plausible that a parallel can be drawn between the potential path and rate of adoption of maker principles and technologies in teacher education and that of online K-12 teacher education.

The current study's data show that roughly half of the current undergraduates and graduates in teacher education programs have experienced maker principles or technologies through a unit or module of instruction at the least. Further, 50% of the programs which do not currently offer a course indicate at least limited interest in offering a course within the next three years. These data suggest that many teachers will soon be entering classrooms with at least some knowledge of maker principles and technologies. Undoubtedly the quality of these teacher education experiences will vary, but a few generalizations can be drawn here. As research shows, successful teacher technology integration is a function of the teachers possessing adequate technological knowledge (Mueller et al., 2008)/TPACK (Mishra & Koehler, 2006), self-efficacy with respect to technology use (Wozny et al., 2006), and a belief system which values the use of technology in education (Ertmer & Ottenbreit-Leftwich, 2010; Ertmer, 2005). The bulk of the experiences currently being offered are of the shorter-term variety (i.e., modules or units). It is questionable that such short-term engagements will have a strong impact on teachers' technology self-efficacy or on their durable belief systems. More likely is that maker modules or units could improve teachers' technological knowledge, which is an essential ingredient to the development of their TPACK. Given their duration, courses perhaps offer a better opportunity for full development of the skills, attitudes, and beliefs necessary to meaningful technology integration than modules or units. This research shows that while maker-focused courses are still relatively rare in teacher education programs, there is an appetite within programs to offer them in the near future, which could grow infrastructure for more meaningful and effective integration of maker principles and technologies in classrooms.

The data also allow for preliminary conclusions to be drawn regarding the factors contributing to decisions either to include or not to include maker principles and technologies in teacher education programs. In both cases, faculty interest in the topic is a main determinant in decisions regarding the inclusion of maker principles and technologies into teacher education programs. For programs planning on increasing the role of making, faculty interest at the faculty level was cited 38% more than a college-level factor (i.e., “Consistent with the college’s mission/strategic plan”) and 117% more than a student-level factor (i.e., “Students have expressed an interest in learning more about it”).

Exploration of the factors cited by programs in which the maker movement is not a presence yields two findings of relevance to proponents of its inclusion in teacher education programs. As is the case with those planning on increasing the role of making in their programs, faculty interest was one of the 2 the most cited factors. The other most cited factor was lack of funding, which indicates a potential conflation of the maker movement with often expensive advanced manufacturing technologies, like 3D printers and laser cutters. While these tools are certainly an important part of many makerspaces (Martin, 2015), they are, by no means, essential (Vossoughi & Bevan, 2014). Indeed, an instructional program built on the principles of the maker movement would require very little additional technology, beyond those which can be leveraged in the process of sharing, such as computers, smartphones, and high-speed internet connections. That perception of the maker movement is skewed towards images of high-tech makerspaces indicates that more awareness of nature of the maker movement among administrators might be necessary so that they are able to make more informed choices.

Another aspect of these data worthy of further exploration is the lack of interest or capacity within many teacher education programs to research the maker movement and its potential impacts on not only teacher professional development but also on student learning. Only 7% of those surveyed reported offering a course for graduate students in researching the maker movement, and almost 50% of respondents indicated no desire to establish a research center focusing on making in the near future. Logic dictates that unsuccessful experiences with technology in classrooms dissuades teachers from continuing on with those technologies in the future. Certainly, effective teacher education and development programs can help to minimize these unsuccessful experiences, but ideally, these teacher education and development programs will be based on thorough research. These data suggest that infrastructure to support a broad range of research on this topic may not yet exist.

Implications for Teacher Education

The results of this survey indicate that there will be a growth in the amount of maker education occurring in teacher education programs over the next few years. Though there is a rich literature base describing how preservice and inservice teachers develop TPACK, self-efficacy, and teacher beliefs in a variety of content areas, there is currently no literature concerning the development of those areas as they relate to maker principles and technologies. Therefore, there is a need for focused research on maker movement and teacher education. Moreover, these data also indicate that there is not a great deal of institutional-level interest in pursuing research agendas related to the maker principles and technologies in teacher education. Instead, faculty interest appears to be one of the primary determinants, if not the primary determinant, of programs' decisions about formalizing research agendas, as well as creating a maker technology infrastructure and offering maker courses/modules/units. Therefore, in the short term, the infusion of maker principles and technologies into teacher education programs will likely be a faculty-led effort.

Research has shown that a combination of positive beliefs about the role of technology in learning (Ertmer & Ottenbreit-Leftwich, 2010; Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010), access to resources and technology infrastructure (Dexter & Riedel, 2003), and meaningful alignment of technological knowledge with pedagogical and content knowledge (Ertmer & Ottenbreit-Leftwich, 2010) will help to create an environment in which preservice teachers will learn to integrate technology into their practice. In addition, if one broadens the scope of inquiry to individual teacher education programs as a unit of change (Tondeur et al., 2012), we see that other factors impact preservice teachers' successful preparation to use new technologies and the pedagogies they enable, including technology planning and leadership, training staff, access to resources, and cooperation within and between institutions. The data presented here indicates that capacity is being built among some individual teacher preparation programs to integrate the maker movement into their programs. These programs are more likely to be able to bridge the use of this technology with pedagogical principles in specific contents and contexts, given the presence of access to technologies and opportunities in courses to develop the necessary pedagogical beliefs and knowledge. Ultimately, research suggests that this effort has the potential to result in a variety of positive impacts on the students who will eventually be served by teacher candidates (Halverson & Sheridan, 2014; Martin, 2015). Though the body of research on the potential of the maker movement to support positive student outcomes is emergent, there is reason to be bullish about its prospects. This study indicates that over the next few years, many teacher candidates will indeed have the opportunity to explore how they might leverage maker technologies and principles in their own practice, and a need exists for research on how best to support these explorations. An awareness among administrators, faculty, and researchers of the current extent to this work is an initial step towards potentially more systematic action.

References

Anderson, C. (2012). *Makers: The new industrial revolution*. New York, NY: Crown.

Anderson, E., & Kim, D. (2006). *Increasing the Success of Minority Students in Science and Technology*. *American Council on Education*. Washington D.C. Retrieved from https://www.acenet.edu/news-room/Documents/Increasing-the-Success-of-Minority-Students-in-Science-and-Technology-2006.pdf

Archambault, L. (2011). The practitioner's perspective on teacher education: Preparing for the K-12 online classroom. *Journal of Technology and Teacher Education*, *19*(1), 73–91.

Armstrong, J. S., & Overton, T. S. (1977). Estimating nonresponse bias in mail surveys. *Journal of Marketing Research*, *14*(3), 396. doi:10.2307/3150783

Attendee Study Maker Faire Bay Area 2014. (2014). Retrieved February 28, 2016, from http://makermedia.com/wp-content/uploads/2013/01/MFBA-2014-research-deck_FINAL.pdf

Blikstein, P. (2013). Digital fabrication and "making" in education: The democratization of invention. In *FabLabs: Of machines, makers and inventors* (pp. 1–21). Retrieved from https://tltl.stanford.edu/sites/default/files/files/documents/publications/2013.Book-B.Digital.pdf

Blustein, D. L., Barnett, M., Mark, S., Depot, M., Lovering, M., Lee, Y., … DeBay, D. (2013). Examining urban students' constructions of a STEM/career development intervention over time. *Journal of Career Development*, *40*(1), 40–67. doi:10.1177/0894845312441680

Brahms, L. (2014). *Making as a learning process: Identifying and supporting family learning in informal settings (Doctoral dissertation)*. University of Pittsburgh, Pittsburgh, PA.

Buechley, L. (2013). Thinking about making. Keynote speech presented at FabLearn Conference, Stanford University. Palo Alto, CA.

Cohen, J. (1960). A coefficient of agreement for nominal scale. *Educational and Psychological Measurement*, *20*(1), 37–46.

Cook, C., Heath, F., & Thompson, R. L. (2000). A meta-analysis of response rates in web- or internet-based surveys. *Educational and Psychological Measurement*, *60*(6), 821–836. doi:10.1177/00131640021970934

CTE Makeover Challenge. (2016). Retrieved March 15, 2016, from http://www.ctemakeoverchallenge.com/

Dexter, S., & Riedel, E. (2003). Why improving preservice teacher educational technology preparation must go beyond the college's walls. *Journal of Teacher Education*, *54*(4), 334–346. doi:10.1177/0022487103255319

Dillman, D. (2000). *Mail and internet surveys: The tailored design method* (Second ed.). New York, NY: John Wiley & Sons.

DiPietro, M., Ferdig, R. E., Black, E. W., & Preston, M. (2008). Best practices in teaching K-12 online: Lessons learned from Michigan Virtual School teachers. *Journal of Interactive Online Learning*, *7*(1), 10–35. Retrieved from https://connect2.uncc.edu/file/racha_1/,DanaInfo=learners.in.th+7.1.2.pdf\nhttp://cdn.learners.in.th/assets/media/files/000/076/582/original_7.1.2.pdf?1285587239

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development*, *53*(4), 25–39.

doi:10.1007/BF02504683

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*(3), 255–284. doi:GALE|A221849729

Hallgren, K. A. (2012). Computing inter-rater reliability for observational data: An overview and tutorial. *Tutorials in Quantitative Methods for Psychology*, *8*(1), 23–34. doi:10.1016/j.biotechadv.2011.08.021.Secreted

Halverson, E., & Sheridan, K. (2014). The Maker Movement in Education. *Harvard Educational Review*, *84*(4), 495–505. doi:10.17763/haer.84.4.34j1g68140382063

Hatch, M. (2014). *The maker movement manifesto*. New York, NY: McGraw-Hill Education.

Hernandez, P. R., Schultz, P. W., Estrada, M., Woodcock, A., & Chance, R. C. (2013). Sustaining optimal motivation: A longitudinal analysis of interventions to broaden participation of underrepresented students in STEM. *Journal of Educational Psychology, 105*(1), 89–107. doi:10.1037/a0029691

Kalil, T. (2013). Have fun--learn something, do something, make something. In M. Honey & D. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 12–16). New York, NY: Routledge.

Kennedy, K., & Archambault, L. (2012). Offering preservice teachers field experiences in K-12 online learning: A national survey of teacher education programs. *Journal of Teacher Education*, *63*(3), 185–200. doi:10.1177/0022487111433651

Kim, C., Kim, M. K., Lee, C., Spector, J. M., & DeMeester, K. (2013). Teacher beliefs and technology integration. *Teaching and Teacher Education*, *29*(1), 76–85. doi:10.1016/j.tate.2012.08.005

Leslie, L. L. (1972). Are high response rates essential to valid surveys? *Social Science Research*, *1*(3), 323–334. doi:10.1016/0049-089X(72)90080-4

Lohr, S. (2010). *Sampling: Design and analysis* (2nd ed.). Boston, MA: Brooks/Cole.

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

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teacher College Record*, *108*(6), 1017–1054.

Mueller, J., Wood, E., Willoughby, T., Ross, C., & Specht, J. (2008). Identifying discriminating variables between teachers who fully integrate computers and teachers with limited integration. *Computers and Education*, *51*(4), 1523–1537. doi:10.1016/j.compedu.2008.02.003

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for English language arts and literacy in history/social studies, science, and technical subjects*. Washington, DC.

National Research Council. (2012). *A Framework for K-12 Science Education*. Washington, DC: National Academy Press.

Obama, B. (2009). Remarks made by the President at the National Academy of Sciences annual meeting. Retrieved February 28, 2015, from http://www.whitehouse.gov/the_press_office/Remarks-by-the-President-at-the-National-Academy-of-Sciences-Annual-Meeting/

Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P. A. (2010). Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers and Education*, *55*(3), 1321–1335. doi:10.1016/j.compedu.2010.06.002

Peppler, K., & Bender, S. (2013). Maker movement spreads innovation one project at a time. *Phi Delta Kappan*, *95*(3), 22–27. doi:10.1177/003172171309500306

Peppler, K., Maltese, A., Keune, A., Chang, S., & Regalla, L. (n.d.). *The Maker Ed Open Portfolio Project: Survey of Makerspaces, Part I*.

Rice, K. (2014). Research and history of policies in K-12 online and blended learning. In R. Ferdig & K. Kennedy (Eds.), *Handbook of Research on K-12 Online and Blended Learning* (pp. 51–82). ETC Press.

Rogelberg, S., & Stanton, J. (2007). Understanding and dealing with organizational survey nonresponse. *Organizational Research Methods*, *10*, 195–209.

Ruel, E., Wagner, W. E., & Gillespie, B. J. (2016). *The practice of survey research*. Los Angeles, CA: Sage Publications.

Sheridan, K., Halverson, E., Litts, B. K., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: Comparative case study of three makerspaces. *Harvard Educational Review*, *84*(4), 505–532. doi:10.17763/haer.84.4.brr34733723j648u

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14.

The Carnegie Classification of Institutions of Higher Education. (2016). Retrieved January 12, 2016, from http://carnegieclassifications.iu.edu/

Tondeur, J., Van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers and Education*, *59*(1), 134–144. doi:10.1016/j.compedu.2011.10.009

Vossoughi, S., & Bevan, B. (2014). Making and tinkering: A review of the Literature. Retrieved from http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_089888.pdf

Wang, X. (2013). Why students choose stem majors: Motivation, high school learning, and postsecondary context of support. *American Educational Research Journal*, *50*(5), 1081–1121. doi:10.3102/0002831213488622

Watson, J., Murin, A., Vashaw, L., Gemin, B., & Rapp, C. (2013). *Keeping pace with K-12 online learning: An annual review of policy and practice, 2013*. Evergreen, CO.

Wozny, L., Venkatesh, V., & Abrami, P. (2006). Implementing computer technologies: Teachers' perceptions and practices. *Journal of Technology and Teacher Education*, *14*(1), 173–207.

Appendix A

Maker Survey

Broadly speaking, the maker movement is characterized by people who engage in the construction, deconstruction, and reconstruction of physical artifacts, and who share both the process of making and their physical products with the broader community of makers.

Maker technologies include desktop manufacturing equipment, including 3D printers, digital die cutters, laser cutters, digital CNC routers, and analog hand tools. Maker technologies also include microcontrollers, such as Arduinos, Raspberry Pi, and MaKey-MaKey.

1) Select your institution name from the list below. [Drop-down menu of all U.S. states, then drop-down menu of all institutions in the study].

2) An example of an **undergraduate** course which focuses on the maker movement is one in which the majority of the readings, assignments, and in-class activities are centered on hands-on making activities. The course could include such activities as designing and building robots, deconstructing and reconstructing electronic devices, or using microcontrollers to collect data and automate various processes.

   Does your college of education/education department offer an **undergraduate course** in which the primary focus is the maker movement?
   - Yes
   - No
   - I don't know
   - We do not offer undergraduate classes [if selected, skip to question 4]

3) Other than any full maker courses you may or may not offer, do any of the courses offered to **undergraduates** at your college of education/education department have a **unit or module** in which students study the maker movement and/or engage in any maker-style activities? Maker-style activities are activities in which students design and create artifacts and share their process with others.
   - Yes
   - No
   - I don't know

4) Some schools offer a **graduate-level** course which focuses on training preservice or in-service teachers to utilize principles of the maker movement in the classroom. These courses typically teach students about not only the technologies involved in making (e.g., 3D printers, digital die cutters, laser cutters, microcontrollers, etc.) but also the pedagogies associated with maker activities (e.g., project- and problem-based learning, inquiry activities, design-based learning, etc.).

   Does your college of education/education department offer a **graduate course** which focuses on training teachers to utilize principles of the maker movement in the classroom?
   - Yes

- No
- I don’t know
- We do not offer graduate classes [if selected, skip to question 8]

5) Some schools offer **master’s- or doctoral-level** courses which primarily focus on the theories, frameworks, and research associated with the maker movement. In these courses students focus primarily on scholarship related to the maker movement, as opposed to participating in hands-on making activities, though those can make up a smaller portion of the coursework.

   Does your institution offer a **master’s- or doctoral-level** course which focuses on **study of and/or research** about the maker movement?
   - Yes
   - No
   - I don’t know

6) Is this class offered regularly, or is it a "special topics"-style class, offered infrequently?
   - The class is offered regularly
   - The class is offered infrequently
   - I don’t know

7) Other than any full maker courses you may or may not offer, do any of the courses offered to **graduate students** at your institution have a **unit or module** in which students study the maker movement and/or engage in any maker-style activities? Maker-style activities are activities in which students design and create artifacts and share their process with others.
   - Yes
   - No
   - I don’t know

8) To what extent does your college of education/education department’s future plans (i.e., within three years) involve **offering courses** on making and/or the maker movement?
   - Significant
   - Limited
   - Not at all
   - I’m not sure

9) To what extent does your college of education/education department’s future plans (i.e., within three years) involve **purchasing maker technologies**?
   - Significant
   - Limited
   - Not at all
   - I’m not sure

10) To what extent does your college of education/education department’s future plans (i.e., within three years) involve **establishing a research center** focused on the maker movement?
    - We already have one

- Significant
- Limited
- Not at all
- I'm not sure

11) To what extent does your college of education/education department's future plans (i.e., within three years) involve **creating a maker lab or a maker space** (e.g., a space available for students to use maker technologies, either as part of a class or independently)?
    - We already have one
    - Significant
    - Limited
    - Not at all

12) [if any of the above answers are "We already have one", "Limited", or "Significant"] Which of the following factors are driving your college of education/education department's desire to include elements of the maker movement in your future plans? (select all that apply)
    - It is consistent with the college's mission/strategic plan
    - It is consistent with the university's mission/strategic plan
    - There is research grant and/or foundation money available for work associated with the maker movement
    - One or more of the faculty believe it to be important
    - Students have expressed interest in learning more about the maker movement and/or maker technologies
    - Schools which are hiring our graduates are incorporating elements of the maker movement into their curricula
    - Other ________________________________

13) To what extent is the maker movement a presence at your college of education/education department?
    - Not at all
    - Limited impact (i.e., there have been discussions about it, committees examining it, etc.)
    - Moderate impact (i.e., some units or modules sprinkled throughout courses, some equipment purchased, etc.)
    - Strong impact (i.e., courses offered, equipment labs, degree programs, research center, etc.)

14) For which reasons has the maker movement not impacted your college of education (check all that apply)
    - Lack of funding
    - Lack of interest from students
    - Lack of interest from faculty
    - We don't believe the maker movement is worth addressing at this time
    - We're not sure how principles of the maker movement can support teaching and learning
    - Other