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Pre-service Teachers' Beliefs About Using Maker Activities in Formal K-12 Educational Settings: A Multi-Institutional Study

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Abstract

This qualitative study examined pre-service teachers' beliefs about using maker activities in formal educational settings. 82 pre-service and early career teachers at three different universities in the United States took part in one-time workshops designed to introduce them to various maker tools and activities applicable to K-12 educational environments. Data was collected from 16 focus groups conducted during the workshops in Spring 2016. Researchers analyzed the data using the Theory of Planned Behavior (Ajzen, 1985, 1991) to better understand the teachers' attitudes, subjective norms, and perceived behavioral control related to making activities, with the ultimate goal of using this information to assist teacher preparation programs in preparing their students to implement maker tools and strategies in their future classrooms. Participants expressed favorable attitudes towards implementing maker activities in their future classrooms and noted these tools and activities aligned with instructional strategies encouraged in their teacher preparation programs, including problem-based learning, inquiry-learning, and hands-on learning activities, but noted several perceived barriers such as access to resources and working with reluctant peers and administrators.

Pre-service Teachers' Beliefs About Using Maker Activities in Formal K-12 Educational Settings: A Multi-Institutional Study

There is growing interest in the use of tools and activities related to the practice of making in formal K-12 educational environments (Halverson & Sheridan, 2014; Peppler & Bender, 2013). As noted by Martin (2015), the modern maker movement is "built from familiar pieces" (p. 31), but it is distinguished from its traditional do-it-yourself and arts-and-crafts antecedents by the deep integration of digital technologies into both making and sharing (Martin, 2015). Though definitions of making vary (Vossoughi & Bevan, 2014), there is general convergence on the core ideas that making involves the production of some kind of artifact and that both the process of making and the resulting product are shared with the broader community of makers (e.g., Halverson & Sheridan, 2014; Hatch, 2014; Honey & Kanter, 2013; Martinez & Stager, 2013; Peppler & Bender, 2013). Other definitions of making incorporate concepts such as iteration (C. Anderson, 2012), ideation (Blikstein, 2013), and agency (Honey & Kanter, 2013).

Making has enjoyed increased adoption in after-school programs, museums and other informal learning environments (Bevan, Gutwill, Petrich, & Wilkinson, 2015; Peppler & Bender, 2013) but increasingly researchers are looking towards making as a tool to support learning in formal K-12 learning environments (Authors, 2016a; Chu, Quek, Bhangaonkar, Ging, & Sridharamurthy, 2015; Halverson & Sheridan, 2014; Peppler & Bender, 2013; Vossoughi & Bevan, 2014). While teacher preparation programs are building making into their programs (Authors, 2017), little attention has been paid towards the building of pre-service teachers' capacity to leverage making in these formal educational contexts.

A parallel may be drawn here between pre-service teachers' intentions to embrace maker principles and technologies as part of their future classroom practice and their intentions to use other technology-based teaching strategies and pedagogies. Research suggests addressing beliefs regarding technology are a key factor in the process of developing pre-service teachers' intentions to use technology in their future practice (S.E. Anderson & Maninger, 2007; Ertmer & Ottenbreit-Leftwich, 2010; Hermans, Tondeur, van Braak, & Valcke, 2008; Sadaf, Newby, & Ertmer, 2012a, 2012b). Various theoretical constructs, such as the Technology Acceptance Model (Davis, 1989), the Theory of Planned Behavior (Ajzen, 1985, 1991), and the Theory of Reasoned Action (Fishbein & Ajzen, 1975) suggest that beliefs contribute to intention, and that ultimately, intention can be converted into behavior. Yet each emphasize there are other factors which influence the conversion of intention to behavior. For example, one may intend to exercise regularly and eat a healthy diet, but due to a variety of factors those intentions are not always converted into consistent behavior. Similarly, pre-service teachers intend to use technology and non-traditional instructional strategies in a meaningful way to support learning in their future classrooms (e.g., S.E. Anderson & Maninger, 2007; Teo, Chai, Hung, & Lee, 2008), yet research shows that often these meaningful uses of technology promoted in pre-service preparation programs defer to more pedestrian uses of technology in practice (Authors, 2016b). To combat this disconnect between intention and practice, it is important to examine the nature of the intention in order to determine how teacher preparation programs can best prepare their students to follow through on their intentions.

Making in K-12 Education

The integration of making activities into educational contexts is not a new idea. Over 20 years ago, Seymour Papert (1991) introduced the theory of constructionism, which suggests that learning is facilitated through the construction and sharing of physical artifacts. However, technological innovations over the past few years, such as 3D printers and Arduino micro-processors, have brought about an increased interest in these types of activities. In 2014, President Obama established a National Day of Making (The White House, Office of the Press Secretary, 2014), and hosted the first ever White House Maker Faire. This proclamation signaled national recognition of the growing *maker movement*. Halverson and Sheridan (2014) describe the maker movement as, "the growing number of people who are engaged in the creative production of artifacts in their daily lives and who find physical and digital forums to share their processes and products with others" (p. 496). This movement has influenced K-12 education as schools have rebranded shop classes as makerspaces, and sought to incorporate making activities to support science, technology, engineering, and math (STEM) initiatives (Agency by Design, 2015).

While research in this area is still emerging, researchers have examined the use of maker activities in formal K-12 environments from elementary (Chu et al., 2015) to high school (Kafai, Fields, & Searle, 2014; Kostakis, Niaros, & Giotitsas, 2015). This research has supported the use of maker activities in educational settings as researchers have suggested connections to previous learning theories such as experiential education, constructionism, critical pedagogy, and problem-based learning (Blikstein, 2013; Halverson & Sheridan, 2014; Oliver, 2016a), and the alignment of these activities to integrated science, technology, engineering, and math (STEM) content areas (Berry et al., 2010; Bevan, Petrich, & Wilkinson, 2014; Hsu, Baldwin, & Ching, 2017; Lacey, 2010; Martin, 2015). Papert's (1991) theory of constructionism is widely considered the theoretical foundation for the use of making activities in education. This theory builds upon Piaget's constructivism and suggests "that the construction of knowledge happens remarkably well when students build, make, and publicly share objects" (Blikstein, 2013, p.5).

Making activities are emphasized in educational approaches such as project-based science and problem-based learning (Halverson & Sheridan, 2014), and support the emphasis on engineering found in the *Next Generation Science Standards* (Authors, 2017; NGSS Lead States, 2013).

Researchers have also suggested that the most important educational benefits arising from maker activities go well beyond formal schooling knowledge (Halverson & Sheridan, 2014), and may exist in areas such as spatial reasoning (Katsio-Loudis & Jones, 2015; Safhalter, Bakracevic Vukman, & Glodez, 2016), as well as student empowerment and identity (Clapp, Ross, Ryan, & Tishman, 2017; Halverson & Sheridan, 2014). Spatial reasoning includes visual perception and drawing as well as the conceptualization of objects or spaces which are not seen at a given moment (Safhalter et al., 2016). Modern maker activities often use 3D modeling software to develop objects which can be subsequently fabricated. Safhalter et al. (2016) conducted a study with students aged 11 to 15, in which students, among other tasks, modeled objects from their environment and defined the structure of the model as well as painted it accordingly. Results suggested that spatial reasoning abilities were improved through the use of these activities. In terms of student empowerment and identity, researchers from Project Zero, a research center at the Harvard Graduate School of Education, suggest that two primary benefits of maker activities are developing agency and building character within students (Clapp et al., 2017). Through interviews with maker educators and teachers engaged in maker-centered learning, these researchers suggest that these activities help students see themselves as ones who are empowered to take action in the world, and relate this life skill to self-reliance and courage. In addition, they suggest participants engaged in making activities build confidence, gain competence with the use of tools and materials, and develop a maker identity. They term these dispositions *maker-empowerment* (Clapp et al., 2017). In addition, other research has suggested that maker activities promote positive dispositions such as growth-oriented and failure-positive mindsets (Hsu et al., 2017; Martin, 2015).

The few existing studies examining maker activities in K-12 educational environments have largely focused on K-12 students. Empirical studies in this field have sought to identify the affordances of various maker tools such 3D printers (Brown, 2015; Kostakis et al., 2015) or electronic textiles (Kafai et al., 2014) for student learning. In addition, non-empirical scholarly work has attempted to develop guidelines for designing environments to support maker learning activities (Blikstein, 2013; Oliver, 2016a, 2016b). Less prevalent however, has been the examination of K-12 teacher preparation to facilitate these types of learning activities and teachers' development of a maker mindset. This gap in the literature is important to fill if we are to fully realize the benefits identified by integrating maker activities into K-12 classrooms. This sentiment is shared by Clapp et al. (2017) who stated "cultivating maker empowerment is not just a student outcome; it is important for educators to feel maker-empowered as well" (p. 163).

Teacher Preparation for Maker Activities

Our previous research examined the extent to which teacher preparation programs in the United States have integrated maker tools and technologies, and findings indicate that opportunities exist for teachers to explore the role of making in education, though not these opportunities are not necessarily widespread (Authors, 2017). Hsu et al. (2017) identified several programs designed to assist educators in utilizing maker activities in their classrooms. For example, Boise State University (2016) offers the online course, Maker Tech: Hybrid Computing and Creative Tinkering for STEAM Education, the University of Wisconsin-Stout (2016) offers a course focusing on establishing makerspaces in K-12 settings, and Stanford

University (Stanford Design School, 2016) provides self-paced materials on the future of making and manufacturing (Hsu et al., 2017). To effectively prepare educators to utilize these tools and activities however, research will be needed to guide our understanding as teacher educators in how to best provide these opportunities (Hsu et al., 2017). While the literature in this area is sparse, the present study builds upon two previous studies in this area.

The first study (O'Brien, Hansen, & Harlow, 2016) examined four pre-service teachers who created and facilitated a making activity as part of a school maker faire. Researchers sought to understand the pedagogical practices that these teachers would need to facilitate maker activities in their future classrooms as well as the types of experiences that would assist in developing these practices. Pre-service teachers in this study reported struggling with feelings of being ill-prepared to handle the unanticipated student questions and reactions to the maker activities. This seems reasonable as activities such as these often take on a more student-centered format, and can differ substantially from traditional classroom activities that are more structured (Halverson & Sheridan, 2014). As well, the issue of assessment in this environment provided challenges as well. Researchers suggested that preparation programs could address the changing role of the instructor during these activities, a role that seems more aligned to that of a facilitator than a traditional didactic instructor.

The second study (Paganelli et al., 2016) explored the use of makerspaces for professional development of in-service teachers. During a conference at a university, 25 in-service teachers engaged in making activities during a one hour experience. Teachers experienced these activities as students. As was the case in the O'Brien el al. (2016) study, these teachers struggled with the open-ended, problem solving nature of the activities, but provided generally positive feedback about the experience as professional development.

The present study adds to the empirical literature base on teacher preparation for the integration of maker tools and activities in their classrooms. Through pre-service and in-service teachers' own words, we illustrate their perceptions of how these tools and activities align with their experiences in their coursework and field experiences, and examine their perceptions of the benefits and constraints of using these types of activities in their future classrooms. Teacher preparation programs can expand on these benefits and provide strategies for overcoming future barriers. In addition, this study fills an important gap in the literature by examining the connections between pre-service and in-service learning experiences and the use of maker tools and activities.

Theoretical Framework

The theoretical framework that underpins this manuscript is Ajzen's (1985, 1991) Theory of Planned Behavior (TPB). TPB is a well-established framework (Greaves, Zibarras, & Stride, 2013) which has been used to understand pre-service teachers' intentions regarding the integration of technologies into their practice (e.g., Cheon, Lee, Crooks, & Song, 2012; Lee, Cerreto, & Lee, 2010; Sadaf et al., 2012b). Research has indicated that pre-service teachers' intentions are a predictor of future technology integration (Hermans et al., 2008). TPB provides a multi-dimensional look at intention by describing three determinants which influence intention: attitude toward the behavior, subjective norms, and perceived behavioral control (Ajzen, 1991). Attitude toward the behavior refers to the favorable or unfavorable appraisal of the behavior. Subjective norms are the social pressures the individual perceives to perform (or not perform) the behavior. Finally, perceived behavioral control refers to the individual's perception of the ease or difficulty of performing the behavior in question. Each of these three determinants is formed by salient beliefs: behavioral beliefs which determine attitude towards the behavior, normative beliefs which lead to subjective norms, and control beliefs upon which perceived behavioral control is based. Each salient belief leads to a determinant which, in varying degrees depending on the specific situation, leads to intention, which itself ultimately influences behavior (see Figure 1). In general, an individual's intention to perform a behavior, such as including maker technologies and strategies into a classroom environment, will be greater the more favorable the individual's attitude towards the behavior is, the more positive the subjective norms are, and the stronger the individual's perception of behavioral control is.

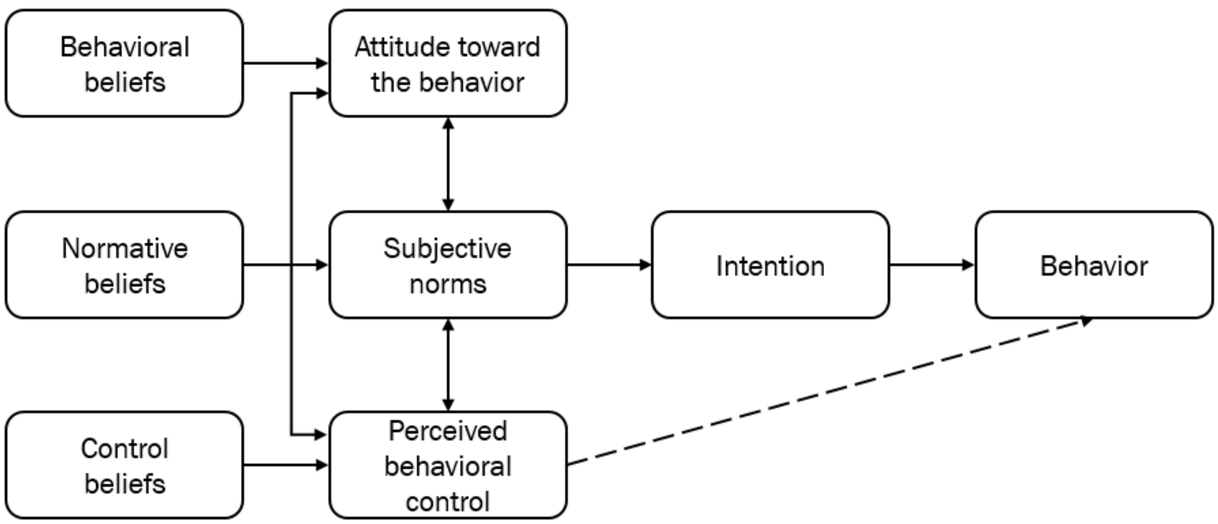

Figure 1. The Theory of Planned Behavior, including salient beliefs (Ajzen, 1991)

It is important to note that each determinant is centered within the individual. Attitudes toward the behavior are based on behavioral beliefs, which in turn are based on value-laden associations between an object or behavior and other objects or behaviors from the individual's experience. Subjective norms are based on normative beliefs, which are informed by the individual's predictions of whether "important referent individuals" (Ajzen, 1991, p.195) would approve or disapprove of a behavior. Last, perceived behavioral control rests on the individual's perception of the ease or difficulty of performing a particular behavior, which reflects the individual's past experiences and his or her own self efficacy (Bandura, 1982) related to the behavior.

Purpose of Study

The ultimate goal of this research is to assist teacher preparation programs in preparing their students to implement maker tools and strategies in their future classrooms. To that end, researchers conducted a series of workshops with 79 pre-service and three in-service teachers to precipitate conversations with the participants on their intentions to include maker principles and technologies in their future practice as educators. Specifically, researchers used the TPB as a framework to explore the following research question: What are the teachers' behavioral, normative, and control beliefs regarding the use of making in their future (or current) classrooms?

Methods

Context

Researchers employed a qualitative exploratory design to explore the research questions. An exploratory design enables the researchers to gain insights and establish hypotheses (Creswell, 2014) because there is little research in this area. The study was conducted at three large research universities located in the United States during Spring 2016. A total of 82 university students participated in the research, 79 pre-service teachers and three early-career, in-service teachers. The participants each attended one of seven 2.5-hour maker workshops designed to introduce them to maker technologies and the pedagogies they support. The workshops consisted of brief lectures, demonstrations of digital fabrication tools (e.g. design software, 2D CNC vinyl cutting machine, 3D modeling software and 3D printing, computer programming, and interactive electronic micro-controllers), and hands-on design activities.

Data Collection

During the workshops, focus group interviews consisting of 3-4 individuals were conducted with all participants. Following ethnographic techniques outlined by Fetterman (2010), researchers created a semi-structured interview protocol that consisted of two tiers of questions to allow for explicit exploration of research constructs but also included flexibility to explore variations of the topics. The first tier of questions was "grand tour questions" (Fetterman, 2010) designed to elicit a broad view of participants' beliefs about making and learning based on the authors' review of the literature that outlined maker dispositions and related pedagogical practices. These questions included, "In what ways do you think that making/creating objects can contribute to student learning?", "In what ways do you think providing choice and autonomy during learning activities can impact student learning?", "In what ways do you think that engaging in iterative design processes can impact student learning?, and "In what ways do you think sharing creations can contribute to student learning?" The second tier of questions included "structured specific questions" (Fetterman, 2010) designed to go into more details about behavioral, normative, and control beliefs. These questions included, "What barriers do you perceive in using maker tools and activities in your future classrooms?" and "Do you envision implementing maker tools and activities into your future classrooms? Why or why not? In what ways?" The focus group leaders then asked follow-up questions, related to the participants' initial answers, which directed the conversation towards a discussion of the salient beliefs related to the TPB. Each focus group lasted for approximately 20 minutes and was audio recorded to facilitate transcription.

Data Analysis

Researchers used the Nvivo qualitative analysis software package to analyze transcribed focus group interviews. First, researchers coded the focus group transcripts using the three TPB categories (attitude toward the behavior, subjective norms, and perceived behavioral control). Using the constant comparison approach (Glaser & Strauss, 2008), researchers then reexamined the data in each category to uncover embedded themes in each.

Two researchers coded a subset of the focus group transcripts to address inter-rater reliability (Maxwell, 2013). As this was a fully-crossed design with two 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. Initial results indicated weak reliability, so the researchers discussed the discrepancies and negotiated modifications in the coding procedures. The two researchers then coded a second subset of the data. Analysis of this second round of coding indicated substantial agreement (Landis & Koch, 1977) between the coders' judgements, $\kappa = 0.75$. Researchers then divided the remainder of the data set and coded them individually. Finally, all three authors met and analyzed the themes that emerged from the coding.

Results

Behavioral Beliefs

Behavioral beliefs refer to a personal evaluation of the behavior, which include whether the individual feels favorably or unfavorably about the importance or effectiveness of the behavior (Ajzen, 1991). In the context of this study, teachers' behavioral beliefs reflect their perceptions of the benefits of implementing maker tools and strategies in their future classrooms in terms of improving student learning. The teachers' behavioral beliefs were generally positive, and analysis of the focus group data suggests three primary perceived benefits; facilitating hands-on engagement with differentiated instruction, richer learning due to the applied nature of making, and potential benefits to content learning.

Participants acknowledged that these types of activities and technologies could facilitate differentiation, which many believed encouraged higher levels of student engagement, leading to positive learner behaviors. The idea that making activities are relevant for a range of learners—a process characterized by some participants as differentiation—was common. As one participant stated, "I feel the tools that we've been using help every learner." Another participant elaborated on how she believed these tools could lead to differentiation: "[The tools are] kinesthetic and tactile. Once [students] make something, you have something you can visually see. They're sharing, get to listen to each other. I feel like it really supports all the modalities, especially for differentiation." Expanding upon the hands-on nature of these maker activities, a few participants connected differentiation to the potential positive impact on classroom behaviors (e.g., "It's a way to engage every student, and that can help with behavior problems too") and attitudes toward learning (e.g., "the more you get kids physically involved and invested in it, the more they'll want to learn"). Another participant contended that "the kids that struggle with focus or struggle with just direct instruction would thrive with this type of thing," expressing an attitude shared by a number of the participants.

Participants also believed that making activities encourage students to apply knowledge in service of task completion, which could lead to richer and more durable learning. This was articulated by one participant who stated, "Direct instruction is important, but having the kids do stuff is what they will remember." In response, another participant drew upon her own experiences by reflecting, "I do remember learning a little bit more when I actually did a project or I did something other than just listening or a worksheet." Another participant expressed how a childhood lesson she experienced was particularly memorable because it involved making:

> We were doing medieval times and we had a whole medieval day. For math we were learning the area of perimeter. We all had to make castles and figure out the math for that. Everything was centered around making something.

These participants demonstrate a belief that hands-on maker activities can inspire learning that may stay with learners longer.

Many participants' positive behavioral beliefs centered on how these types of activities could connect to standards and learning objectives as well as specific content concepts. Reflecting upon one of the workshop tasks, a participant reflected, "Using the things that we did today gives kids a concrete understanding of how the tools can be used and how it helps to understand a particular standard." This brought up a conversation about how maker activities could connect to standards in various content areas. Language arts was of particular interest, as illustrated when one participant suggested that maker activities had no connection to language arts content. In response, another participant scoffed and referenced Scratch, a block-based coding language designed for use by children: "No way man, this totally fits. I mean Scratch alone! C'mon! I use it with elementary kids. There are so many connections to writing in there. The logic, the sequence." Similarly, another participant claimed, "I loved Scratch! Making a video game is all about storytelling, conflict...rules...setting...character development." The group ended agreeing about the potential connections with computer programming but remained unclear about connecting 2D digital fabrication and 3D modeling other than as content which could provide sources for writing prompts.

Mathematics-focused participants, on the other hand, were very keen on the idea of 2D digital fabrication techniques, as one participant said:

> The whole time I was thinking about one of my students. He wants to be an architect, and I was thinking of how he would love doing this. Because for area and perimeter, I let them draft their houses and he loved it. The whole time I'm just imaging how much he would like to do this, where he can make his own shapes and actually see it come out. How many other students you can inspire and see them shine in places you didn't know that they had that talent?

Similarly, one participant remarked how 3D modeling software could be used to address mathematical content:

> I think one thing kids really struggle with in elementary school math-wise is proportions and measurements. With a program like [Tinkercad], you could really see, if I could shrink it by this ratio or expand it by this scale. Scale and ratios. That could actually really help them visualize, “What is a millimeter? Well, 50 millimeters is actually really small.” Because they can't do that in their head, they have to see it. This can help them see it in a different way that would click with some of them.

When reflecting about how a more abstract approach to teaching does not always resonate with students, one participant laughed and said:

> I remember one of my kids… was like, “Why do we need to learn this? We know shapes, rectangles and circles.” It was really funny because it would have probably opened his eyes to understanding there are different properties and characteristics of shapes, that it goes a little further than rectangle, prism, and so forth.

Through reflecting on personal teaching and learning experiences, participants explained how these types of maker activities could positively impact students by providing hands-on learning because, as one participant noted, "that's how you learn your whole life. You learn by doing. You learn by experiencing," to which another participant laughed and lamented, "Then you go into school and it's like, 'All right, sit in a desk and listen.' " This type of positivity towards the potential of making to enhance the classroom experience was widespread among participants, and as a result participants' behavioral beliefs were largely positive.

Normative beliefs

Subjective norms refer to perceived social pressures either to perform or not perform a behavior (Ajzen, 1991). In the context of this study, early- and pre-service teachers' normative beliefs reflect their perceived social pressure either to implement or not implement maker activities in their future classrooms. Analysis of the focus group data suggest three perceived sources of subjective norms: administrators, peer teachers, and encouraged instructional strategies, which the participants regarded as manifestations of the values of the field of education.

Though participants had limited experience working with administrators, many believed they would influence their decision to utilize maker tools and activities in their future classrooms. Participants reported "you need administrative support as well," "the administration has to buy into it," and "ultimately it all boils down to your principal." While these statements suggest constraints, some participants suggested otherwise. For example, one participant drew on her current student-teaching experience and suggested, "I know that the practicum [student-teaching] place I'm at right now, this principal is all about STEM. So if you can tie it at all to that STEM program, you can do it."

Participants reflected on their interactions with the in-service teachers they worked with in their student-teaching experiences when describing the subjective norms they perceived from their peers. These in-service teachers included their mentor teachers as well as teachers in their departments, grade levels and schools. They suggested that future peer teachers may be resistant to change, fearful of new technologies, and unreceptive to changing their practice. One participant envisioned peer influence occurring through team planning activities, and stated that in terms of employing maker activities, "you would like to use them. But then, my first-grade class, all four of the first-grade classes have the same exact lessons, every day for every subject." Another participant concurred, and added:

> They have a grade level team of teachers. The teachers have to literally argue and compromise lots of plans. They all have to contribute but they all have to agree on the same thing. Every first-grade class wants to do the same thing. I might be comfortable with it, but if the people I'm working with are not, I don't know how I'll handle that.

One participant, however, held more positive beliefs about peer influence, and recollected her experience with peer teachers by noting, "My teachers would be like, 'Oh, yeah definitely. I'm bored of my own curriculum, I want something new, but I'm not sure what to incorporate.'" This belief that peer teachers would be receptive to including making into curriculum was not widely held among participants, however.

Participants viewed the instructional strategies that their preparation programs encouraged them to use as manifestations of the values of the broader educational community. Because they saw making as consistent with so many of these encouraged strategies, they believed that making was being encouraged by the field at large. In particular, participants reported that hands-on learning, a focus on integrating STEM (science, technology, engineering, and math) content areas, project-based learning, and inquiry-based learning may be well supported by these tools and activities, thereby providing a positive influence on teachers' beliefs about integration of these tools and activities. One participant noted that maker tools and strategies, "[fit] in perfectly. Pretty much our entire emphasis now is inquiry." Another described her experience of reconciling recommended teaching methods with her experiences in her student-teaching environment and how these maker tools and strategies could help bridge the gap:

> This is one of the best examples of inquiry-based learning that I've seen, and that's something we've been struggling with, because we're not seeing it in our practicum classes, but we're being told that this is the new way that we're teaching.

Several participants also mentioned the use of multiple representations and a need to move away from direct teacher-centered instruction. One participant described how maker tools promote more student-centered teaching strategies by stating, "You can't do a direct instruction and then give someone a 3D printer. It contradicts itself." Finally, one participant summed up her thoughts on addressing current pedagogical trends and the alignment with maker tools and strategies:

> I think that going forward it could be useful and I think it could very much be in line with where we're headed in education and being more creative and working with things in a different way and teaching different ways.

Because making activities, as conceptualized by the participants, aligned with the instructional strategies they were encouraged to adopt, participants felt encouraged by their teacher preparation programs to adopt making into their practice, which stood in contrast to many of the negative pressures they anticipated coming from their peer teachers.

Control beliefs

Perceived behavioral control broadly refers to the perceived amount of control a person has over the internal and external factors that influence the attainment of a behavioral goal (Ajzen, 1985). In the context of this study, early- and pre-service teachers' control beliefs reflect their perceived internal and external barriers to implementing maker activities in their future classrooms. To best provide an illustration of the control beliefs of the teachers in this study, focus group data was sub-coded under control beliefs by internal and external barriers. Internal barriers included perceived constraints that were within the control of the participants and external barriers were constraints that were perceived by participants as being outside of their control.

Participants believed their ability to integrate maker activities and their required technological knowledge would be two primary internal barriers. This feeling was exemplified by one participant, who stated, "if the kids try to make something, and it comes out completely wrong, you don't want to be like, 'What do I do to fix this?' and not know." Another participant concurred, recognizing her limited ability to implement maker tools and activities: "I'm the barrier. This stuff makes me feel uncomfortable. I mean I could see myself using it to make manipulatives like with the paper cutting machine but I don't think I could integrate it into a lesson." However, one participant, while acknowledging her constraints, also expressed enthusiasm for using maker tools and activities:

> I don't know how to write that into a lesson plan yet, but I do know that it would be really cool to have and be starting to get acquainted with, as a teacher. You can use it for a lot of stuff. I just don't know what stuff yet.

Often participants' reluctance to integrating these tools seemed to stem from their perceived lack of technological knowledge. One participant acknowledged her desire to integrate these activities, but cautioned, "I would use it. However, I don't feel as confident in my technical abilities so I would prefer to have someone there to make sure I'm not messing everything up." Several participants indicated that assistance by a more experienced technology integrator would be beneficial.

Time constraints, access to maker technologies, and state standards were reported as the primary external barriers to integrating maker activities. Several participants believed implementing maker activities would require additional class time, and expressed that this time is limited. One participant stated, "We only have like 45 minutes each class period by the time they get settled and stuff. I'm not sure if that would be enough time for them to really like get into it." They noted that technologies they were exposed to in the workshop, such as 3D printers, can take several hours to print an artifact, and that this would span several class periods. As well, they believed these technologies may often be situated in computer labs or other areas outside of their immediate classrooms, and using these facilities required additional instructional time as well. One participant, reflecting on the technology used during the workshop activity added that a maker-style lesson would "take a course of a couple of days, so if you have a lab that has it in there you need to make sure that you can allot that time in the lab."

Though it was expressed in the workshops attended by the participants that maker activities can use non-digital everyday materials (i.e. cardboard, recyclables, etc.), participants focused on the cost of the digital tools when considering barriers to implementation. One participant noted that, "There are other issues facing urban schools they would take care of first, before they would get a 3D printer. I think that would be way down the line of things that they would get." They often pointed to a lack of other resources in their student-teaching environments as examples, and questioned whether these emerging maker technologies would be supported in their future schools. This was articulated by one participant describing her student-teaching environment: "I can see them saying, I need textbooks, and other books as well...and the leak in the roof to be fixed... I need a hundred other things, along with this." The perceived cost, in these cases, represented an insurmountable barrier to the inclusion of making into the teachers' practice.

Another external barrier referenced by the participants was their belief that state standards would negatively constrain their ability to implement maker type activities in their future classrooms. One participant reported, "It's hard once you bring in SOLs [Standards of Learning] and testing and all the other benchmarks." Another agreed by stating, "There's only so many SOL's that you can link into something that you can do that with." It should be noted, however, that several participants articulated a more neutral opinion, and suggested these types of activities could foster creative learning activities while still addressing standards. For example, one participant suggested, "You could use it with SOLs, with math, science. They have to know measurement." Another concurred by stating, "If I could tie it to the required reading they might be more likely to actually read the darn thing." Finally, one participant expressed a positive reaction to perceived links between these activities and standards by noting:

> Every SOL for every grade has a component of trial and error, and checking your hypothesis, and seeing if your experiment's going to work. You could tie this into every single grade. I really don't see that as an issue.

Despite these occasional positive control beliefs, however, participants' levels of perceived behavioral control was low.

Discussion

Key Findings

Participants in this study reported behavioral, normative and control beliefs that when interpreted through the lens of TPB, provide insight into their intention, and potentially their ultimate inclusion of maker tools and strategies in their future classrooms. Participants' behavioral beliefs were predominately positive about implementing maker tools and strategies in their future classrooms, a finding supported in other research in this area (Burghardt & Krowles, 2006). They believed these tools and strategies could promote student learning in various content areas, and articulated ideas for implementation in these areas. As well, they believed these tools and strategies promote hands-on and differentiated learning opportunities, a belief that when paired with the normative belief that these tools and activities support encouraged instructional strategies, provides a solid rationale for implementation in their future classrooms. These positive pre-service teacher reactions to the use of maker tools reaffirms similar findings in the literature (Paganelli et al., 2016).

However, while maker tools and strategies clearly aligned with strategies encouraged in their teacher preparation programs, participants, reflecting on their student-teaching experiences, reported normative and control beliefs that would indicate a lower likelihood of the participants' planning to implement these tools and activities. First, they envisioned barriers arising when collaboratively working with peers and requesting support from administrators in their future schools. Several participants, noting a gap identified in previous research between encouraged instructional strategies in their teacher preparation programs and instructional strategies they experienced in real classrooms during their student-teaching opportunities (Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010; Pope, Hare, & Howard, 2002), believed their future peers and administrators may be hesitant to embrace emerging maker technologies or change existing practices. Second, they believed their knowledge of operating emerging maker technologies and integrating these tools and strategies into their instruction would not be sufficient. These beliefs may be due to their lack of exposure to these tools and strategies. The workshop attended by participants was the first time many of them had worked with these types of technologies. This low self-efficacy towards technology integration has been identified by other researchers who suggest beginning teachers often do not feel well prepared to integrate technology in their future classrooms (Sang, Valcke, Braak, & Tondeur, 2010). In addition, the lack of experience with these tools and strategies appears to have also contributed to additional constraining control beliefs. For example, some participants cited time as a primary barrier, and believed implementing these types of activities would require a great amount of additional time. This perspective however, suggests that participants conceptualized these activities as add-ons to their core teaching practice, and not as primary, integrated activities in teaching content.

Implications for Practice

Emerging research supports the use of maker activities and strategies in formal and informal learning environments (Bevan et al., 2015; Standish, Christensen, Knezek, Kjellstrom, & Bredder, 2016). The findings of this study are important as they illustrate pre-service teacher beliefs which, if positively impacted in a teacher preparation program, could lead to the inclusion of maker principles and tools in formal educational contexts. The following recommendations are intended for teacher preparation programs, and illustrate how they can better assist pre-service teachers in understanding how to incorporate maker tools and activities in their future classrooms.

Behavioral beliefs that these tools and strategies can increase student learning in different content areas can be built upon by providing pre-service teachers with access to the technologies required to develop and implement maker tools and strategies in their student-learning experiences. Access to technology in teacher preparation programs has been identified as a key theme in assisting pre-service teachers in integrating technologies in their future classrooms (Tondeur et al., 2012). Experiences in utilizing maker tools and strategies in multidisciplinary contexts, as well as facilitating and assessing maker activities will bolster pre-service teachers' efficacy in adopting these methods (Brophy, Klein, Portsmore, & Rogers, 2008). Pre-service teachers' normative beliefs about the hurdles of working with reluctant future peers and administrators can be addressed by building upon the connections between encouraged instructional strategies and maker activities. Teacher preparation programs could engage in collaborative projects with K-12 schools to retrieve feedback on utilizing innovative technologies from in-service teachers as well (Sadaf et al., 2012b). In addition, aligning theory and practice will assist pre-service teachers in situating the technologies into their perceived future practice (Tondeur et al., 2012). Participants in this study acknowledged the alignments between maker activities and inquiry-based learning, hands-on learning, and project-based learning. Providing pre-service teachers with access to supporting research and enabling them to articulate these connections may empower them to implement these activities in their future classrooms. In addition, as maker technologies continue to be adopted by the general public, comfort with using these tools should increase as well, and by assisting pre-service teachers with developing curriculum involving less expensive maker tools, they may be more likely to implement these activities in their future classrooms.

Conclusion

This study has provided insight into pre-service teachers' behavioral, normative, and control beliefs about implementing maker tools and activities in their future classrooms. Though research on the use of these tools is emerging, early- and pre-service teachers' beliefs indicate a clear alignment with effective instructional strategies. To realize the potential of these tools in formal K-12 educational contexts, early- and pre-service teachers require effective learning experiences to assist them in integrating these tools and strategies into their practice, and to support these learning experiences, teacher preparation programs will need to address their students' existing beliefs.

Through the use of the TPB, this study provides a roadmap by which teacher preparation programs can design effective learning experiences that address pre-service teachers' behavioral, normative, and control beliefs. As we heard from the voices of the participants, these beliefs rest along a continuum of positive and negative beliefs. The findings of this study can inform teacher preparation programs by providing practical recommendations to bolster and support positive beliefs and mitigate and overcome negative beliefs. By addressing teachers' beliefs in this way, programs may increase their influence on their students' future actions in this area.

Limitations of the Study

This study is limited by the use of the TPB framework as it examines only pre-service teachers' intentions, as opposed to actual practice. This limitation has been noted in similar research by Sadaf et al. (2012a), who utilized the framework to examine pre-service teachers' intentions to integrate Web 2.0 technologies in their future classrooms. Sadaf et al. (2012a) note, "although intention has been proven to be a critical predictor of technology use, the intentions of participants might change as they start teaching in schools" (p. 189). Additionally, participants in this study took part only in one three-hour workshop, and many reported this was their first exposure to maker tools and activities.

Recommendations for Future Research

Research on the benefits of integrating maker tools and activities into formal K-12 educational contexts is still emerging, and further empirical studies in this area will inform not only how these elements are integrated into K-12 classrooms but also how teacher preparation programs will provide effective learning opportunities for their candidates. As effective maker teaching strategies are identified and correlated with existing best teaching practices in specific content areas, the alignment with teacher preparation practices should become more evident. In alignment with other research utilizing the TPB framework (Sadaf et al., 2012b), future research examining "the specific interventions that align with pre-service teachers' behavioral, normative, and control beliefs" (p. 944) will guide teacher preparation programs in providing effective learning experiences for their candidates in this area.

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