Making Makers: Creative Self-Efficacy, Technology & the Theory of Planned Behavior

Matthew Norris

Matthew Norris, Fab Lab Tulsa
Tulsa, OK USA
www.makingofmakers.com
mljnorris@gmail.com

Abstract

Fab Labs, Makerspaces and Hackerspaces are part of a decentralized global Do-It-Yourself movement providing unique resources to tinkerers, hobbyists, inventors and artists to make almost anything. Individuals who use these facilities are often called “makers”. This preliminary research offers insight into why people intend to return to making by testing a “maker” behavioral model blended from the theory of planned behavior, the technology acceptance model, and creative self-efficacy. The results demonstrate this model by identifying three key characteristics which predict a maker’s intentions to continue making, namely social interactions, creative behaviors, and maker behavioral control. A survey of the membership of Fab Lab Tulsa and other US based Fab Labs was used to study the maker model by examining the members’ attitudes and behaviors about creativity and making, technology, their social group, their openness to experience, and their creative role identity. It also examined the correlation with their intention to return to make. This preliminary research has implications for any Fab Lab that seeks to increase its membership or facility usage. Future work includes developing the survey for non-English languages and non-US cultures.

Keywords

Makers, Fab Lab, Theory of Planned Behavior, Creative Self-Efficacy, Technology Acceptance Model

1 Introduction

Fab Labs, Makerspaces and Hackerspaces are proliferating at a rapid pace, and are all part of a decentralized global Do-It-Yourself movement providing unique resources to tinkerers, hobbyists, inventors and artists to make almost anything almost anywhere. These facilities are havens for clever individuals who have nowhere else to go (Gershenfeld, 2015). The people using these facilities are called many things, but the most fitting moniker is “maker,” a term which Make Magazine founder Dale Dougherty coined in 2005, along with the term “maker movement” (Dougherty, 2016). Makers make many things ranging from robots to furniture, food to mobile computing applications, or drones to wooden toys. The advent of these “making” facilities is a precursor to a new model of personal manufacturing that emphasizes mass personalization instead of mass production. This challenges everything. When things can be made for one, for a few or for many, then new possibilities exist for economic, manufacturing and social development (Gershenfeld, 2015). These possibilities are further enhanced when it is “possible to fabricate items globally by doing it locally across many locations, and shipping the data to make the product, but not the product itself” (Gershenfeld, 2015). In contrast to current industrial practices, the maker movement democratizes technology so that design projects maintain a personal context and are of personal interest while simultaneously having the potential to be shared and distributed globally through a network of making and invention (Lassiter, 2015).

This paradigm shift presents many interesting questions, primary of which is “what makes a maker?” In other words, why do people engage in making initially and why do they continue making? Also, what influences a non-maker to become a maker? These questions must be answered if Fab Labs, Makerspaces and Hackerspaces are to become common resources in society for makers and non-makers alike.

1.1 Fab Lab Tulsa

One such organization, the Hardesty Center for Fab Lab Tulsa, was founded in 2008 with the mission of providing 21st century tools and equipment to the general public to make almost anything (Pritchett, 2014). An outgrowth of a program which originated at MIT, the Fab Lab concept brings together five core pieces of computer numeric controlled (CNC) equipment into a single facility for individuals to design and fabricate everything from shoes to electronic sensors, and nearly everything in between.

Fab Lab Tulsa, a 501(c)3 non-profit corporation, of Tulsa, Oklahoma USA, had nearly 16,000 visitors in 2013 including about 2,500 students (N. Pritchett, personal communication, 2013). Building upon that traffic, the lab has almost 400 dues-paying members but still relies heavily on philanthropic foundations, corporations and individual donors to sustain its operations.

So what possibilities exist to boost the number of dues-paying members? To answer that it is essential to understand the intentions of the current members to continue making at Fab Lab and paying dues; and the intentions of first time users to return to make again and become dues-paying members. Therefore, the central question of this research is to understand the antecedents to a maker's intention to return to make using a proposed maker behavioral model blended from the theory of planned behavior, the technology acceptance model, and creative self-efficacy. To examine this question, this research used a survey of Fab Lab membership, users and volunteers to study their attitudes and behaviors regarding creativity and making, technology, their social group, their openness to experience, and their creative role identity.

In some respects, the research can be likened to a business plan that examines key factors which influence Fab Lab survival, namely the retention of users. This research used empirical analysis of user (i.e. customer) attitudes, opinions and beliefs to understand potential predictors of Fab Lab growth. With this understanding, there exists, consequently, the potential to determine which of those predictors can be influenced to the benefit of the organization.

Academic research into the subjects of makers, making, makerspaces and Fab Labs appears to be quite new. In developing introduction and background material for this research, the majority of existing sources found, in order of prevalence, were related to libraries and their integration of makerspaces, the relationship between makers and the general field of innovation, makers and entrepreneurship, and finally a small segment about makers and intellectual property. Popular sources abound, however, in books, blogs and websites but they don't add to the present research beyond what has already been cited.

More specifically for Fab Labs, this is not the first academic research involving Fab Lab Tulsa. The Center of Applied Research for Nonprofit Organizations (CARNO) from the University of Oklahoma-Schusterman Center in Tulsa conducted research focused on measuring the influence that Fab Lab Tulsa has on children's measures of self-perception and attitude regarding science, technology, engineering and math (STEM) experiences (Dubriwny, Pritchett, Hardesty, Hellman, 2016). The study was conducted on school-age children from Tulsa metro area schools wherein students used Fab Lab for a project, and were measured for self-perception with a pre-test/post-test design. The results indicate Fab Lab had a statistically significant effect on students' self-efficacy regarding STEM experiences.

2 Maker Behavioral Model

The research tested a hypothesized model of maker behavior which attempts to explain the antecedents to a maker's intention to return to making. It is blended from the theory of planned behavior (TPB) (Azjen, 2002), the technology acceptance model (TAM) (Davis, Bagozzi, & Warshaw, 1989), and creative self-efficacy (Bjornberg & Davis, 2015). Each of these contributes to the proposed model in a different way. The theory of planned behavior forms the backbone of the model owed largely to its widespread use and acceptance explaining behavior. The technology acceptance model is essential because it was believed that it will help account for a maker's acceptance or reluctance to use the technology typically found in a Fab Lab. Creative self-efficacy is a component of the proposed model because it was hypothesized that creativity and the creative process are integral to making.

2.1 Theory of Planned Behavior Background

Icek Azjen proposed the Theory of Planned Behavior (TPB) in 1985 as an expansion of the Theory of Reasoned Action (Azjen, 1985). The theory of reasoned action follows the causes and links from beliefs, through attitudes and intentions, to actual behavior. It focuses primarily on behavior which is within a person's volitional control (Azjen, 1985). The TPB is applicable, however, when the probabilities of success and actual control are not perfect. This means that the success of an attempt to execute a behavior depends on both the strength of the attempt and also on the individual's control over factors like information, skills, abilities, will power, time, opportunity, etc (Azjen, 1985). Overall, people will attempt a behavior if their referent social norms (i.e., subjective norm or peer pressure) motivate them and if they believe the consequences of success are greater than the consequences of failure (i.e., their attitude toward the behavior). Further, they will succeed in their attempt if they have adequate control (i.e., perceived behavioral control) over internal and external factors, as in this research, their free time to visit the Fab Lab, transportation or finances (Azjen, 1985).

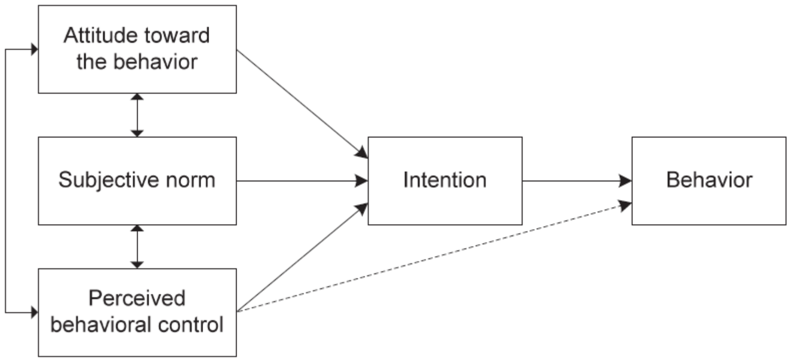

Figure 1 – Theory of Planned Behavior (Azjen, 2002)

The TPB, shown in Figure 1, is widely used to describe behavior across a number of domains. It has been used to predict above-average participation in volunteerism (Greenslade & White, 2005) and also individual creative performance (Choi, 2004). In other research, the TPB has also found use in identifying factors influencing teachers to use educational technology (Lee, Cerreto, & Lee, 2010) as well as studying offline and online civic engagement amongst young adults from different ethnic groups (Jugert, Eckstein, Noack, Kuhn, & Benbow, 2013). Given its wide use and focus, the TPB is a relevant model for this research about makers and their intention to return to making.

2.2 Technology Acceptance Model Background

The Technology Acceptance Model (TAM) was introduced in 1986 by Fred Davis as an adaptation of the theory of reasoned action which was specifically tailored for modeling user acceptance of information systems (Davis, Bagozzi, & Warshaw, 1989). Ideally, the TAM is a model that is not only helpful for prediction but also explanation. This means that both researchers and practitioners can identify why a system is unacceptable and can pursue corrective steps (Davis et al, 1989). TAM (See Figure 2) postulates that a person's behavioral intention to use a system is influenced first by their beliefs about the system's ease of use and perceived usefulness, and second by a person's attitude toward using the system. Perceived usefulness, as well, influences behavioral intention (Davis et al, 1989) while behavioral intention finally influences actual system use.

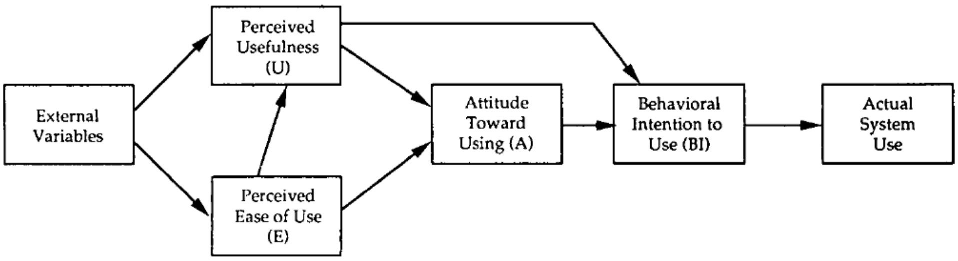

Figure 2 – Technology Acceptance Model (Davis, Bagozzi, & Warshaw, 1989)

Technology ease of use is defined in this research as the degree to which an individual perceives a particular piece of maker technology as easy to use or free of effort (Davis et al, 1989). Perceptions of ease of use will vary between people and will vary depending on the sophistication of the technology.

Technology usefulness is defined as the prospective user's subjective probability that using a specific maker technology will increase his or her making performance (Davis, Bagozzi, & Warshaw, 1989). Usefulness will be determined by the effectiveness of the technology at achieving the requirements of the creative effort or the desires of the maker.

Like the TPB, TAM is used in several technology domains. It is used in education to predict teachers' adoption of technology (Holden & Rada, 2011) and mobile technology (Tsai, Want, & Lu, 2011). Further TAM helps to predict consumer acceptance of smart grid technology (Toft, Schuitema, & Thogersen, 2014), and nurses' acceptance of electronic medical record systems (Kuo, Liu, & Ma, 2013).

In this research, maker technology is defined as technology used in a Fab Lab. This includes the design tools (e.g., design software, computer coding tools, and CNC programming tools), main equipment (e.g., 3D printers, CNC router, laser cutter, vinyl cutter, mini-mill, and electronics workbench) and supporting equipment (e.g., band saw, belt sander, other power tools, and hand tools).

Therefore, the TAM is especially appropriate to this research given the observations of Fab Lab Tulsa staff about user's mixed reactions to the computing and fabrication systems in the lab.

2.3 Creative Self-Efficacy Background

In this research, creativity is defined as any creation which is novel, appropriate, and useful as determined by society or a group (Sawyer, 2012). Creativity also includes elements of style, defined as the degree to which the creation combines unlike elements in a refined, developed, and coherent unit (Besemer, 2006). This means that both the context of a creation (its novelty and style) and its perceived usefulness will determine whether or not it is creative. With this definition, creative products may range from knitting or other crafts to metal shapes machined with computer controlled equipment. Building upon creativity, creative self-efficacy is a "domain-specific efficacy belief describing individuals' beliefs that they are able to generate creative outcomes" (Bjornberg & Davis, 2015). Their attainment of such a creative behavioral goal, however, is dependent on their control of the behavior involved (Azjen, 1985). In other words, in creative pursuits those people with high creative self-efficacy believe they can develop novel ideas or solutions because of their high perceived behavioral control (PBC).

Bjornberg and Davis (2015) demonstrate through a meta-analytic examination that there are five antecedents to creative self-efficacy in organizations, namely creative role-identity, openness to experience, workplace support, leadership, and workplace creativity expectations. In the blended maker model, the antecedents leadership, and workplace creativity expectations will not be examined because they focus externally on individual's workplace.

Fab Lab Tulsa, as it relates to makers, is not a workplace having the typical departments, teams, support, leaders, management or expectations found in a typical employment setting. Therefore, three elements remain: workplace support, creative role identity and openness to experience. These are relevant to this research because they focus on both the social support system and internally on personal characteristics. Workplace support is analogous to the support a user receives from fellow users within a Fab Lab, and refers to perceptions that other users care about and value another user's contributions (Bjornberg & Davis, 2015). It will be known in this research as the social support system, and is tested with the IPIP TCI scale for empathy (Goldberg et al, 2006). Creative role-identity is an internalized identity developed by an individual over time based upon expectations placed upon them by others (Bjornberg & Davis, 2015). Creative role identity creates a motivational pull toward creative endeavors and engagement which increase creative self-efficacy over time. The final antecedent to creative self-efficacy, openness to experience, is an internal characteristic of those individuals' who are more open to new ideas and experiences, and more willing and confident to try new things (Bjornberg & Davis, 2015). Having such openness will lead to increased creative self-efficacy over time.

2.4 Blended Maker Behavioral Model

The blended maker behavioral model (MBM) is a modification of the TPB using components from the TAM and creative self-efficacy. The model is shown in Figure 3. It includes the hypothesized relationships between the elements in the model, and their direction of influence.

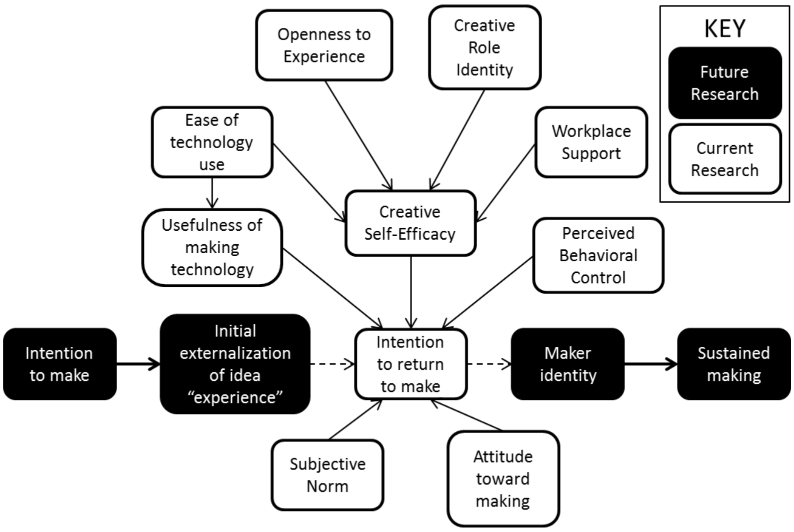

Figure 3 – Blended Maker Behavioral Model

Elements noted as Future Research in Figure 3 are shown for reference only and are borrowed from research on sustained volunteerism (Penner, 2002).

Creativity is believed to be a key component of making, and so the elements openness to experience, creative role-identity, and creative self-efficacy are borrowed from research by Bjornberg and Davis (2015) about creative self-efficacy, as noted previously. Openness to experience is defined as the degree to which an individual is willing and confident to try new things (Bjornberg & Davis, 2015). It could be any new experience but in this research, an example might be an individual enrolling to be a member of Fab Lab Tulsa, or a current member starting a new project with an unfamiliar piece of equipment.

Creative role identity has a social context in this research. For example, in a work or non-work organizational scenario, team members may view one person as particularly creative. Those expectations would influence that team member to internalize and to develop a creative role identity, and therefore to increase their likelihood of continued making. In this research, individuals assessed of their own creative role identity.

Finally, both creative self-efficacy and PBC are used in the MBM. While each are measures of self-efficacy, they nonetheless focus on different but equally important aspects of this trait. Creative self-efficacy focuses on creative behavior while PBC focuses on an individual's more mundane circumstances like their availability to visit Fab Lab, their financial resources to afford a membership, or their capacity to envision and complete maker-type tasks. Both are necessary in this research.

The elements subjective norm, attitude, intention to return to make, and PBC are borrowed from the TPB. Subjective norm is used so that the relationship between an individual's intention to return to make and the influence of their social relationships on their intention can be understood.

The elements ease of technology use and usefulness of maker technology are borrowed from the TAM. They are used to test the relationship of technology to both creative self-efficacy and intention to return to making. Regarding ease of technology use, it is believed that an individual who finds technology easy to use will have higher creative self-efficacy because if the individual can effectively use technology for making, then his or her belief that the technology can be used to generate creative outcomes will be enhanced. With regard to the usefulness of maker technology, its relationship to intention to return to make is based on the TAM, and is essential to understand because experience at Fab Lab Tulsa demonstrates that technology usage is a barrier to making.

3 Methods

3.1 Participants

Participants in the study were adult members of Fab Lab Tulsa or other US based Fab Labs, ranging from those with new memberships to longer-term memberships. The design of the study had no influence on the adult members who participated. Fitting with recent demographics from Fab Lab Tulsa the respondents were majority male, between the ages of 30 and 49 years, (King, Holbrook, Sanders, & Williams, 2014). Specifically, the results were 81% male, 19% female (N=83) with an average age of 44 years (SD=14.1, N=80). Their educational levels showed most had completed university with 35% having graduate degrees, 35% bachelor's degrees, 20% some college, and 10% high school or trade school (N=93).

3.2 Measures

Several constructs were measured. Creative self-efficacy, technology acceptance, subjective norm, attitude toward making, creativity and intention to return to make were measured in this study with instruments which have been shown to be valid and reliable in prior research. Content validity was evaluated through selection, review and revision of the survey items before distribution.

After the initial set of items for the measures were selected, the survey was further developed and revised. First, the survey was tested with a group of graduate students knowledgeable of survey design who were also studying the creative process. The cohort proofread the survey for basic grammar and understanding, and provided both written and verbal feedback to improve revisions. They were also timed when they took the survey, which helped establish that it could be completed in 15 minutes or less. The survey was then revised, and re-evaluated by graduate faculty. Many items received only minor alteration but those for intention to return to make and for attitude with beliefs were thoroughly reworked using information from Icek Azjen's own website which includes a rubric for survey development (Azjen, 2016). These items for intention and attitude were reworked because their applicably to makers was not sufficient. After the rework the items were evaluated by faculty and approved. The instruments for all measures were appropriate for survey design, and were applied on new and seasoned members alike. The measures are explained in Table 1.

Measure	Sample	Reliability	Scale	Source
Intention to Return to Make	It is likely I will continue making as much or even more this next month as I have in the past month.	$\alpha = 0.97$	6-point Likert Type strongly disagree (1) to strongly agree (6)	Greenslade and White, 2005
Creative Role Identity	I often think about being creative.	$\alpha = 0.80$	6-point Likert Type strongly disagree (1) to strongly agree (6)	Farmer, Tierney, & Kung-McIntyre, 2003

Measure	Sample	Reliability	Scale	Source
Openness to Experience	Have a vivid imagination.	$\alpha = 0.82$	6-point Likert Type very inaccurate (1) to very accurate (6)	Goldberg et al., 2006 (International Personality Item Pool)
Creative Self-Efficacy	I have confidence in my ability to solve problems creatively.	$\alpha = 0.868$	6-point Likert Type strongly disagree (1) to strongly agree (6)	Seo et al, 2015
Attitude Toward Making (Direct Measures)	Unpleasant – Pleasant	$\alpha = 0.94$	6-point evaluative semantic differential scale ranging from (3) to (-3)	Greenslade and White, 2005
Attitude Toward Making (Beliefs)	Expressing my creativity is important.	$\alpha = 0.95$	6-point Likert Type strongly disagree (1) to strongly agree (6)	Azjen, 2016
Subjective Norm	When it comes to making, I want to be like my friends.	$\alpha = 0.69$	6-point Likert Type strongly disagree (1) to strongly agree (6)	Azjen, 2016
Perceived Behavioral Control	How much making I do is up to me.	$\alpha = 0.68$	6-point Likert Type strongly disagree (1) to strongly agree (6)	Azjen, 2016
Workplace Support	Other Fab Lab users are reassuring to me.	$\alpha = 0.86$	6-point Likert Type strongly disagree (1) to strongly agree (6)	Goldberg et al., 2006 (International Personality Item Pool)
Perceived Technology Support	Using technology will improve my making.	Composite = 0.95	6-point Likert Type strongly disagree (1) to strongly agree (6)	Teo et al, 2012
Perceived Technology Ease of Use	I find tools easy to use.	Composite = 0.91	6-point Likert Type strongly disagree (1) to strongly agree (6)	Teo et al, 2012

Table 1: Survey Measures

4 Procedure

Test procedures included data collection and analysis. Following IRB approval, data collection was conducted via online instrument and survey tools to collect data on technology ease of use, technology perceived usefulness, openness to experience, creative role-identity, creative self-efficacy, creativity, attitude toward making, subjective norm, intention to return to make and demographics for every participant regardless of experience. Participants were only allowed to respond once.

The responses from the survey were collected, reviewed and analyzed with IBM SPSS for descriptive statistics, reliability, and correlations; and then validity was examined (IBM Corp., 2015). The survey was opened on March 21, 2016 and closed on May 31, 2016 after approximately 96 responses were collected from three Fab Labs in the United States: Fab Lab Tulsa (Tulsa, OK), BiG Fab Lab (Bowling Green, OH), and AS220 (Providence, RI). Fab Lab San Diego (San Diego, CA) was invited to participate but no responses were collected from San Diego area zip codes. Similar community based Fab Labs in Biddeford, ME and El Paso, TX were contacted, but did respond to requests.

There were two major issues which surfaced during the survey. The first being that the vast majority of respondents were from zip codes near Tulsa, OK, despite multiple efforts to expand the pool of responses and also a 25 USD cash incentive. Of the 96 respondents, 86 were from Tulsa, 9 were from Bowling Green, and 1 was from Providence. The second issue was that the items for intention were missed in the original survey release. This required another release, and only 10 responses were recorded for intention to return to make. Fortunately, this oversight was not fatal and the MBM did demonstrate a statistically significant relationship between intention and perceived behavioral control (Figure 5).

After collection, the raw data was first reviewed for general issues and typographical errors. Examples would include correcting the birth year of a respondent who only answered with a 2-digit year, instead of the requested 4-digit year; or removing the word “months” from a response asking how many months the respondent had been using a Fab Lab. Second, the reverse coded data was corrected. Reverse coded items were used on scales for creative role identity, openness to experience, attitude (with direct measures), and intention to return to make.

Next, the individual items were collated and averaged according to their respective element in the Maker Behavioral Model (MBM). For instance, the element workplace support is comprised of five items, which were averaged together for each valid response to form a composite score for workplace support for each respondent. Valid scores from every respondent were then averaged in order to generate an overall composite score for workplace support. This same process was repeated for every item and every element until overall composite scores were generated for each element.

Fourth, the descriptive statistics and Cronbach’s Alpha for reliability for each element were calculated. The descriptive statistics include the number of valid responses, the mean, the minimum, the maximum, the range, the standard deviation and the variance. Cronbach’s Alpha was calculated for each element, evaluated and then recalculated after 1 or more items were removed to increase the Alpha and improve reliability. One item each was removed from attitude (with beliefs), attitude (with direct measures), and subjective norm; which improved Cronbach’s Alpha from 0.947 to 0.951, 0.839 to 0.883, and 0.654 to 0.698, respectively.

Finally, Pearson’s Correlation Coefficients (r) were calculated for every element in the Maker Behavioral Model, including respondent age, the number of weeks since their last project completion, and the number of months they have been using Fab Lab. The resulting correlation coefficients demonstrate the relationships within the MBM and reveal potential levers for operating a successful Fab Lab.

5 Results

Variable	**M**	**SD**	**N**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1 Workplace Support	4.7364	.70241	88	*0.860*													
2 Creative Role Identity	5.4167	.84908	88	-.010	*0.752*												
3 Perceived Behavioral Control	4.6954	.54139	85	.253*	.254*	*0.681*											
4 Openness to Experience	4.6767	.65380	86	.294**	.499**	.389**	*0.742*										
5 Creative Self-Efficacy	5.0833	.61536	88	.175	.463**	.292**	.440**	*0.752*									
6 Attitude (Beliefs)	2.0155	1.48448	86	.010	.050	.104	.102	.142	*0.951*								
7 Attitude (Direct)	5.6897	.67589	87	.180	.210	.049	.059	.184	.028	*0.839*							
8 Perceived Tech Usefulness	5.2143	.88365	84	.222*	.048	.088	.015	.158	.012	-.027	*0.950*						
9 Perceived Tech Ease of Use	4.4177	.88933	83	.236*	-.116	.218	-.058	-.017	.102	.031	.338**	*0.878*					
10 Subjective Norm	3.8477	.77251	88	.269*	.073	.217*	.100	-.020	.042	.143	.148	.187	*0.698*				
11 Intention to Return to Make	4.733	0.78253	10	.249	.440	.746*	.258	.302	.060	.165	-.050	.194	.350	*0.962*			
12 Age (Years)	44.3	14.1	80	.100	-.167	-.048	-.063	-.181	-.026	.210	-.095	.075	-.070	-.154	-		
13 Weeks Since Last Project	6.2	9.7	80	.015	.110	.078	.081	-.098	-.099	.122	-.469**	-.107	-.065	.098	.133	-	
14 Months as a Fab Lab User	15.1	12.8	84	.148	-.018	.162	-.056	-.012	.171	-.020	-.102	.107	-.118	.397	.090	-.063	-

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2: Mean, Standard, N, and Pearson's Correlations

6 Discussion

The hypothesized Maker Behavioral Model (MBM) is shown in Figure 3 (note the key for current and future research). Causation within the relationships between the elements is hypothesized by the direction of the arrow. For instance, the MBM hypothesizes that creative role identity is a predictor of creative self-efficacy, which in turn predicts intention to return to make.

The hypothesized Maker Behavioral Model annotated with the Pearson's Correlation Coefficient data is shown in Figure 4 (the key for future and current research has been removed). Here only four relationships show both strength and statistical significance. For instance, creative role identity correlates within 95% to r=.463; or in other words, 21% of the variance in creative self-efficacy is explained by creative role identity, and vice versa. This compares to the even stronger relationship between perceived behavioral control and intention to return to make. This relationship correlates within 95% to r=.746, or 55% of the variance in intention to return to make is explained by perceived behavioral control. The same holds true, respective to their correlation coefficients and relationships, for openness to experience and ease of technology use.

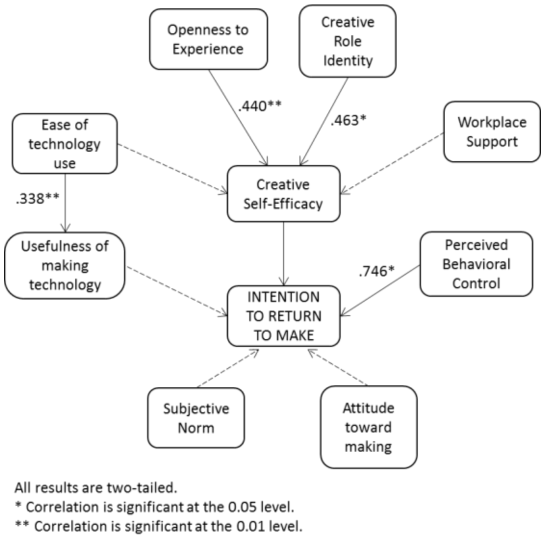

Figure 4 - Hypothesized Maker Behavioral Model (annotated with results)

What's notable is the lack of other relationships revealed in Figure 4 within the hypothesized MBM. Relationships without strength or significance are shown with dashed arrows. In some cases, there were strong relationships but there was no statistical significance. In these cases, it is further hypothesized that if the pool of respondents had been larger then statistical significance would have been attained and the MBM would be further demonstrated. In other cases, the relationships were too weak and simply may not exist as predicted.

There are two basic options for assessing the research results data and the MBM. The first is to map the data onto the hypothesized model; this was done in Figure 4. The second option is to re-evaluate the structure of the MBM using the relationships revealed in the data; this is done in Figure 5. The Maker Behavioral Model which is supported by the data looks different than the hypothesized model. Note that causation within the relationships between the elements is still hypothesized by the direction of the arrow, and must be further tested.

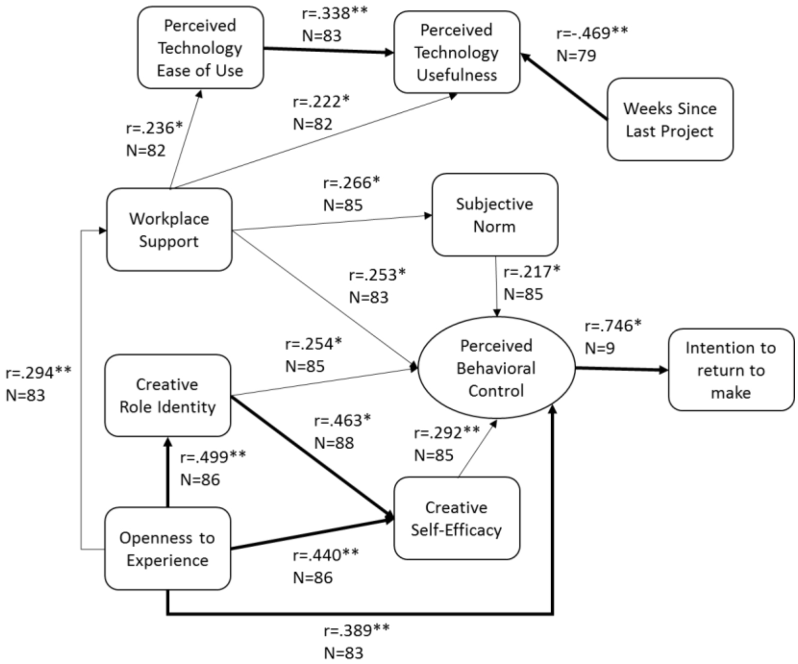

Figure 5 – Supported Maker Behavioral Model

Overall, the supported MBM in Figure 5 demonstrates the role that both an individual's characteristics and their social circumstances play in influencing an individual's intention to return to make in a Fab Lab. The individual's characteristics are rooted in creative self-efficacy, while their social circumstances are derived from both their experiences within the Fab Lab and their experiences with their own peer groups. Technology appears in the supported MBM but does not appear to contribute to a person's intention to return to make. Within this context, the analysis and explanation of the model begins with an examination of its validity.

The construct validity of the supported MBM was determined first through the assessment of content during survey development. The analysis for content validity was discussed in section 4. Second, construct validity was assessed through an examination of convergent validity with the previous research from which it is composed.

Namely, because the MBM is a combination of the Theory of Planned Behavior (TPB), Creative Self-Efficacy (CSE), and the Technology Acceptance Model (TAM), the validity of the MBM can be evaluated by a comparison of the data with those applicable theories. Beginning with the Theory of Planned Behavior, the three major antecedents to intention are attitude, subjective norm, and perceived behavioral control so shown in Figure 1. In this research, however, the data shows that only perceived behavioral control has any relationship to intention to return to make, and that neither attitude nor subjective norm play a role. It is hypothesized that the lack of these relationships is because the items for intention were not available in the first survey release (as noted in section 4), and that had the full cohort of responses included the items for intention that the relationships for attitude and subjective norm would've been supported. This, however, must be tested in future research. The presence of the relationship between intention and perceived behavioral control, fortunately, was both present and predicted; and so lends validity to the MBM based on previous research which demonstrates the same relationship.

Creative Self-Efficacy is predicted by creative role-identity, openness to experience, workplace support, leadership, and workplace creativity expectations (Bjornberg & Davis, 2015). As noted, leadership and workplace creativity expectations were omitted from the survey because they were not believed to be relevant to makers or Fab Labs. Of the three remaining antecedents, creative role-identity and openness to experience were likewise demonstrated to be antecedents to creative self-efficacy in the MBM (Figure 5). Workplace support, however, did not demonstrate a statistically significant relationship to creative self-efficacy even though it did have statistically significant relationships to other elements in the MBM. This lack of a relationship between workplace support and creative self-efficacy in this research may be due in part to the make-up of each of these constructs. Recall that in this research, workplace support is based on empathy (see Table 1). It was used because it was an existing and reliable scale which contained items consistent with social support within a social context. The scale for workplace support used in previous research may not have had this same emphasis, and so may not measure the same behavior as the scale used in this research. Likewise, the scale for creative self-efficacy used in this research was borrowed from previous research and may not have been identical to the scale used in Seo et al (2015).

More interesting than the missing relationship between workplace support and creative self-efficacy is the demonstrated relationship between workplace support and perceived behavioral control. Prima facie, this relationship is logical when considering that a supportive Fab Lab work environment should predict an individual's increased perception of their ability to control their making behavior. Conversely, it is worth consideration that a supportive Fab Lab work environment might also reduce negative perceptions, besides encouraging positive perceptions. The relationship between workplace support and perceived behavioral control is more convincing in this case, because an individual may perceive more control over their making behavior if there are fewer instances of Fab Lab workplace social toxicity. It is possible to imagine a Fab Lab user perceiving more control the less they are concerned about negative social experiences in a Fab Lab. It is further possible that there is a ceiling to workplace support within a Fab Lab, meaning that more workplace support may not result in more perceived control of making, but that a less supportive Fab Lab may result in less. The scale for workplace support did not contain items for negative support or workplace behaviors, and so this may be tested in future research.

Workplace Support has other demonstrated relationships to other features of the MBM, besides perceived behavioral control; including subjective norm and both perceived technology ease of use and usefulness. Its relationship to subjective norm is not surprising given that both elements are social measures which assess an individual's perceived relationship to others. The items in the scale for subjective norm are primarily concerned with determining how much of a maker's social circle supports making in general, their making behavior specifically, and finally how much of their social circle is composed of other makers. The positive relationship between workplace support and subjective norm may be explained, therefore, if one considers that greater workplace support within a Fab Lab may result in more social connections and peer relationships between makers which would, in turn, increase their measure for subjective norm. The relationships in Figure 5 between workplace support and technology ease of use and usefulness were not hypothesized by the MBM but are logical nonetheless. Even though the scales for perceived technology ease of use and usefulness do not contain items about receiving technical help through other Fab Lab users, this style of peer to peer "tech support" is common in a variety of social and work environments; and so helps explain this demonstrated relationship between workplace support and technology. The technology acceptance model also figures prominently in the MBM, in particular the elements perceived technology ease of use and usefulness. These are related in previous research (Teo et al, 2012); and, fortunately, also have a demonstrated relationship in this research.

Workplace support is also related to openness to experience in the MBM (Figure 5). In this relationship, openness to experience is a self-identified personality trait (Goldberg et al., 2006) whereas workplace support is a report of their perceptions or experiences of other's support within a Fab Lab. This relationship indicates that an individual's openness to experiences may influence and increase their perception of workplace support, perhaps because an open person may be less cynical about their encounters within the Fab Lab and therefore more likely to feel supported. This was not tested directly, however, and would be subject to future research.

The element Weeks Since Last Project (Figure 5) was not hypothesized in the MBM, but was featured in the research in order to understand its relationship to other elements in the MBM. The only statistically significant relationship that developed, however, was a strong negative correlation with perceived technology usefulness. This means that the more recently an individual completed a project, then the more useful they perceived Fab Lab technology; which is logical and also fits with the experiences that many people have had after they have recently used some piece of technology. Other relationships in the MBM involving weeks since last project bear examination in future research.

Perceived Behavioral Control (PBC) figures prominently in the MBM, especially since it is a direct antecedent to intention. There are six statistically significant relationships with Perceived Behavioral Control demonstrated in the model (Figure 5), namely openness to experience, creative self-efficacy, creative role identity, subjective norm, workplace support, and intention to return to make.

The relationship between openness to experience and PBC is potentially explained by the confidence and motivation that openness might offer a person and their perception of control. The scale for openness (see Table 1) contains items about a person's imagination, and attraction to new and abstract ideas. Someone with these qualities could very well approach their activities and interactions with greater confidence or energy, and so therefore express more perceived control of their behaviors, especially if they're makers. In short, imagination and new ideas, as expressed through openness, may hold special importance for PBC as it relates to makers, making and Fab Labs. Likewise, creative self-efficacy and creative role identity may have similar relationships with PBC as openness, in particular if one considers that the scales for each contain items for creativity, and that the scale for creative self-efficacy actually contains an item for confidence.

The relationship between subjective norm and PBC may be explained by the social support that a maker's peer group provides. The scale for subjective norm contains items about support for making, and the importance of making, and so would appear to enhance a maker's perceptions of behavioral control.

Finally, there is the relationship between PBC and Intention to Return to Make, which is the strongest positive relationship demonstrated in the MBM. This finding is consistent with previous research, and so helps validate this research in the context of making. And so the more an individual perceives they can control their making behaviors the more likely they are to return to make.

7 Recommendations

The Maker Behavioral Model has implications for Fab Labs. As noted earlier, by measuring a maker's intention to return to their Fab Lab to make again, the results of this research informs Fab Labs and similar operations of the particular keys or ingredients to increasing membership or usage, improving membership retention, and enhancing member satisfaction. To a certain extent, these recommendations are part of a business plan or strategy for building a sustainable Fab Lab which operates well into the future.

The supported maker behavioral model from Figure 5 is simplified into three essential pieces; social interactions, creative behavior and maker behavioral control shown in Figure 6.

- Social interactions are composed of workplace support and subjective norm.
- Creative behavior is composed of creative role identity, openness to experience and creative self-efficacy.
- Maker behavioral control is composed of perceived behavioral control.

This section will discuss each of the pieces of the simplified maker behavioral model, make basic recommendations, and then rate each one for the effort required to implement the recommendation and the potential impact it might have on a Fab Lab. See Table 3. This discussion will not include the role of technology because the results indicate they are not predictors of intention as was originally hypothesized.

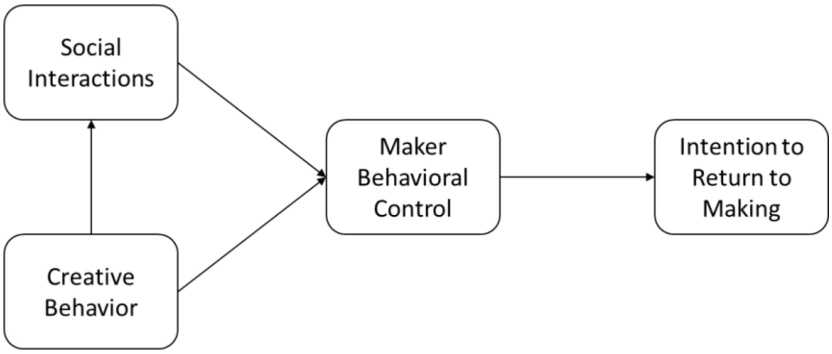

Figure 6: Simplified Maker Behavioral Model

RECOMMENDATION	EFFORT HIGH	EFFORT MEDIUM	EFFORT LOW	IMPACT HIGH	IMPACT MEDIUM	IMPACT LOW	PEARSON'S CORRELATION (r)
Social Interactions							
Subjective Norm (influencing peer groups)	X					X	0.217
Workplace Support (friendliness messaging)			X		X		0.253
Creative Behaviors							
Role Identity/Self-Efficacy (creativity classes)		X			X		0.292
Role Identity/Self-Efficacy (project highlights)		X			X		
Role Identity/Self-Efficacy (creativity messaging)			X		X		
Openness to Experience (cross training)	X			X			0.389
Openness to Experience (non-maker events)	X			X			
Openness to Experience (openness messaging)			X	X			
Maker Behavior Control							
Equipment	X			X			0.746
Software		X		X			
Training	X			X			
Mentoring			X	X			

Table 3: Impact v. Effort for Simplified Maker Behavioral Model

7.1 Social Interactions

Social interactions consist of a user's perception of both workplace support within their Fab Lab, and their subjective norm. Workplace support is loosely interpreted as how friendly, supportive or welcoming that people within a Fab Lab are to each other. Subjective norm is a measure of how much support for making that makers perceive from their friends and family. One is specifically internal to the Fab Lab environment, the other is generally external. Of the five antecedents of perceived behavioral control from Figure 5, subjective norm was the least strongly correlated. Workplace support had a slightly stronger correlation.

Subjective norm could be influenced in a Fab Lab environment by effecting the perceptions that maker's have of their peer group. This is likely quite difficult to do, however, unless there is significant overlap between the lab membership and the maker's peers. The most impact would be had if those groups were the same, and were therefore equally accessible to lab organizers for receiving influential media or messages. If there is little or no overlap, then changing the subjective norm likely requires high effort from lab leaders to communicate with separate groups, with low impact on outcomes.

Workplace support, however, presents opportunities for increased impact with low effort. In this case, messages can be focused on the lab users. Those communications could contain messages about the need for friendliness or other related values between users, and could also explain the positive relationship between support and a user's experience. Any other initiatives which seek the same outcome should also see similar results.

7.2 Creative Behaviors

Creative behaviors consist of creative role identity, creative self-efficacy, and openness to experience. Creative role-identity is defined as an internalized identity developed by an individual over time based upon expectations placed upon them by others. In short, it is how closely a person identifies themselves as creative. Creative self-efficacy is a belief describing individuals' beliefs that they are able to generate creative outcomes and solve problems creatively. Openness to experience is defined as the degree to which an individual is willing and confident to try new things (Bjornberg & Davis, 2015).

Fortunately, creativity is a skill which can be taught and learned (Sawyer, 2012), and so creative behaviors like creative role identity and creative self-efficacy are apt for influence with low to medium effort and high impact. These include:

- Teach classes or lectures on creativity and the creative process
- Highlight member projects through web & social media
- Develop lab messaging and media which explicitly recognizes & encourages creativity
- Tell users they are creative. Research indicates that suggesting that everyone can be creative will prompt more creativity (Sawyer, 2012).

That said, openness to experience is a personality trait that likely cannot be influenced directly or uniformly across an individual's entire spectrum of behaviors; but within the context of the Fab Lab, it would be worth the effort for a lab to encourage openness. This could be done in a number of ways with potentially high effort but also high impact:

- Encouraging cross training on machines and software
- Hosting non-maker events at the lab and encouraging makers to attend (book events, art shows, lectures, musical events, etc.)
- Help makers associate their lab as a hub of various activities & interests

7.3 Maker Behavioral Control

Maker behavior control is perceived behavioral control but within the context of making. It is a maker's perception of their ability to control their making behavior. In general, perceived behavioral control includes a wide range of characteristics, but for this research it includes subjects such as Fab Lab equipment, hardware or software resources, technical support and design ideas.

Maker behavioral control is a first order antecedent to a maker's intention to return to make, and therefore is an essential piece of any lab effort. Programs aimed at improving the quality, quantity or type of lab equipment; or enhancing training or mentoring services would involve high effort because of cost or implementation time but would likely be high impact. Supporting user design activities or ideation through improved creativity efforts, however, would require low to medium effort with the same high impact.

8 Future Work

Future work will focus on development of a survey for international English language speakers in order to broaden the test population and to persist with determining the reliability and validity of the maker behavioral model. The next analysis will also use Structural Equation Modeling to determine the directionality of the relationships in the MBM. Future research may include validation of the recommendations made in section 7.

9 Conclusions

There are several important conclusions to draw from this research.

- The maker behavioral model demonstrates that a maker's intention to make appears to consist of three characteristics, namely social interactions, creative behaviors, and maker behavioral control.
- Previous research indicates that some of these characteristics can be influenced to the benefit of Fab Labs and other maker organizations.
- Technology was not related to a maker's intention to return to make.
- Attitudes, both direct measures and beliefs, were not related to a maker's intention to return to make.
- A maker's perception of their ability to control their making behavior was the biggest predictor of maker intention.
- Creative behaviors were the second biggest predictors of maker intention.

Acknowledgement

The author would like to acknowledge the staff and membership from Fab Lab Tulsa, BiG Fab Lab, and AS220 for their participation in the survey. Jennifer Kisamore, Ph.D., Brigitte Steinheider, Ph.D., Chan Hellman, Ph.D. and Nathan Pritchett also deserve appreciation for their guidance in their roles on the thesis committee representing the University of Oklahoma – Schusterman Center.

References

Azjen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl, & J. Beckman, Action-Control: From Cognition to Behavior (pp. 11-39). Heidelberg: Springer.

Azjen, I. (2002). Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior. Journal of Applied Social Psychology, 32, 665–683.

Azjen, I. (2016). Icek Azjen Homepage. Retrieved from University of Massachusetts: http://people.umass.edu/aizen/

Besemer, S. (2006). Creating products in the age of design: How to improve your new product ideas. Stillwater, OK, USA: New Forums Press, Inc.

Bjornberg, N., & Davis, D. (2015). Creative self-efficacy: Meta-analytic examination of antecedents and creativity. Proceedings from Society for Industrial and Organizational Psychology. Philadephia.

Choi, J. N. (2004). Individual and contextual predictors of creative performance: The mediating role of psychological processes. Creativity Research Journal, 16, 187-199.

Choi, J. N. (2012). Context and creativity: The theory of planned behavior as an alternative mechanism. Social Behavior and Personality, 404(4), 681-692.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. Management Science, 35(8), 982-1003.

Dougherty, D. (2016, February 7). Fact Sheet - Maker Media. Retrieved from Maker Media: http://makermedia.com/press/fact-sheet/

Dubriwny, N., Pritchett, N., Hardesty, M., Hellman, C. (2016). Impact of Fab Lab Tulsa on student self-efficacy toward STEM education. Journal of , STEM Education, 17(2), 21-25.

Farmer, S. M., Tierney, P., & Kung-McIntyre, K. (2003). Employee creativity in Taiwan: An application of role-identity theory. Academy of Management Journal, 46(5), 618-630.

Gershenfeld, N. (2015, January 23). Conversations. Retrieved from www.edge.org: www.edge.org/conversation/neil_gershenfeld-digital-reality

Goldberg, L. R., Johnson, J. A., Eber, H. W., Hogan, R., Ashton, M. C., Cloninger, C. R., & Gough, H. C. (2006). The International Personality Item Pool and the future of public-domain personality measures. Journal of Research in Personality, 84-96. Retrieved from http://ipip.ori.org/

Greenslade, J. H., & White, K. M. (2005). Prediction of above-average participation in volunteerism: A test of the theory of planned behavior and the volunteers functions inventory in older Austrailian adults. Journal of Social Psychology, 145(2), 155-172.

Holden, H., & Rada, R. (2011). Understanding the influence of perceived usability and technology self-efficacy on teachers' technology acceptance. Journal of Research on Technology in Education, 43(4), 343-367.

IBM Corp. (2013). IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

Jugert, P., Eckstein, K., Noack, P., Kuhn, A., & Benbow, A. (2013). Offline and online civic engagement among adolescents and young adults from three ethnic groups. Journal of Adolescent Youth, 123-135.

King, K., Holbrook, T., Sanders, N., & Williams, P. (2014). Fab Lab Tulsa survey results: OKC+T Consulting. University of Oklahoma-Schusterman Center. Tulsa: Unpublished Academic Work.

Kuo, K.-M., Liu, C.-F., & Ma, C.-C. (2013). An investigation of the effect of nurses’ technology readiness on the acceptance of mobile electronic medical record systems. Medical Informatics & Decision Making, 13(88), 1-14.

Lassiter, S. (2015, May 30). What is a Fab Lab. Retrieved from Fab Foundation: http://www.fabfoundation.org/fab-labs/what-is-a-fab-lab/

Lee, J., Cerreto, F. A., & Lee, J. (2010). Theory of planned behavior and teachers' decisions regarding use of educational technology. Educational Technology & Society, 13(1), 152-164.

Penner, L. A. (2002). Dispositional and organizational influences on sustained volunteerism: An interactionist perspective. Journal of Social Issues, 58(3), 447-467.

Pritchett, N. (2014). Fab Lab Tulsa mission statement. Retrieved from Fab Lab Tulsa: www.fablabtulsa.com/mission/

Sawyer, R. K. (2012). The science of human innovation: Explaining creativity. Oxford: Oxford.

Seo, Y. W., Chae, S. W., & Lee, K. C. (2015). The impact of absorptive capacity, exploration, and exploitation on individual creativity: Moderating effect of subjective well-being. Computers in Human Behavior, 42, 68-82.

Teo, T. (2012). Examining the intention to use technology among pre-service teachers: An integration of the Technology Acceptance Model and Theory of Planned Behavior. Interactive Learning Environments, 20(1), 3-18.

Toft, M. B., Schuitema, G., & Thogersen, J. (2014). Responsible technology acceptance: Model development and application to consumer acceptance of smart grid technology. Applied Energy, 134, 392-400.

Tsai, C.-Y., Want, C.-C., & Lu, M.-T. (2011). Using the technology acceptance model to analyze ease of use of a mobile communication system. Social Behavior and Personality, 39(1), 65-70.