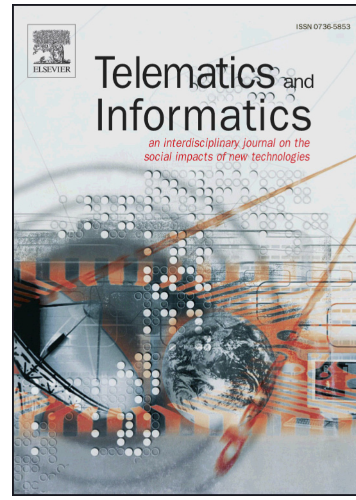
Accepted Manuscript



Understanding makerspace continuance: A self-determination perspective

Sang-Yeal Han, Jaeheung Yoo, Hangjung Zo, Andrew P. Ciganek

PII: S0736-5853(16)30477-4
DOI: http://dx.doi.org/10.1016/j.tele.2017.02.003
Reference: TELE 917

To appear in: *Telematics and Informatics*

Received Date: 26 September 2016
Revised Date: 13 January 2017
Accepted Date: 11 February 2017

Please cite this article as: Han, S-Y., Yoo, J., Zo, H., Ciganek, A.P., Understanding makerspace continuance: A self-determination perspective, *Telematics and Informatics* (2017), doi: http://dx.doi.org/10.1016/j.tele.2017.02.003

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Sang-Yeal Han
Graduate School of Innovation and Technology Management
Korea Advanced Institute of Science and Technology (KAIST)
291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
Email: sangyeal.han@kaist.ac.kr

Jaeheung Yoo
Software Policy Research Institute
22 Daewangpangyo-ro 712beon-gil, Bundang-gu, Seongnam 13488, Republic of Korea
Email: jayoo@spri.kr

Hangjung Zo[@]
School of Business and Technology Management
Korea Advanced Institute of Science and Technology (KAIST)
291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
Voice: +82-42-350-6311
Fax: +82-42-350-6339
Email: joezo@kaist.edu

Andrew P. Ciganek
College of Business and Economics
University of Wisconsin-Whitewater
800 West Main Street, Whitewater, WI 53190-1790
Voice: +1-414-517-5522
Email: ciganeka@uww.edu

Submitted to the *Telematics and Informatics* on September 26, 2016
Revised and resubmitted to the *Telematics and Informatics* on January 12, 2017

[@] Please direct future correspondence to the identified authors.

Vitae

Sang-Yeal Han is a Ph.D. candidate in the Graduate School of Innovation and Technology Management at the Korea Advanced Institute of Science and Technology (KAIST). Before joining KAIST, he was a manager in the Strategy Department at LG-ERICSSON. His research interests focus innovation strategy and entrepreneurship of start-ups as well as the impact of emerging technologies on business and society.

Jaeheung Yoo is a senior researcher at the Software Policy Research Institute in Korea. He received his doctoral degree in information systems from KAIST. He has published papers in the Asia Pacific Journal of Information Systems, the Information Journal, Online Information Review and has presented at several IEEE-sponsored international conferences. His research focuses on the human and social factors in information use through various information technologies such as social networking services, cloud computing, and new media platforms.

Hangjung Zo is an Associate Professor of Management Information Systems (MIS) in the School of Business and Technology management at KAIST. He gained his Ph.D. in MIS from the University of Wisconsin-Milwaukee. His research interests include web services and web-based systems, e-business, e-government, software engineering, business process management and IT strategy. His papers have appeared in IEEE Transaction on Systems Man and Cybernetics, Decision Support Systems, Journal of Business Research, Electronic Commerce Research and Applications, and Computers and Education, among others. He was the chair of the ICT Innovations and Progresses in Developing Countries Workshop at ICCIT 2009.

Andrew P. Ciganek is an Associate Professor of Information Technology at the University of Wisconsin-Whitewater. His research interests include examining the managerial and strategic issues associated with the decision-making process of innovative technologies. His research has appeared in the Journal of Business Research, Behaviour & Information Technology, Enterprise Information Systems, Online Information Review, Information Development, and Computers & Education, among others. He earned his Ph.D. in Management Science with a concentration in MIS from the University of Wisconsin-Milwaukee.

Understanding makerspace continuance: A self-determination perspective

Abstract

Makerspaces are informal physical spaces located in community settings or educational institutions where people immerse themselves in creative making. Makerspaces hold incredible potential for fostering essential skills needed for the future and are increasing in number worldwide. Previous research has identified many diverse makerspace initiatives and has demonstrated their potential, but few research has examined makerspace sustainability. Makerspace sustainability is a significant issue as diminished participation, activity, utilization, and retention limit its success. This study examines makerspace sustainability by understanding which factors influence makerspace continuance intention. This study proposes and empirically tests a conceptual framework based on self-determination theory to identify the motivations of makerspace users. An analysis of data collected from 121 South Korean makerspace users indicates that makerspace environmental support is significantly related to a makerspace user's basic psychological needs. Those psychological needs positively impact intrinsic motivation, which ultimately influences makerspace continuance intention. This research has several implications for academics while recommendations are proposed that have immediate application for practitioners which are informed by the study results.

Keywords: Makerspace; Environmental support; Innovation; Self-determination; Intrinsic motivation; Continuance intention

1. Introduction

Makerspaces are informal physical spaces located in community settings or educational institutions where people immerse themselves in creative making (Adams Becker et al., 2016). Makerspaces are generally open to the public and, similar to fitness centers, users usually pay fees to utilize shared resources (Baichtal, 2011). Makerspaces are places for people to turn their ideas into products and also benefit users by offering training and use of shared tools, such as digital fabrication equipment like three dimensional (3D) printers and laser cutters (Anderson, 2012; Kim and Shin, 2016). People with diverse personal interests (e.g., woodworking, electronics, and robotics) participate in makerspace activities to meet and collaborate.

Makerspaces hold incredible potential for fostering skills needed for the future and are increasing in number worldwide, locating in schools, museums, libraries, and other community spaces (Brady et al., 2014; Buerkett, 2014; Hlubinka et al., 2013; Sheridan et al., 2014). People develop problem-solving and critical thinking skills at a makerspace while engaged in a variety of hands-on activities (Kurti et al., 2014; Stacey, 2014). Makerspaces facilitate learning which transitions people from being users of knowledge to knowledge creators. Makerspaces are venues that support technology innovation and entrepreneurship (Fox, 2014; Hatch, 2013; Lindtner, 2014; Lindtner et al., 2014; Stacey, 2014). These are all essential skills that prepare individuals to face new global challenges and reflect the contemporary learning people both desire and need (AAC&U, 2007).

Previous research has identified many diverse makerspace initiatives and has demonstrated their potential (e.g., Fox, 2014; Lindtner et al., 2014; Oliver, 2016a), but few research has examined makerspace sustainability. Chinese makerspaces have experienced challenges maintaining individual membership despite a major increase in the number of makerspaces in China (Saunders et al., 2016). The average number of daily makerspace users was found to be much lower than what was expected in South Korea (Song, 2015). Makerspace sustainability is a significant issue as diminished participation, activity, utilization, and retention limit its reach, success, and fuel concerns of a makerspace bubble bursting (Saunders et al., 2016).

This study addresses makerspace sustainability by understanding which factors influence makerspace continuance intention. This study proposes and empirically tests a conceptual framework based on self-determination theory (SDT) to identify the motivations of makerspace users. The study results present useful insights and offer guidelines for specific makerspace elements that can be improved or reinforced to promote continued makerspace usage.

The remainder of this manuscript is organized as follows. Section 2 of this paper reviews the theories that are the foundation of the research model. The research model and hypotheses are developed in Section 3. Section 4 presents the research methods. The results are presented in Section 5. Section 6 discusses the study results including the relevance that this research has for researchers and practitioners. Section 7 offers concluding remarks as well as study limitations, which reveal opportunities for future research.

2. Theoretical background

2.1. Self-determination theory

SDT is a macro theory to illuminate the dynamics of motivation, psychological needs, and well-being in a social-environmental context (Deci and Ryan, 1985; Ryan and Deci, 2000). SDT has been widely used in the literature on human motivation (Hagger and Chatzisarantis, 2007) and gained empirical support in a variety of fields including education (Hew and Kadir, 2016a, b; Standage et al., 2005; Zhang et al., 2011), health care (Russell and Bray, 2010; Ryan et al., 2008), psychopathology (Bureau et al., 2012; Chen et al., 2015), physical exercise (Hagger and Chatzisarantis, 2007; Standage et al., 2005), and video games (Peng et al., 2012; Rigby and Ryan, 2011).

SDT captures several stimuli which inspire specific courses of action and distinguishes between different types of motivation: amotivation, intrinsic motivation, and extrinsic motivation (Deci and Ryan, 1985). Amotivation is the least self-determined type of motivation and is characterized by a lack of an intention to behave. Extrinsic motivation refers to behaviors that are carried out in order to obtain outcomes separate from the achieved task. Examples of extrinsic motivation are monetary incentives, evaluations, reward and punishment systems, and social pressures. Intrinsic motivation is the most self-determined type of motivation where an individual finds motivation within the domain of the task itself. Intrinsic rather than extrinsic motivation affects the decision-making process in situations where an individual can independently decide their behavior (Deci and Ryan, 1985).

The Basic Psychological Needs Theory (BPNT; Deci and Ryan, 2000; Roca and Gagné, 2008; Ryan, 1995) is a central tenant of SDT and proposes three psychological needs that impact motivation: autonomy, competence, and relatedness. Autonomy is a desire to possess the freedom of choice to determine actions through one's own volition (Gagné and Deci, 2005). Competence is the need for an individual to believe in one's own capabilities (Yoon and Rolland, 2012), which is a concept similar to self-efficacy (Bandura, 1986). Lastly, relatedness is the desire to feel included with others throughout one's activities (Ryan and Deci, 2000). Satisfaction of the three psychological needs is essential for promoting intrinsic motivation and psychological well-being (Deci and Ryan, 2000). Conversely, a lack of basic need satisfaction decreases intrinsic interest and causes negative outcomes like ill-being and psychopathology (Deci and Ryan, 2000; Vansteenkiste and Ryan, 2013).

SDT argues that contextual support can aide autonomy, competence, and relatedness fulfillment. Contextual support are external events and conditions offered while participating in an activity that satisfies a person's psychological needs (Chen and Jang, 2010; Deci et al., 1991). Higher levels of autonomy can be achieved when a person is provided with choices, recognition, and self-determination opportunities through contextual support (Deci et al., 2001; Williams and Deci, 1998). A number of studies concerning educational practices reveal that autonomy-supportive teachers have had a positive and significant influence on students' intrinsic motivation, curiosity, and desire to be challenged (e.g., Deci et al., 1981; Flink et al., 1990; Ryan and Grolnick, 1986). Peng et al. (2012) established that competence-supportive game features (e.g., opportunities to acquire new skills, optimal challenges through dynamic difficulty adjustment) enhance a players' competence. Standage et al. (2005) found that students who perceived relatedness support (e.g., encouragement for collaboration from a teacher) experienced relatedness. Additionally, Niemiec and Ryan (2009) and Zhang et al. (2011) report that students experience higher levels of intrinsic motivation when they are offered contextual support designed to fulfill autonomy, competence, and relatedness.

A makerspace is a learning, making, and socializing space where participants are primarily motivated intrinsically to use a makerspace in a voluntary manner (Milne et al., 2014; Moilanen, 2012; Sleigh et al., 2015). An understanding of the contextual factors that affect a makerspace user's basic psychological needs is an important issue for those individuals interested in promoting makerspace sustainability. This study uses SDT to hypothesize that makerspace environmental support acts as contextual support and positively fulfills a user's basic psychological needs, which enhances their intrinsic motivation and continuance intention toward makerspaces.

2.2. Makerspace environmental support

Makerspaces are physical spaces where people can experience new tools and technologies (e.g., 3D printers, open source designs), and have started to receive interest, curiosity, and attention from the general public (Kostakis et al., 2015). No consensus exists on a definition of a makerspace (Davee et al., 2015). Maker Media first coined the term makerspace in 2005 and described it generically as, "A collection of tools does not define a makerspace. Rather, we define it by what it enables: making" (Hlubinka et al., 2013, p. 1). Oliver (2016a, p. 160) defined a makerspace as, "a physical space with shared resources to pursue technical projects of personal interest with the support of a maker community." The Educause Learning Initative (2013, p. 1) defined a makerspace as, "a physical location where people gather to share resources and knowledge, work on projects, network, and build. Makerspaces provide tools and working room in a community environment." Sheridan et al. (2014, p. 505) described makerspaces as, "informal sites for creative production in art, science, and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products." Makerspaces are physical spaces that fundamentally support its users to pursue projects.

Makerspaces have three supportive roles which allow users to easily experience and continuously participate in makerspaces: technical, economic, and social support. A makerspaces' primary role is as a technical workshop (Hlubinka et al., 2013; Litts, 2015; Oliver, 2016b). Technical support for makerspaces is the availability of space, tools, materials, training programs, and on-the-spot assistance provided for users to pursue projects. Makerspaces should be equipped with diverse tools, sufficient materials, and enough space to work on projects in an autonomous and safe manner.

Economic support is the provision of low-cost access to makerspace resources. Self-arrangement of a production environment requires a significant amount of up-front costs and continual expenditures for maintenance (Burke, 2014). Makerspaces secure tools, resources, and spaces while dispersing the cost among users, similar to the membership fee model of fitness centers (Baichtal, 2011). Makerspaces alternatively secure funds and donations from government agencies, organizations, and schools to reduce the costs for users (Fontichiaro, 2016; Maker Education Initiative, 2015).

Social support for makerspaces is peer learning opportunities experienced through interaction and cooperation among users, which generates a creative learning platform (Baichtal, 2011; Hlubinka et al., 2013; Milne et al., 2014). The makerspace community consists of people with a desire to learn useful skills from each other and cooperate with other like-minded individuals (Burke, 2014; Milne et al., 2014). Makerspaces can help match mentors with users who need guidance (Hlubinka et al., 2013) and facilitate peer learning opportunities as well as social events like group sessions where project feedback is solicited and received (Burke, 2014; Hlubinka et al., 2013).

3. Research model and hypotheses

This study proposes a research model based on the above theoretical background (see Figure 1). The research model hypothesizes that makerspace environmental support directly influences a user's basic psychological needs, like autonomy, competence, and relatedness. A user's psychological needs enhance their intrinsic motivation, which ultimately affects makerspace continuance intention.

<Insert Figure 1 about here>

3.1. Technical support of makerspaces and user's basic psychological needs

The technical support makerspaces provide may influence autonomy and competence by providing resources necessary for project completion. Autonomy entails "acting with a sense of volition and having the experience of choice" (Gagné and Deci, 2005, p. 333). Technical support may enhance a user's feelings of autonomy by providing a wide range of options (e.g., tools, materials, spaces, training courses) resulting in the selection of specific, preferred alternatives (Burke, 2014). Technical training programs exist for users to choose of their own volition to acquire the requisite knowledge to complete their projects. Competence is "an individual's belief that he or she can perform a particular task or behavior effectively" (Yoon and Rolland, 2012, p. 1135). The technical support makerspaces provide can improve a user's capabilities from the acquisition of new skills and learning suitable for their specific project. Users will have increased feelings of confidence as they are able to achieve desired results after obtaining new and relevant knowledge. This study hypothesizes:

H1. *The technical support makerspaces provide will have a positive influence on a user's feelings of autonomy.*

H2. *The technical support makerspaces provide will have a positive influence on a user's feelings of competence.*

3.2. Economic support of makerspaces and user's basic psychological needs

The economic support makerspaces provide may influence autonomy and competence by helping to reduce the cost of participation. Several trials are usually necessary to correct errors or mistakes during the prototyping process. These trials are termed "productive failures" as they allow users to attempt new and different methods to improve prototype development (Hlubinka et al., 2013; Kurti et al., 2014). Each prototype failure incurs an additional cost for re-trial. The economic support makerspaces provide reduces the burden of such costs, which acts as a control over a user's projects. A reduced cost burden increases a user's perception of the freedom they have in their projects from an ability to test various tools or select different courses of action to achieve goals (Burke, 2014). The economic support makerspaces provide may increase feelings of autonomy. Users can spend more time with tools and materials with a reduced cost burden, which improves speed, precision, and capabilities (Hlubinka et al., 2013). These improvements may enhance a user's feelings of competence to attain desired outcomes effectively. This study hypothesizes:

H3. *The economic support makerspaces provide will have a positive influence on a user's feelings of autonomy.*

H4. *The economic support makerspaces provide will have a positive influence on a user's feelings of competence.*

3.3. Social support of makerspaces and user's basic psychological needs

The social support makerspaces provide may influence a user's need of competence and relatedness by providing opportunities to learn from peers. Makerspaces typically hold social events, such as a showcase or workshop where users share their projects and exchange feedback openly with peers or mentors (Hlubinka et al., 2013). Users can learn skills from peer learning, leverage the experience of others, and may find solutions to problems within their projects. The social support makerspaces provide may increase a user's confidence in problem solving and positively influence feelings of competence. Feelings of relatedness (i.e., "the need to feel belongingness and connected with others" (Ryan and Deci, 2000, p.73)) may also increase as users network with peers and attain recognition from respected individuals. This study hypothesizes:

H5. *The social support makerspaces provide will have a positive influence on a user's feelings of competence.*

H6. *The social support makerspaces provide will have a positive influence on a user's feelings of relatedness.*

3.4. User's basic psychological needs, intrinsic motivation, and continuance intention

The fulfillment of basic psychological needs, including autonomy, competence, and relatedness, directly precedes intrinsic motivation (e.g., Hollembeak and Amorose, 2005; Neys et al., 2014). Levels of intrinsic motivation should intensify as the psychological needs of makerspace users are fulfilled by the support a makerspace provides. Makerspace users gain intrinsic motivation as they feel increased levels of freedom from the activities they engage in (fulfillment of autonomy), acquire and accumulate skills and knowledge (fulfillment of competence), and interact with other users (fulfillment of relatedness). This study hypothesizes:

H7. *Autonomy will have a positive influence on a makerspace user's intrinsic motivation.*

H8. *Competence will have a positive influence on a makerspace user's intrinsic motivation.*

H9. *Relatedness will have a positive influence on a makerspace user's intrinsic motivation.*

Intrinsic motivation is a significant antecedent of a user's intention to use a technology (Davis et al., 1992; Roca and Gagné, 2008). Intrinsic motivation can be the strongest motivator to continue activities, particularly in voluntary use contexts (Yoo et al., 2014). Individuals that are mandated to use a specific system will continue to use that system strictly for utilitarian purposes. Hedonic factors become more important when individuals have the control to select which system to use among available alternatives (Kang et al., 2009). Users voluntarily participate in a makerspace environment. Intrinsic motivation should positively influence a user's self-determined choice of continuous usage. This study hypothesizes:

H10. *A makerspace user's intrinsic motivation will have a positive influence on their continuance intention towards makerspaces.*

4. Research method and analysis

4.1. Measurement items

A survey was conducted to collect data for empirically verifying the proposed research model. All survey items were drawn from prior literature. The measurement items examining the support provided by makerspaces were developed from literature concerning the concept and development of makerspaces (Baichtal, 2011; Burke, 2014; Hlubinka et al., 2013; Litts, 2015; Milne et al., 2014; Oliver, 2016b). The measurement items examining autonomy, competence, and relatedness were adapted from the Basic Need Satisfaction Scale in General (Gagné, 2003). The measurement items examining levels of intrinsic motivation were adapted from the Intrinsic Motivation Inventory (Ryan et al., 1983). The measurement items utilized to examine continuance intention were adapted from Bhattacherjee (2001a, 2001b). Table 1 lists the measurements of each variable. All measurement items employed a 7-Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree").

<Insert Table 1 about here>

4.2. Data

Online and offline surveys were utilized to collect data from makerspace users in South Korea. The initial questionnaire was pretested and refined by 14 makerspace users and 3 researchers. The online survey participants were solicited from 12 popular makerspace online communities over a period of two weeks (February 17 to March 2, 2015). Surveys were solicited offline at makerspaces when no additional online surveys were collected after repeated reminders. Makerspace administrators approved solicitation of makerspace users to complete offline surveys on the condition that their users would not be inconvenienced. A relatively few offline surveys were collected due to the extensive time, effort, and care necessary to solicit offline survey samples.

A minimum of 100 samples were required to ensure study robustness using a partial least squares (PLS) analysis of ten structural paths following Hair et al.'s (2011, p. 144) rule of thumb that the number of observations be "ten times the largest number of structural paths directed at a particular latent variable in the structural model." 132 total samples were collected at the end of the data collection period (113 online and 19 offline surveys). 11 incomplete surveys were discarded resulting in a final sample size of 121, which exceeded the minimum sample size required for this study (103 online and 18 offline surveys). No significant differences existed in sample characteristics and data analysis between the usable online and offline samples (n = 121) and the usable online samples (n = 103). The study reports the combined results of the usable online and offline samples (n = 121).

The proportion of men participating in this study was greater than women (68% male, 32% female). The relatively high proportion of male participation is similar to the gender ratio reported in other makerspace studies. 77% of makerspace survey respondents in China were male in Saunders et al. (2016). 80% of makerspace survey respondents in the United Kingdom were male in Sleigh et al. (2015). A skewed gender representation among makerspace users has also been observed in the United States. Guthrie (2014) and Faulkner and Mcclard (2014) acknowledge an underrepresentation of women in makerspaces in the United States. The unbalanced gender ratio response rate in this study is consistent with the response rate in other makerspace studies and may accurately reflect the gender composition of the makerspace user population.

The majority of respondents (77%) were between 21-40 years of age with the average education equal to or above college level. Most of the highly educated respondents (87%) had majored in science or creation-related fields before they started using makerspaces (i.e., natural sciences, engineering, or related to art and design). 73% of respondents indicated that they had some knowledge of fabrication before their first makerspace visit (e.g., electronics, computer engineering, design, and/or craft skills). 85% of the respondents reported utilizing makerspaces for more than one month while 60% reported utilizing makerspaces for more than four months.

<Insert Table 2 about here>

5. Results

5.1. Measurement model

A PLS technique was employed with SmartPLS 3.0 to test the internal consistency reliability, convergent validity, and discriminant validity (Gefen and Straub, 2005). A PLS method places minimal restrictions on the measurement scales, sample size, and residual distributions (Hsiao, 2011). This study applied a bootstrapping technique by resampling 5000 times to test the significance of the model against the 121 cases.

The Cronbach's alpha, Dijkstra-Henseler's rho (ρA), and composite reliability (CR) were examined to determine internal consistency reliability. The minimum values of Cronbach's alpha, ρA, and CR were 0.724, 0.732, and 0.844 respectively (see Table 3). Each value exceeded the conventional threshold of 0.7, indicating good reliability (Henseler et al., 2016).

Convergent validity was examined by investigating the value of the average variance extracted (AVE) and running a factor analysis. The value of AVE is recommended to be no less than 0.5 and each latent variable's factor loading greater than 0.7 to demonstrate convergent validity (Gefen and Straub, 2005). The AVE value was lowest for the competence variable (0.603), but still exceeded the threshold value of 0.5 (see Table 3). The factor loadings of latent variables were all greater than 0.7. Convergent validity was demonstrated among the latent variables examined in this study (see Table 4).

Discriminant validity assesses whether variables are clearly identifiable. Gefen and Straub (2005) argue that a variable's discriminant validity is acquired if the square root of the AVE for each variable is greater than the correlations between the variable and other variables. The study results show that the value of cross-loading estimates for the latent variables was significantly greater than the other model variables (see Table 5). The

Hetero-Trait Mono-Trait Ratio (HTMT) criterion was also employed to assess discriminant validity. Discriminant validity was satisfied as all HTMT ratios were below the recommended threshold of 0.85 (Henseler et al., 2015) (see Table 6). The model's explanatory power (R^2) to the destination variable, continuance intention, was 0.424.

<Insert Table 3 about here>
<Insert Table 4 about here>
<Insert Table 5 about here>
<Insert Table 6 about here>

5.2. Hypotheses tests

The structural model results illustrate that 8 out of 10 hypotheses were supported (see Figure 2). The relationship between technical support and competence as well as between social support and competence were not supported. The data confirms that the three environmental supporting roles provided by makerspaces fulfilled basic psychological needs. Technical support (β = 0.341, *t*-value = 3.371, $p < 0.001$) and economic support (β = 0.338, *t*-value = 4.196, $p < 0.001$) each displayed a significant impact on autonomy. Economic support displayed a significant influence on competence (β = 0.520, *t*-value = 5.989, $p < 0.001$) while social support displayed a highly significant effect on relatedness (β = 0.620, *t*-value = 10.320, $p < 0.001$).

The fulfillment of basic psychological needs positively influenced a user's intrinsic motivation, which positively impacted continuance intention. All three psychological needs (i.e., autonomy, competence, and relatedness) were positively associated with intrinsic motivation. Competence exhibited the highest level of influence (β = 0.350, *t*-value = 4.639, $p < 0.001$), followed by relatedness (β= 0.303, *t*-value = 4.344, $p < 0.001$), and autonomy (β = 0.289, *t*-value = 3.571, $p < 0.001$). Intrinsic motivation displayed a highly significant effect on a user's continuance intention (β = 0.651, *t*-value = 12.236, $p < 0.001$).

<Insert Figure 2 about here>

The study's research model consisted of four mediator variables (autonomy, relatedness, competence and intrinsic motivation). A mediation analysis was conducted following the procedure proposed by Nitzl et al. (2016) to confirm the intermediating role in the relationships between the independent and dependent variables. The mediation analysis for the four mediators was performed using 5000 bootstrap re-samples, which generated t-statistics and confidence intervals (CIs). All mediating effects were significant and the 95% bias-corrected CIs did not include zero, which supports the significance of the mediating effects (Nitzl et al., 2016) (see Table 7).

<Insert Table 7 about here>

6. Discussion

6.1. Key findings

The results illustrate several interesting findings. Economic support had the most influence among the three environmental support factors. Makerspace environmental support is essential as it allows users to easily experience and continuously participate in makerspaces. Economic support satisfied both autonomy and competence and was the only environmental support factor that satisfied competence. Competence had the greatest influence on intrinsic motivation and emphasizes the importance of a makerspace user's confidence in their abilities to accomplish their projects.

Technical support was positively associated with autonomy. Makerspace technical support fulfilled a user's need for autonomy and is consistent with the results of previous studies evaluating the role of context (Gagné et al., 2003; Peng et al., 2012; Standage et al., 2006). Technical support did not affect a user's need for competence. A possible explanation is that makerspace training programs may not properly meet a user's demand for knowledge. For example, South Korean makerspaces lack skilled staff members with in-depth expertise in the usage of digital fabrication tools (MSIP, 2015). The majority of participants in this study possess knowledge of fabrication (73%) and have an academic background in engineering or art (87%) (see Table 2). Advanced makerspace training programs may need to be offered to increase feelings of competence among continual makerspace users, who are generally not novices in their fields of expertise.

Social support had a significant effect on relatedness, which is a result consistent with previous studies (Sheldon and Filak, 2008; Standage et al., 2005; Zhang et al., 2011). Social support had no effect on competence, which was unexpected and counter to expectations that peer learning would fulfill this requirement. A possible explanation for this result might be due to a knowledge-sharing issue among users at makerspaces. Kwon and Kim (2014) reported that knowledge-sharing and co-working is sparse at South Korean makerspaces. A relatively low rate of makerspace peer learning and knowledge-sharing exhibited in this study might diminish feelings of competence among continual makerspace users.

Basic psychological needs, facilitated by makerspace environmental support, exhibited a positive relationship with intrinsic motivation. This result is consistent with SDT (Deci and Ryan, 1985, 1991; Ryan and Deci, 2000, 2002). Competence had the greatest impact on intrinsic motivation while intrinsic motivation influenced continuance intention. This result is consistent with previous research (Heijden, 2004; Sørebø et al., 2009; Standage et al., 2003). 42% of continuance intention was explained in this study by intrinsic motivation (R^2 = 0.424). This result demonstrates that when makerspace users fulfill their need for competence, they will gain higher intrinsic motivation and ultimately have a stronger intention for continued usage.

6.2. Implications

This study has theoretical implications that inform the current literature and may guide future studies. This study demonstrates that SDT is a useful research framework to examine makerspaces, which are globally growing platforms for education, innovation, and entrepreneurship (Hlubinka et al., 2013; Saunders et al., 2016; Stacey, 2014). SDT is a relatively robust theory that postulates that social context can promote need satisfaction and subsequent motivation, which has been tested in a variety of contexts (e.g., online community, e-learning, gaming, physical exercise, work place). This study demonstrates the importance of makerspace contextual support to fulfill psychological need satisfaction and enhance intrinsic motivation. This result is meaningful as it extends the results of previous SDT research into the domain of makerspaces.

This study extends literature on makerspaces by empirically validating arguments from previous qualitative studies about the motivations of makerspace users. Previous studies have primarily focused on investigating makerspaces following a qualitative research approach, such as with case studies or user interviews. This study provides empirical evidence on makerspace environment effectiveness to support and promote a user's intrinsic motivation, based arguably on the most influential motivation theory (Hagger and Chatzisarantis, 2007). Future studies must continue to examine the relationship between intrinsic motivation and other outcomes associated with makerspace sustainability, like persistence, creativity, and performance.

This study also offers several insights relevant for makerspace practitioners. A greater understanding of individuals that continually use makerspaces is essential as these users likely will be leaders that can best motivate others to participate in makerspaces. Current levels of makerspace technical and social support are not effective enough to facilitate the psychological need of competence, which is the strongest factor affecting intrinsic motivation. Technical support for makerspaces must reflect the interests of their users. The makerspace tools, materials, and training programs available must mirror the needs and capabilities of the environment that the makerspace is physically located. Fostering partnerships with schools or companies can be a useful way to supplement specialized tools, materials, educational resources, and expertise for makerspace users. For example, a 3D printer company may partner with a local makerspace and offer open seminars to educate makerspace users about its products and services. This type of partnership benefits the makerspace by providing essential technical support but also the 3D printer company by facilitating corporate social responsibility and enhancing the skillsets of the community and prospective workforce.

Makerspace operators must intervene and facilitate peer learning and collaboration on projects to improve the effectiveness of social support on competence. Makerspace users freely come and go and the types of projects that users work on are heterogeneous. An emphasis on recruiting quality participants and not simply securing large quantities of participants is preferred to foster the right connections to sustain strong collaborations. Quality participants include individuals that share similar interests and areas of expertise which can be recruited at conferences, workshops, or cooperative learning events hosted by makerspaces that target specific interests (e.g., woodworking, electronics, robotics, etc.).

Economic support must be a priority for makerspaces to make users feel greater autonomy and competence in their projects. Greater autonomy and competence will positively influence intrinsic motivation and ultimately continuance intention. Economic support should not solely be derived from user fees, which may be perceived by users as a loss of control and autonomy over their project. Practitioners should seek economic support from a variety of sources as appropriate, including user fees, corporate and community donations, and external grants. Makerspaces benefit entire communities as they foster skills that prepare individuals to face new global challenges and reflect the contemporary learning people both desire and need. Makerspaces should establish business models which incorporate their communities and include external funding as a source of economic support (Fontichiaro, 2016; Litts, 2015). Both public and private funding sources as well as non-traditional avenues like crowdfunding sites (i.e., Kickstarter.com and Indiegogo.com) can have an important role in sustaining makerspace economic support (Fontichiaro, 2016; Oliver, 2016b).

7. Conclusions

This study examined makerspace sustainability by understanding which factors influence makerspace continuance intention using a research model based on SDT. Multiple antecedents of makerspace continuance intention were identified and empirically tested in a research model using survey data from South Korean makerspace users. The study results support the theoretical tenets of SDT. Makerspace environmental support was significantly related to a makerspace user's basic psychological needs. Makerspace technical support was strongly associated with autonomy, and makerspace economic support was strongly associated with autonomy and competence, while makerspace social support was strongly associated with relatedness. Makerspace technical and social support unexpectedly were not associated with competence. As psychological needs were fulfilled, they significantly influenced intrinsic motivation, which ultimately influenced makerspace continuance intention.

The study results must be understood acknowledging its limitations. The data collected and used in the study analysis was cross-sectional. Future studies should collect and analyze longitudinal data to observe possible dynamism in a user's continuance intention. Relationships among the study variables may change as makerspaces improve environmental support, which would be fascinating to capture and observe. This study collected data from a relatively modest sampling of makerspace users in South Korea. The study participants were all makerspace users and appropriate to survey for an examination of makerspace continuance intention. The study results should still offer a useful reference for communities worldwide that are planning their own makerspaces. Future studies should consider soliciting participants from diverse populations to help generalize the current study findings. Roughly 42% (R^2=.424) of the variance in makerspace continuance intention was explained by the research model. Additional factors exist that affect a makerspace user's continuance intention. Previous studies have suggested that switching costs and social influence may also impact continuance intention (e.g., Burnham et al., 2003; Venkatesh et al., 2003). Future studies should explore additional factors to generate a more complete understanding of which factors influence makerspace continuance intention.

Acknowledgment

This work is carried out by the project for supporting university centers for entrepreneurship, funded by the Korea Small and Medium Business Administration (Grants No. N04140205-15).

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Table 1. Measurement of research variables

Variables	Item	Measurement items	Reference
Technical Support (TS)	TS1	The makerspace offers sufficient manufacturing spaces for my creation activity.	Hlubinka et al. (2013) Litts (2015) Oliver (2016b)
	TS2	The makerspace provides various tools, in sufficient quantity, for my creation activity.	
	TS3	The makerspace has a sufficient quantity of the various materials needed for my creation activity.	
	TS4	The makerspace offers various training courses and on-the-spot support.	
Economic Support (ES)	ES1	I am able to save costs on space by using the makerspace.	Baichtal (2011) Burke (2014)
	ES2	I am able to save costs for tools by using the makerspace.	
	ES3	I am able to save costs for materials by using the makerspace.	
	ES4	I am able to save costs on training courses by using the makerspace.	
Social Support (SS)	SS1	The makerspace supports the collaboration among peers.	Hlubinka et al. (2013) Burke (2014) Milne et al. (2014)
	SS2	The makerspace provides aids to share knowledge and skills among peers.	
	SS3	The makerspace supports the communication among peers.	
	SS4	The makerspace provides chances to meet experts and mentors.	
Autonomy (AUT)	AUT1	I feel like I am free to decide for myself what to make at the makerspace.	Gagné (2003)
	AUT2	At the makerspace, I can express my thoughts and opinions regarding creation.	
	AUT3	At the makerspace, there is much opportunity for me to decide what and how to make my projects.	
Competence (COM)	COM1	I feel confident that I can do my project well at the makerspace.	Gagné (2003)
	COM2	I have been able to learn interesting new skills at the makerspace.	
	COM3	Most days I feel a sense of accomplishment from what I do at the makerspace.	
	COM4	I feel capable of utilizing creation tools at the makerspace.	
Relatedness (REL)	REL1	I like the people I interact with at the makerspace.	Gagné (2003)
	REL2	I get along with the people I come into contact with at the makerspace.	
	REL3	There are many people at the makerspace that I am close to.	
	REL4	People at the makerspace are generally pretty friendly towards me.	
Intrinsic Motivation (IM)	IM1	I enjoy creation activities very much at the makerspace.	Ryan et al. (1983)
	IM2	Creation activities at the makerspace are fun to do.	
	IM3	I would describe creation activities at the makerspace as very interesting.	
Continuance Intention (CI)	CI1	I will frequently use the makerspace in the future.	Bhattacherjee (2001a, 2001b)
	CI2	I intend to continue using the makerspace rather than discontinue its use.	

Table 2 Respondent characteristics

Characteristics	Respondents (n=121) Number	Percentage
Gender		
Male	82	68
Female	39	32
Age		
16-20	16	13
21-30	65	54
31-40	28	23
41+	12	10
Education		
Less than high school	11	9
College student	42	35
College Graduate	46	38
Advanced degree	22	18
Major		
Humanities	16	13
Engineering	85	70
Art and Design	20	17
Experience period of makerspace		
Less than 1 month	18	15
Between 1~4 months	30	25
Between 4~8 months	32	26
Between 8~12 months	25	21
Over 12 months	17	14
Having knowledge of fabrication before using makerspace		
Yes	88	73
No	33	27

Table 3 Research variable measurements

	Cronbach's alpha (>0.7)	ρA (>0.7)	CR (>0.7)	AVE (>0.5)
TS	0.843	0.846	0.895	0.681
ES	0.841	0.840	0.893	0.677
SS	0.852	0.855	0.900	0.693
AUT	0.724	0.732	0.844	0.643
COM	0.782	0.798	0.858	0.603
REL	0.920	0.921	0.943	0.807
IM	0.906	0.906	0.941	0.843
CI	0.905	0.905	0.955	0.913

Table 4 Cross-loadings

	TS	ES	SS	AUT	COM	REL	IM	CI
TS1	**0.804**	0.256	0.432	0.410	0.207	0.366	0.240	0.257
TS2	**0.843**	0.348	0.397	0.372	0.233	0.369	0.288	0.322
TS3	**0.885**	0.451	0.517	0.430	0.260	0.324	0.326	0.346
TS4	**0.763**	0.343	0.496	0.385	0.250	0.358	0.363	0.329
ES1	0.238	**0.819**	0.204	0.392	0.449	0.194	0.538	0.539
ES2	0.264	**0.829**	0.217	0.378	0.480	0.223	0.532	0.494
ES3	0.382	**0.864**	0.443	0.405	0.410	0.302	0.494	0.411
ES4	0.505	**0.777**	0.500	0.413	0.506	0.419	0.481	0.397
SS1	0.533	0.345	**0.862**	0.311	0.208	0.554	0.333	0.263
SS2	0.560	0.346	**0.835**	0.322	0.261	0.465	0.338	0.335
SS3	0.374	0.304	**0.821**	0.364	0.265	0.479	0.406	0.336
SS4	0.404	0.389	**0.810**	0.374	0.306	0.553	0.418	0.346
AUT1	0.536	0.479	0.298	**0.812**	0.430	0.289	0.470	0.414
AUT2	0.354	0.367	0.467	**0.828**	0.418	0.462	0.531	0.376
AUT3	0.243	0.298	0.219	**0.764**	0.471	0.384	0.501	0.450
COM1	0.141	0.445	0.228	0.514	**0.805**	0.380	0.535	0.497
COM2	0.320	0.417	0.353	0.458	**0.785**	0.409	0.475	0.540
COM3	0.281	0.550	0.277	0.438	**0.799**	0.389	0.570	0.532
COM4	0.128	0.288	0.074	0.239	**0.713**	0.261	0.415	0.442
REL1	0.509	0.363	0.642	0.516	0.435	**0.863**	0.549	0.437
REL2	0.378	0.309	0.514	0.386	0.410	**0.896**	0.550	0.510
REL3	0.296	0.312	0.530	0.378	0.431	**0.911**	0.535	0.456
REL4	0.337	0.265	0.525	0.382	0.410	**0.922**	0.528	0.463
IM1	0.329	0.562	0.421	0.597	0.593	0.565	**0.940**	0.580
IM2	0.320	0.573	0.402	0.563	0.593	0.551	**0.942**	0.603
IM3	0.367	0.577	0.417	0.551	0.605	0.545	**0.870**	0.608
CI1	0.358	0.586	0.376	0.487	0.622	0.495	0.626	**0.956**
CI2	0.369	0.482	0.359	0.492	0.621	0.497	0.618	**0.955**

Table 5 Correlations of the constructs and square root of AVE

	TS	ES	SS	AUT	COM	REL	IM	CI
TS	<u>0.825</u>							
ES	0.427	<u>0.823</u>						
SS	0.560	0.418	<u>0.832</u>					
AUT	0.485	0.483	0.413	<u>0.802</u>				

COM	0.288	0.564	0.313	0.545	0.776			
REL	0.428	0.350	0.620	0.467	0.471	0.898		
IM	0.369	0.622	0.450	0.622	0.651	0.603	0.918	
CI	0.380	0.560	0.385	0.512	0.650	0.519	0.651	0.956

*Note: Each under-line element is a square root of the AVE.

Table 6 Hetero-Trait Mono-Trait Ratio

	TS	ES	SS	AUT	COM	REL	IM	CI
TS								
ES	0.499							
SS	0.661	0.487						
AUT	0.602	0.607	0.519					
COM	0.345	0.670	0.366	0.709				
REL	0.483	0.391	0.691	0.573	0.544			
IM	0.422	0.712	0.511	0.770	0.761	0.659		
CI	0.435	0.641	0.438	0.636	0.768	0.569	0.719	

Table 7 Mediation test

Mediator	Mediated path	Original sample	Sample mean	Standard deviation	*t*-value	Significance ($p < 0.05$)	95% CIs (Bias-corrected)
AUT	TS→IM	0.099	0.100	0.038	2.610	Yes	[0.031, 0.182]
AUT	ES→IM	0.098	0.101	0.040	2.531	Yes	[0.032, 0.185]
COM	ES→IM	0.182	0.187	0.054	3.477	Yes	[0.085, 0.292]
REL	SS→IM	0.188	0.187	0.051	3.635	Yes	[0.091, 0.291]
IM	AUT→CI	0.188	0.191	0.056	3.433	Yes	[0.080, 0.299]
IM	COM→CI	0.228	0.233	0.056	4.158	Yes	[0.124, 0.346]
IM	REL→CI	0.198	0.195	0.047	4.196	Yes	[0.104, 0.286]

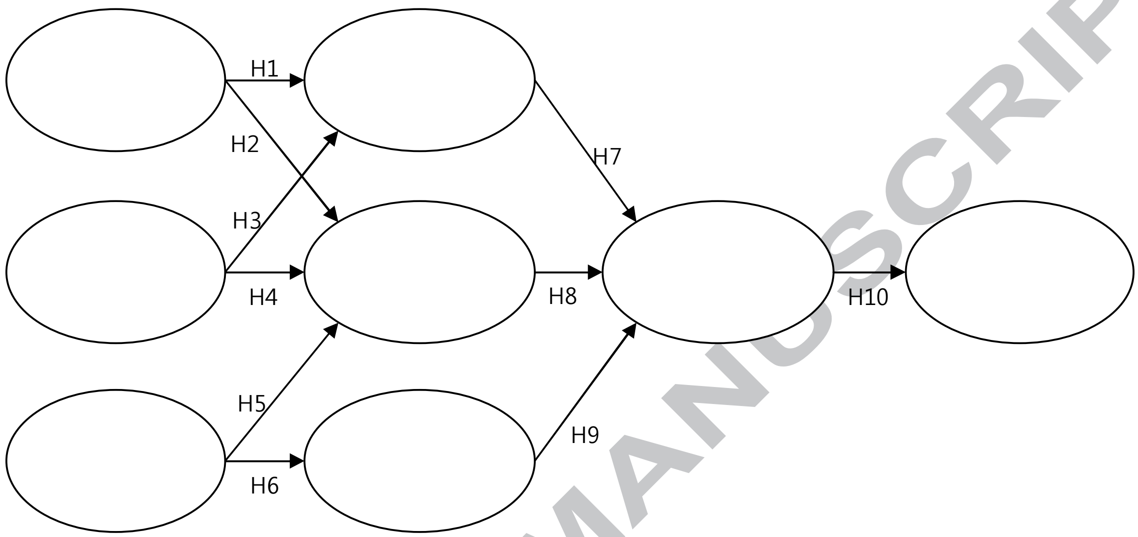
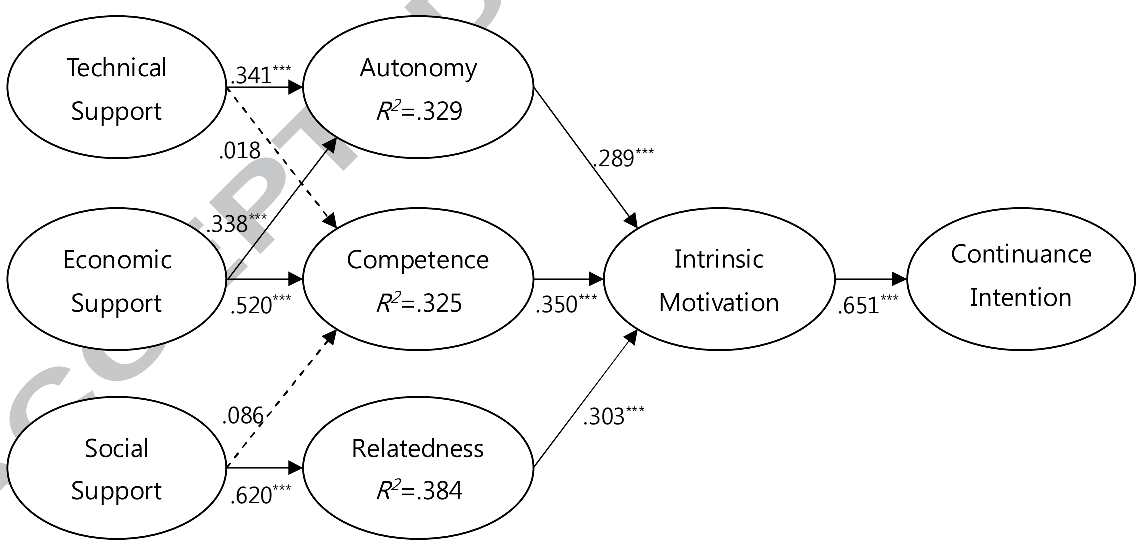


Figure 1 Research model



Note: * p < .05; ** p < .01; *** p < .001;

Figure 2 PLS analysis of the research model

Highlights

- This study examines makerspace continuance intention using self-determination theory.
- Technical, economic, and social support enhance a users' basic psychological needs.
- Psychological need fulfillment increases intrinsic motivation.