# Development and validation of an attitude assessment scale for the use of 3D printing in education

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## ABSTRACT

The purpose of this study was to develop and validate a scale aiming to assess pre-service teachers' attitudes towards 3D printing for teaching and learning processes. The data were collected from 250 pre-service teachers in different departments at a public state university. The validity of the scale was tested with exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). As a result of EFA, the scale consisted of three factors; perceived ease of use, perceived usefulness, and intention to use, with 18 items in 5 point Likert scale. The fit values from the CFA confirmed the three-factor structure of the scale. The correlations among the factors were positive, and collinearity among the factors was not evident. The scale and factors demonstrated a satisfactory level of internal reliability, ranging from 0.68 to 0.94. The findings of this study showed that the scale was valid and reliable, and could be used by researchers interested in technology integration in teaching and learning environments.

**Keywords**: *three-dimensional printing; pre-service teachers; attitude; scale development*

## INTRODUCTION

Technically 3D printing, also similar to additive manufacturing in industry, refers to creating three dimensional solid objects from three-dimensional computer-aided design materials by adding up the layers of the objects (Johnson, Adams Becker, Estrada, & Freeman, 2015). In order to print physical 3D objects, first of all, a user must design or import a digital model using 3D modeling software, open source or commercial. Additionally, online repositories provide free or commercial 3D models for designers. After the design phase, the model is put into a slicing software which is used to adjust the 3D printer setting and object properties such as the thickness, and the size of the object. With the help of the slicing software, the 3D object is cut into many slices. Then the 3D printer deposits the filament layer by layer on the plate (Maloy, Trust, Kommers, Malinowski, & LaRoche, 2017). Although several materials might be used as raw material for printing, today, Acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) are the most widely used 3D printer filaments.

The research studies in the literature have shown that 3D printing technologies have been used in several fields such as engineering, defense, medicine, arts, and education. Proponents of 3D printing assume that it is a revolutionary emerging technology and provides "novel opportunities that have never before been feasible for creative production and prototypes" (Canesca, Fonda, & Zennaro, 2013, p. 13). Markets and Markets (2017) reported that the 3D printing market is expected to be worth more than 32 billion US$ by 2023. In addition to this, Sculptes's Report (2017) on the state of 3D printing stated that 1000 participants from 62 different countries in various professions such as engineering, CEOs, freelancers, and designers were surveyed on the use of 3D printing in their occupation. It was found that of the respondents, 90% of them considered 3D Printing as a competitive advantage in their strategy, 47% of them saw a greater return on investment than the previous year, 49% of them increased their expenses in 3D Printing in 2017, and 72% of them expected their spending on additive manufacturing to increase for 2018.

Although it is estimated that between 2016 and 2020, the global 3D printing market in education will grow at a CAGR of 28.57% (Research and Markets, 2016), the current state shows that 3D printing has not been the primary and common instructional technology for teaching and learning environments. Factors that prevent the integration of 3D printing technology in learning environments are the lack of software and hardware, technical support, administrative support, and teachers' lack of knowledge, as well as its novelty (Demir, Çaka, Tuğtekin, Demir, İslamoğlu & Kuzu, 2016). Besides, the cost of hardware and raw material is high for today (AbouHashem, Dayal, Savanah & Štrkalj, 2015). Although the use of 3D printing in instructional settings has not been common yet, both the 2014 higher education and the 2013 K-12 edition of the NMC Horizon Report (New Media Consortium, 2013; 2014) stated that it is an important development for instructional technology, and schools have begun to use 3D printers to demonstrate the design process and create models.

## LITERATURE REVIEW

Research has shown that teaching materials produced with the 3D printing technology have enhanced learning outcomes in different fields such as medical, engineering, and art education (Bartellas, 2016; Casas & Estop, 2015; Unver, Atkinson & Tancock, 2006). The 3D printing process can facilitate students' construction of their mental models (Harel & Papert, 1991) and encourage students to collaborate, design, and discover by designing and creating. During the design process, learners are active in decision making, problem-solving and constructing knowledge rather than consumption of content. In addition to this, 3D printing and design engage learners to express their design ideas by stimulating learners to make connections related to the artifacts (Kostakis, Niaros & Giotitsas, 2015). In addition, working with 3D design and production tools may result in the development of different spatial abilities (Brown, 2015; Huang & Lin, 2017). In school settings, 3D printers have been used to concretize abstract issues and to enhance students' imagination. Thus, 3D printing provides an invaluable experience for students to design their own artifacts and to foster STEM-related activities (Brown, 2015).

There are several challenges teachers and learners may encounter while implementing 3D printing in school settings. Oropallo and Piegl (2016) offered different challenges with 3D printing in education, including optimization of design space, designing 3D objects, pre- and post-processing, printing methodologies applied by 3D printers, errors for 3D printing control, and multi-material printing. As it is a challenging and time-consuming task, the overall 3D printing process is a steep learning curve (Oropallo & Piegl, 2016). Because consumer-based 3D printers have not been developed enough and they are relatively new to the market, consumers face different challenges. Due to the incorrect design, glitch of the hardware, and incorrect print settings, prints may fail. Although thousands of free and paid 3D models have been available on the Internet, most of them do not respond to teachers' needs and requests. However, starting to design a 3D model from scratch or modifying it is a difficult and time-consuming effort. Moreover, 3D printers are slow in printing (Trust & Maloy, 2017). For example, printing a 3 or 4 inches model may take up more than one hour.

Researchers have been studying the variables affecting the integration of technology in learning environments. Ertmer (1999) concluded that two types of barriers influencing educational technology integration are first-order barriers and second-order barriers. The first-order barriers are external barriers and consisted of equipment, time, training, and support. However, the second-order barriers are internal to teachers and include teachers' beliefs such as self-efficacy, attitudes towards educational technology, epistemological beliefs, pedagogical beliefs and the perceived value of technology in learning environments.

Governments have invested a considerable amount of time, effort and budget on integrating technology into classrooms. Through the investments, the first-order barriers have been overcome, as more technological resources are available and pre- and in-service teachers today are more familiar with and trained in using technology than ten years ago (Fraillon, Ainley, Schulz, Friedman, & Gebhardth, 2014). Thus, researchers turned their attention to pre- and in-service teachers' attitudes and beliefs. Researchers have emphasized the role of attitudes toward information and communication technology (ICT) in the successful use of ICT in the classroom (Teo, 2010). Moreover, Huang and Liaw (2005) asserted that teachers' attitudes toward a specific technology is a strong predictor of its use for teaching and learning.

Research has emphasized that one of the factors that influence the success of any technology integration act in school settings depends upon the attitudes of teachers toward the given technology (Hew & Brush, 2007). In terms of the Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980), Technology Acceptance Model (TAM) (Davis, 1989), and other technology integration models, attitude is a crucial variable in determining behavioral intention to use a technology, which will affect the actual use of the technology. If a teacher has a positive attitude toward educational technology or a specific educational technology, he/she is likely to integrate that technology into his/her teaching process. Thus, it is important to understand actual teachers' and future teachers' attitudes towards using technology for teaching (Shapka & Ferrari, 2003).

Attitudes toward a specific technology are shaped by a number of variables. These variables include perceived usefulness (Rovai & Childress, 2002; Teo, 2010), perceived ease of use (Moon & Kim, 2001), and behavioral intention to use (Ma, Anderson & Streith 2005). Perceived usefulness is a subjective belief that using a specific technology will enhance his/her productivity or job performance (Vankatesh, 1999). The degree of their beliefs on the 3D printing technology will help them to perform teaching effectively will influence their attitudes towards that technology. Perceived ease of use means a person's beliefs on using a specific technology without an effort (Davis et al., 1989). If pre-service teachers believe that 3D printing is too hard to use and that the effort of using 3D printing outweighs the performance benefits of usage, they tend to have negative attitudes towards that technology. The behavioral intention was defined as a measure of the likelihood of someone performing a given behavior (Ajzen and Fishbein, 1980). It is believed to be correlated with teachers' attitudes towards 3D printing technology.

A number of studies in marketing have been implemented in order to assess consumers' perceptions or attitudes toward 3D printing technology (Bruner, Delley & Denkel, 2017; Malloy, 2016). However, only a few studies investigated teachers' opinions or perceptions on the use of 3D printing for teaching and learning (Schelly et al., 2015; Maloy et al., 2017). Trust and Maloy (2017) found that to teachers experienced with 3D printing in education, 3D printing projects have the potential to support learners in developing 21st-century skills such as collaboration, problem-solving, self-paced learning, critical thinking, and creativity. In a recent phenomenological study, Karaduman (2018) examined pre-service social studies teachers' views on using 3D printing technology for teaching social studies lessons. After analyzing the interview data, he concluded that pre-service teachers had positive attitudes towards 3D printing and were willing to use it in their future lessons.

In terms of technology integration, teacher preparation programs can initiate change and prepare future teachers through the application of technology integration requirements. Hence, it is suggested that technology integration begins with pre-service teachers (Diem, 2000). Although pre-service teachers are provided training on technology knowledge and skills and are given numerous opportunities to interact with educational technology in a variety of ways, optimistic roles of technology in the classroom might be presented to them during their training. Whereas, the actual working environment of in-service teachers and the ideal work environment of pre-service teachers are different. This discrepancy may influence their views on and attitudes toward technology. Results of the studies employed with pre-service teachers might be different than the results of the similar research conducted with in-service teachers (Baydas & Goktas, 2017; Teo, 2015). Therefore, the measures aimed to evaluate pre- and in-service teachers' views on and attitudes toward technology need to be different.

Until recently, valid and reliable instruments to assess pre-service teachers' attitudes towards different specific technologies have been tested and validated, that is, computers (Teo, 2010), e-learning (Haznedar & Baran, 2012), social media (Marin & Tur, 2015) and augmented reality (Díaz-Noguera, Toledo-Morales, & Hervás-Gómez, 2017). The nature, purpose, and ways of use of these technologies are different than 3D printing. Additionally, previous studies have investigated pre- and/or in-service teachers' views and concerns about 3D printing in education with interviews and open-ended questions. These studies heavily depend on descriptive data and subjective reports to investigate the views and concerns of teachers. In this frame; in the literature, no scale whose validity and reliability have been proven has been found to measure pre-service teachers' attitudes toward 3D printing for teaching, and a valid and reliable instrument is needed. Hence, the purpose of the current study is to address a gap in current research on 3D printing in education by systematically developing a reliable and valid self-report instrument for pre-service teachers in order to investigate their attitudes towards the use of this new technological tool in the teaching process. It is considered that gaining an understanding of the pre-service teachers' attitudes towards 3D printing may provide useful insights into potential integration and use of this technology in teaching and learning.

## METHOD

### Sample

The data were collected from undergraduate students studying in a faculty of education at a public state university in the 2016-2017 academic year. Among the 258 pre-service teachers, eight of the responses to scale were deleted because of the missing data. Hence a total of 250 pre-service teachers' responses were used for data analysis. Using the convenience sampling technique, the participants were drawn from Primary School Mathematics Teaching (29.2%), Special Education (26.8%) and the Language Teaching Departments (44.0%) at different grade levels. In the study, 68.4% of the pre-service teachers were female, and 31.6% were male. The pre-service teachers were told about the purpose of the study and the necessity of voluntary participation. They were also assured of the confidentiality of their responses to the items. The instrument was administered to the students in their regular class time with the permission of the instructor of the course. It took nearly 10 minutes to fill the instrument.

A presentation was made to the pre-service teachers before data collection. The presentation included the history and the technology of 3D printing, the use of this technology in different fields such as industry, medicine, design and design, the development process of 3D models, printing of 3D models, examples for the use of 3D printing technology for teaching and learning with the advantages, disadvantages and limitations of using 3D printing in education. In addition, several examples f 3D printed materials were demonstrated to the pre-service teachers. The presentation was made in 12 classrooms and in each class, it lasted nearly 90 minutes.

**Development process of the items**

First, an extensive literature review about 3D printing, attitude, and attitude towards using several technologies for teaching and learning was undertaken in order to create an item pool. A pool consisting of 26 items on perceived ease of use, perceived usefulness and behavioral intention to use was presented to experts in instructional technology, educational measurement and evaluation, and language teaching for content validity. Based on the reviews of the experts, necessary changes and improvements were made, and 4 items were deleted from the scale. The pilot form of the scale consisted of 22 items on a 5 point Likert type scale which used fixed choice response formats, to obtain participant's preferences or degree of agreement with a given statement, and were generally designed to measure attitudes or opinions (Field, 2009). These options were arranged and scored as “(1) strongly disagree”, “(2) disagree”, “(3) not sure”, “(4) agree”, and “(5) strongly agree”.

**Data analysis**

Initially, to define the factor structure of the scale, a principal component exploratory factor analysis (EFA) was performed. After that, a confirmatory factor analysis (CFA) was applied to test whether the model obtained in EFA fit to the hypothesized model (Sümer, 2000). Finally, in order to determine how each item could contribute to the variance of the instrument and to validate the scale items, an item analysis was performed, and the correlation between the factors was computed.

In the first phase of the study, the EFA was implemented. The Kaiser-Meyer-Olkin (KMO) value was measured to test how suited the data was for factor analysis, and Bartlett’s Test of Sphericity (BTS) was computed to find out the independency of all variables in relation to one another (Field, 2009). It was suggested that the KMO values between 0.7 and 0.8 are good, values between 0.8 and 0.9 are great and values above 0.9 are excellent (Çokluk, Şekercioğlu & Büyüköztürk, 2010; Field, 2009). The number of factors to extract was determined based on three criteria: (1) eigenvalue greater than 1, (2) the amount of common variance explained, and (3) the scree-test (Field, 2009; Kline, 1994). The lowest factor loading was determined as 0.40 to create factor patterns (Tabachnick & Fidell, 2001).

Secondly, the CFA was run to confirm or reject the model as a result of the EFA. The model was tested using the covariance matrix. Multiple goodness of fit index values were reported (Thompson, 2000). In addition to $\chi^2/df$, several goodness of fit indices including the goodness of fit index (GFI), the standardized root mean square residual (SRMR), the comparative fit index (CFI), the root mean square error of approximation (RMSEA), normed fit index (NFI), and adjusted goodness of fit index (AGFI) were used to test the offered model. The acceptable conformity values (Çokluk et al., 2010; Kline, 2005) for this study are presented in Table 1.

**Table 1:** *Criteria for Goodness of Fit Indexes*

| Goodness of fit statistics | Perfect | Acceptable |
|---|---|---|
| χ2/df | ≤3 | ≤5 |
| RMSEA | ≤ ,05 | ≤ ,08 |
| SRMR | ≤ ,05 | ≤ ,08 |
| GFI | ≥ ,95 | ≥ ,90 |
| AGFI | ≥ ,90 | ≥ ,85 |
| CFI | ≥ ,95 | ≥ ,90 |
| NNFI | ≥ ,95 | ≥ ,90 |

In the last phase, to measure the internal consistency reliabilities of each dimension, Cronbach's alpha coefficient was calculated. It was determined that a scale with an alpha value of .70 was reliable (Field, 2009; Kline, 2005). In addition to this, item-total correlation and Cronbach's alpha item deleted values were checked for the contribution of each item to the reliability of the factors and the overall reliability. Moreover, the high correlation between the factors of the scale is a problematic issue. Multicollinearity makes it impossible to control the unique contribution of the variables to the overall scale (Field, 2009). Therefore, possible high correlations ($r > .80$) were examined with Pearson Correlation Coefficient.

## RESULTS

### Findings regarding EFA

Firstly, to test the appropriateness of data for EFA, the data were subjected to KMO and BTS. EFA was conducted for 22 items, and four of them which had lower than 0.40 loading were removed from the scale. Then, a second EFA was applied to 18 items which had 0.40 or higher factor loading value, and KMO and BTS were calculated. KMO sampling adequacy was found as 0.93, and BTS were determined as 3109.26 ($p=0.00$) which means that the sample size was acceptable and the data were appropriate for the factor analysis.

As a result of the application of the EFA to 18 items, it was decided that three subscales would be extracted according to eigenvalue greater than 1 and scree plot. The difference between the factor loadings of each item was greater than 0.10 (Çokluk et al., 2010). It was understood that the first factor, *intention to use*, consisted of 12 items, the second factor, *perceived usefulness*, consisted of 4 items, and the last factor, *perceived ease of use*, consisted of 2 items. As shown in Table 2 below, the factor loadings rotated with varimax ranged between .59 and .83. As a result, it was found that the common variance for each of the three factors was 52.05% (intention to use), 7.87% (perceived usefulness) and 6.57% (perceived ease of use) respectively.

**Table 2:** *Factor loadings and common factor loads of each item after varimax rotation*

| | | Factors | | |
|---|---|---|---|---|
| Item # | Intention to use | Perceived usefulness | Perceived ease of use | Common factor loads |
| 22 | .826 | | | .74 |
| 21 | .804 | | | .71 |
| 14 | .744 | | | .64 |
| 12 | .732 | | | .67 |
| 15 | .725 | | | .67 |
| 13 | .713 | | | .65 |
| 20 | .705 | | | .71 |
| 18 | .698 | | | .72 |
| 19 | .683 | | | .66 |
| 16 | .623 | | | .55 |
| 11 | .596 | | | .44 |
| 17 | .592 | | | .55 |
| 7 | | .816 | | .74 |
| 8 | | .809 | | .76 |
| 9 | | .764 | | .77 |
| 10 | | .686 | | .61 |
| 1 | | | .830 | .71 |
| 2 | | | .809 | .68 |
| Total variance explained | 52.05 | 7.87 | 6.57 | |

Çokluk et al. (2010) and Tavşancıl (2010) suggested that, for social science studies, the value of total variance between 40% and 60% is sufficient, and for any factor to be meaningful, at least 5% of the total variance should be explained by that factor. In this study, the total variance explained was found to be 66.49% which might be acceptable. An analysis of the component matrix indicated that the factor loadings of all items were higher than 0.44, and this showed why the items were mostly loaded into the first factor (Field, 2009).

**Findings regarding CFA**

The confirmatory factor analysis was run in order to test whether the three-factor model obtained in EFA fit the data (Sümer, 2000). LISREL statistic software was used to run EFA and a covariance matrix was prepared. A path diagram was produced and goodness of fit statistics were computed for the three-factor model with 18 items. T-values for the path diagram are shown in Figure 1. The t-values for all items were statistically significant at 0.05 level.

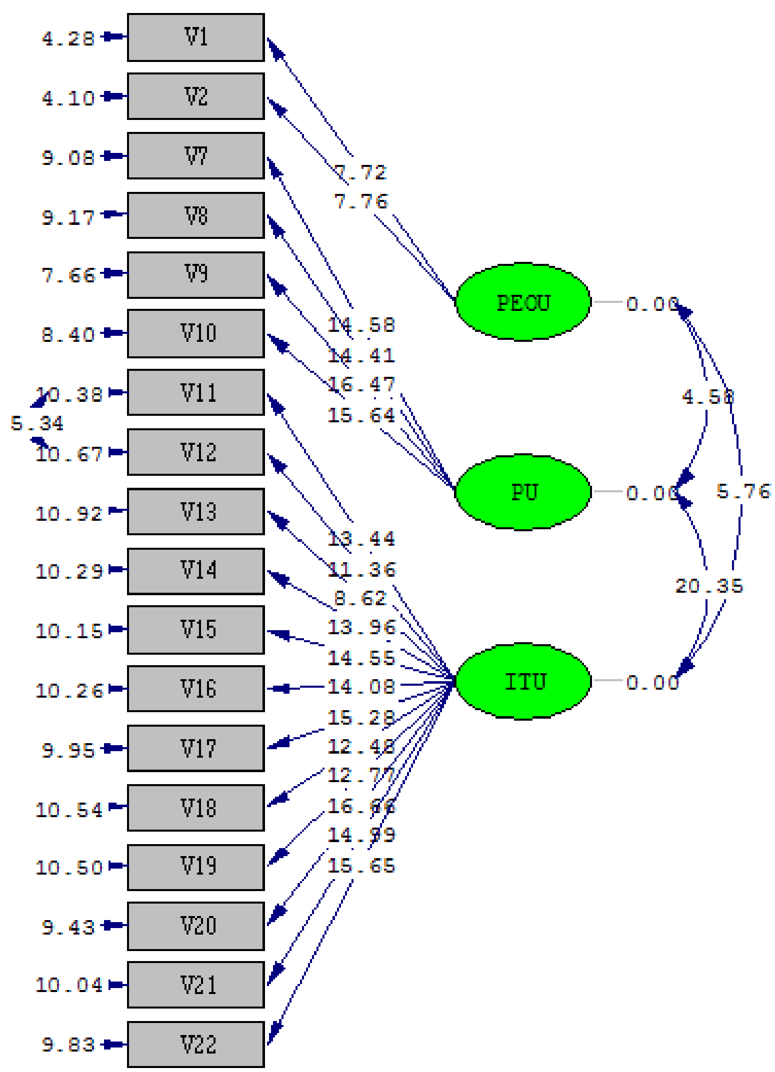


**Figure 1:** *Path Analysis Diagram for the scale within CFA*
PEOU: perceived ease of use; PU: perceived usefulness; ITU: intention to use

As a result of the CFA, the goodness of fit values were found as $\chi 2/df=380.19/131=2.90$, $p<0.05$, RMSEA=0.080, SRMR=0.056, GFI=0.91, AGFI=0.85, CFI=0.97, and NNFI=0.97. The results show that although RMSEA, SRMR, GFI, and AGFI fit values indicated an acceptable fit, the remaining observable fit values ($\chi 2/df$, SRMR, CFI, and NNFI) indicated a perfect fit (Çokluk et al., 2010; Kline, 2005). It could be stated that the proposed model indicated that the factors were confirmed by the CFA.

**Item discrimination**

The discrimination powers of each item, each factor, and the whole scale were computed. For this reason, the lowest 27% and the highest 27% total scores were determined, and two groups were formed. The t-test values of the independent groups were calculated with the mean scores in the group. Table 3 presents the t-values and significance levels of discrimination power.

**Table 3:** *Item discrimination powers*

| Items | t | Items | t |
|---|---|---|---|
| Item1 | 5.191 | Item14 | 16.693 |
| Item2 | 4.986 | Item15 | 13.769 |
| Item3 | 12.633 | Item16 | 16.179 |
| Item4 | 16.251 | Item17 | 16.226 |
| Item5 | 14.086 | Item18 | 15.949 |
| Item6 | 11.981 | ITU | 25.684 |
| Item7 | 10.628 | PEOU | 5.963 |
| Item8 | 15.105 | PU | 19.469 |
| Item9 | 15.545 | Total | 22.180 |
| Item10 | 14.033 | df: 134 | |
| Item11 | 13.950 | N=250 | |
| Item12 | 15.336 | $p < 0.05$ | |
| Item13 | 12.983 | | |

PEOU: perceived ease of use; PU: perceived usefulness; ITU: intention to use

The values in Table 3 indicate that the independent sample t-test values regarding the 18 items ranged from 5.191 to 16.693. In addition, the t-value for the whole scale was found to be 22.180. The level of each difference was found to be significant ($p < .05$). Therefore, both the whole scale and each item have high item discrimination power.

**Findings regarding reliability and correlation**

In the last phase of the study, to examine the internal consistency of the items in the scale, the Cronbach alpha coefficient of each factor and the whole scale, and the correlations among the factors were calculated. The analysis showed that all data have item-total correlations between 0.51 and 0.78 for each factor, which can be considered as satisfactory (Field, 2009). Moreover, it was found that the removal of two items from the scale would increase the Cronbach's alpha value from .941 to .943. However, this increase was negligible and both values reflected a good degree of reliability (Field, 2009). The internal consistency reliability coefficient for the whole scale was observed as 0.94. The Cronbach's alpha reliability coefficient was found as 0.94 for the intention to use factor, 0.87 for the perceived usefulness factor, and 0.68 for the perceived ease of use factor. Only in the perceived ease of use factor, the reliability coefficient was observed below 0.70.

However, this can be explained by the limited number of items (n=2), but it was acceptable (Field, 2009; Kline, 2005). According to the findings, the Cronbach alpha reliability values of the whole scale and subscales can be considered as satisfactory.

The Pearson correlation coefficients among the factors of the scale were computed and are displayed in Table 4. The results showed the correlations between the factors were significant at the 0.01 level, and the correlation coefficients were not higher than the critical value of 0.80 for multicollinearity. Hence, multicollinearity between the factors was not worthy of concern (Cohen, Cohen, West & Alken, 2003; Field, 2009).

**Table 4:** *Correlations between the factors of the scale*

| | Intention to use | Perceived ease of use | Perceived usefulness |
|---|---|---|---|
| Intention to use | 1.00 | .31* | .73* |
| Perceived ease of use | | 1.00 | .27* |
| Perceived usefulness | | | 1.00 |

* Correlation is significant at the 0.01 level

## DISCUSSION

Although 3D printing technology has been used since the beginning of the ’80s, its use for teaching and learning and research on this topic is limited. The development of 3D printing has brought new opportunities in school settings (Brown, 2015). The experience of teachers and pre-service teachers with this technology is at a low level. Successful technology integration in education depends on several factors such as access to technology, sufficient resources, pedagogical beliefs, and teachers’ attitudes towards the use of technology. Hence, teachers and pre-service teachers’ attitudes towards 3D printing technology for teaching and learning is one of the factors which will influence their use of this technology in schools.

Although 3D printing technology has been used in school for a few years, researchers have begun to investigate its effects on learning outcomes. However, there is a lack of a valid and reliable instrument to assess pre-service teachers’ attitudes towards 3D printing technology. In this study, a scale was developed in order to assess pre-service teachers’ attitudes towards 3D printing for teaching and learning. The initial form of this scale was 5-point Likert type scale with 22 items and was administered to 258 pre-service teachers. The items were scored as “(1) strongly disagree”, “(2) disagree”, “(3) not sure”, “(4) agree”, and “(5) strongly agree”. EFA and CFA were administered on the data in order to form the constructs and validate the model offered by scale.

During EFA, four of the items were removed from the initial form of the scale, and the remaining items were collected under three factors, and it showed that the scale had construct validity. The factors were named as *intention to use*, *perceived usefulness*, and *perceived ease of use*. The variance estimated with three factors was calculated as 66.49%. Component factor loads of the items varied between 0.59 and 0.83, which was good (Field, 2009). Next, the CFA was conducted to verify the factor structures of the scale as a result of the exploratory factor analysis. As a result, the CFA confirmed the attained model by the EFA (RMSEA=0.080, SRMR=0.056, GFI=0.91, AGFI=0.85, CFI=0.97, and NNFI=0.97) (Çokluk et al., 2010; Kline, 2005).

Item total correlation and Cronbach's alpha if item deleted values were checked for the contribution of each item to the reliability of the factors and the overall reliability. The analysis showed that each item in the scale satisfactorily measures the feature that was expected to be measured with the general scale (Korkmaz, 2012). The scale's and the factors' internal consistency coefficients were calculated, and they were found to have the satisfactory level of reliability ($\alpha_{\text{intention to use}} = 0.94$, $\alpha_{\text{perceived usefulness}} = 0.87$, $\alpha_{\text{perceived ease of use}} = 0.68$, and $\alpha_{\text{total}} = 0.94$). Also, the correlation between the factors of the scale was at a moderate level, and collinearity between the factors was not determined.

## SUMMARY

This study aimed to develop and confirm an attitude scale used to evaluate pre-service teachers' attitudes toward 3D printing technology in education. A principal component factor analysis was run to determine the factors of the scale, and it demonstrated good construct validity. The principal component analysis offered that the Pre-Service Teachers Attitudes Towards 3D Printing in Education Scale consisted of three constructs: intention to use, perceived usefulness, and perceived ease of use. Confirmatory factor analysis was used to test the hypothesized model offered by principal component analysis and indicated that the factors and the model offered by the principal component analysis were confirmed. Cronbach's alpha test suggested that all scale items showed acceptable internal reliability. The internal reliability level of each factor and the whole scale were found to be satisfactory. Furthermore, the correlations among the factors were statistically significant but small enough to support the existence of three different factors.

## LIMITATIONS AND RECOMMENDATIONS

Pre-service teachers' attitudes towards 3D printing technology for teaching and learning are one of the important aspects that researchers can study in teacher education and educational technology integration. However, although different measurement tools were created to assess in- or pre-service teachers' beliefs on different technologies, a valid and reliable scale had not been developed previously to evaluate pre-service teachers' attitudes towards 3D printing in education. This study was a first attempt to develop a valid and reliable metric to measure the attitudes of pre-service teachers. Researchers may use this scale as a whole scale or each factor of this scale can be a part of a study. Researchers might investigate the correlation between pre-service teachers' attitudes towards 3D printing in education and other variables in education. In addition, their attitudes might be compared in terms of different variables such as gender, department type and grade level.

Although the scale developed as part of this study showed good psychometric properties, it has some limitations that should be considered for future studies. Firs, the sample of this study consisted of 250 pre-service teachers from three different departments. Hence, in future research, data could be collected from more pre-service teachers from different departments. Second, the scale was developed in the Turkish language and applied in Turkish pre-service teachers' context. In order to increase the use and validity of this scale, it should be adapted for different cultures and contexts. Third, as this study was an exploratory study, it did not check the criterion-related validity. Further research may focus on the correlation of pre-service teachers' attitudes toward 3D printing in education and other similar scales.

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