Journal of Information Technology Education: Research

An Official Publication of the Informing Science Institute InformingScience.org

JITEResearch.org

Volume 16, 2017

# Pre-Service Teachers' Intention to Use MUVEs as Practitioners – A Structural Equation Modeling Approach

Emmanuel Fokides * | University of the Aegean, Rhodes, Greece | fokides@aegean.gr

*Corresponding Author

## Abstract

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| Aim/Purpose | The study examines the effectiveness of university courses in shaping pre-service teachers' intention to use 3D multi-user virtual environments (MUVEs) when they become practicing teachers. |
| Background | Four variables (perceived usefulness, perceived ease of use, self-efficacy, and attitude toward use), as well as behavioral intention to use MUVEs, were used to build a research model that extended the Technology Acceptance Model, and structural equation modeling was used for parameter estimation and model testing. |
| Methodology | Self-reported data was gathered from 325 pre-service teachers studying at the Department of Primary School Education at the University of the Aegean in Greece. |
| Contribution | The study demonstrated the applicability of the TAM as a model that can adequately explain pre-service teachers' intention to use MUVEs as practicing teachers. |
| Findings | Results analyses revealed a good model fit and, overall, 64% of the variance in behavioral intention was explained. Perceived usefulness and perceived ease of use were the most influential factors. |
| Recommendations for Practitioners | In order to increase the odds of a successful use of MUVEs in educational settings, institutions need to address specific organizational factors that will positively influence pre-service teachers' intentions to use them and provide experiences relevant to that technology. Also, more emphasis is needed on the usability of MUVEs. |

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| Keywords | MUVEs, pre-service teachers, structural equation modeling, Technology Acceptance Model |

Accepting Editor: Donna Satterlee │ Received: October 10, 2016 │ Revised: December 10, 2016; January 21, 2017 │ Accepted: January 22, 2017.

Cite as: Fokides, E. (2017). Pre-service teachers' intention to use MUVEs as practitioners – A structural equation modeling approach. *Journal of Information Technology Education: Research, 16,* 47-68. Retrieved from http://www.informingscience.org/Publications/3645

## INTRODUCTION

In education, technology is commonly viewed as an enabler; it is widely used, to a varying degree, for supporting teaching. The rapid advances in information and communication technologies (ICT) have transfigured technology. From an enabler it became a driver, forcing changes in all aspects of human activity, leading many to envision the transformation of education by technology (e.g., Seidel & Rubin, 1977). Unfortunately, education is not responsive to changes; new technology trends are not easily accepted by the prevailing educational establishment. At the same time, the technological advances are constantly pushing for even more changes. This has resulted to a profound contradiction. Outside the classroom, students are highly engaged in using cutting-edge technologies many of which are inherently educational and could easily be exploited by schools. Inside the classroom, these technologies are shut out of school-based learning.

Consequently, we have to rethink and reorganize what, where, and how we teach our children with and through technology. For teachers, however, this would be a monumental challenge, since, to a great extent, how to use technology in teaching remains unexplored to modern pedagogy, and everything is new and strange to in-service and pre-service teachers. Therefore, it is at the hands of schools of education to provide pre-service teachers with the necessary expertise that will allow them to: (a) become proficient users of diverse, and even advanced and emerging, forms of educational technologies; and (b) make good use of the above tools during their teaching.

One of the technologies with high educational potential is virtual reality (VR). VR is an 'umbrella' term and various sub-genres do exist, one of which is 3D multi-user virtual environments (MUVEs). The realization of the educational potential of MUVEs, as explained in the coming section, led to the addition of two courses to the undergraduate curriculum of the Department of Primary School Education at the University of the Aegean. It can be argued that any course related to technology is effective not only if it manages to render pre-service teachers able in using the given technology, but also if it manages to positively influence their intention to use this technology when they become practicing teachers. That is because positive feelings toward an ICT tool and intention to use it are closely related to the actual use of this tool (Macharia & Pelser, 2014). Consequently, one should not only examine knowledge acquisition, which is, more or less, expected to be good if the courses are well organized, but also if the courses manage to shape positive intentions toward use. Thus, the study at hand had a two-fold purpose: (a) to examine if, by which factors, and to what extent the intention of pre-service teachers to use MUVEs when they become practicing teachers was affected, after studying the relevant courses; and (b) on the basis of the findings, to examine the implications for educators and administrators in higher education, as well as to other parties involved in education.

The paper is organized as follows. First, a brief review of the literature on MUVEs in education is presented, followed by a presentation of the courses. Next, the research rationale and methodology are presented followed by results. Subsequently, results are discussed and the conclusion completes the work.

## MUVES IN EDUCATION

The most popular MUVE is Second Life (SL) (http://secondlife.com). In SL, the user can create a virtual self and explore 3D virtual environments together with other users, hence the term 'multi-user'. In 2007, the OpenSimulator project (http://opensimulator.org) was launched to take a further step; it is an open source MUVEs platform, supporting diverse types of clients while maintaining compatibility with SL. The aforementioned are only two of a growing number of applications trying to exploit the potential of MUVEs.

In short, MUVEs allow the simulation of real or imaginary environments that 'fool' the human senses; users have the feeling of being in a real world (Hew & Cheung, 2010). VR, as well as MUVEs, soon grasped the educators' attention; social interaction, peer feedback, collaboration between users, visual and audio stimuli are but a few of their advantages (Zheng & Newgarden, 2011). These advantages can be attributed to four MUVEs' key features: immersion, interaction, imagination, and interest (Cho et al., 2002):

- Immersion: Is the degree at which the person is integrated into the virtual world, disregarding the external stimuli of the real world.
- Interaction: User's actions produce reactions from the simulation and vice versa.
- Imagination: Real, as well as imaginary objects and environments, can be realized in a MUVEs application. So, the user can set his imagination free.
- Interest: By manipulating the virtual objects, talking with avatars, and walking through the virtual environment, people take an interest in it.

The above led to the most longstanding and direct benefit for education: motivating learning (O'Neil, Wainess, & Baker, 2005).

Constructivism provides the theoretical framework for MUVEs' educational uses (Dickey, 2005). This theory supports the notion that learners construct knowledge on the basis of what they already understand and as they make connections between new and old information (Ertmer & Newby, 2013). MUVEs are used for constructivist learning because of the opportunities for learners to express their personal thoughts, to explore, to collaborate, to be immersed in the environment, to become active learners (Mikropoulos & Natsis, 2011), and, thus, to construct their knowledge (Pan, Cheok, Yang, Zhu, & Shi, 2006). Together with the motivating learning and the in-world activities, the educational process becomes more effective (Martin et al., 2011).

There are numerous studies in both formal and informal education, across all knowledge domains, and across all levels of education, demonstrating the benefits when using MUVEs and VR applications in general. To give an example, in science education simulations allow the representation of the content in a non-textually-mediated way, which, in turn, allows students to understand complex concepts and, later on, use this knowledge to interpret real scientific problems (Squire, Barnett, Grant, & Higginbotham, 2004). MUVEs are important tools not only for teaching concepts related to science, but also for addressing the related misconceptions (Barnett, Yamagata-Lynch, Keating, Barab, & Hay, 2005). That is because they can encompass both small and large scales (Schneps et al., 2014), but also the user has the freedom of moving to multiple perspectives in time as well as in space (Mintz, Litvak, & Yair, 2001).

Alas, the contribution of MUVEs to the everyday teaching practices still remains minimal (close to none), for reasons that little have to do with their effectiveness. One of the core problems is that teachers do not know how to integrate this technology into their teaching in meaningful ways (Meltzoff, Kuhl, Movellan, & Sejnowski, 2009). Moreover, MUVEs are rarely used in teachers' education. In most cases, they are not the subject of the course *per se* but they are used as a content delivery method (e.g., Ludlow & Hartley, 2016; Steed, 2014). Only a handful of courses critically examine MUVEs' educational uses and instruct the future teachers on how to integrate them into their teaching.

## A Brief Description of the Courses

As already mentioned, two courses related to MUVEs were added to the Department's undergraduate curriculum. Students attend these courses during their last two years of their studies, after having successfully completed most of the other ICT related ones. One course is mandatory while the other is elective but, in both, the same software tools are used for the development of MUVEs; Opensimulator for hosting students' applications, Firestorm (http://firestormviewer.org), or any other open source viewer, for the development and viewing of the virtual worlds, and a number of open source software tools for image, sound, and video editing. Together these tools constitute the MUVEs developing kit (MUVEs DK), which is given to all students at the beginning of each semester.

The theoretical background of MUVEs and their impact on education are discussed, but the courses are more focused on providing hands-on experiences to students. This is done by critically examining diverse didactic scenarios which are, at a later stage, implemented through the development of applications using the MUVEs DK. The main objectives of the mandatory course are students to be able to determine and follow the steps for the development of an application, to know the different techniques used, and to identify and deal with critical issues related to the development and use of virtual environments from a technical perspective (e.g., how to avoid overloading the virtual world and, at the same time, making it interesting and functional), but also from an educational perspective (e.g., how to present the learning material or how to evaluate the learning outcomes). The elective course has the same objectives, but the educational scenarios are more complex and make use of the advanced features of the MUVEs DK. Given that MUVEs have the potential of becoming an important educational tool in the near future, as discussed in the preceding section, the goals of these courses are for future teachers to: (a) become proficient users of MUVEs; (b) be able to develop their own MUVEs; and (c) efficiently use them in their everyday teaching.

There are limitations to the unobstructed conduct of these courses. While students consider themselves as being average users, in reality their actual knowledge of computers is low (Fokides, 2016). To leverage this disadvantage and provide successful experiences to students, multiple supporting mechanisms are set up: (a) lecture notes and the textbook are given during the first lecture; (b) between lectures, small group meetings take place, where students' progress is checked and problems are solved; (c) there is an official discussion group on the Department's LMS, as well as an unofficial one on Facebook; (d) all lectures are videotaped and offered as a free open course program; and (e) technical support is provided on demand and on a regular basis. Most importantly, the MUVEs DK comes with an extensive inventory of more than 14,000 3D objects, so that students can populate their worlds virtually with anything they can think of, and a library of more than 3,000 ready-to-use scripts (code snippets) for adding interactions or behaviors to the objects.

The underlying philosophy behind this set-up is that students are primarily educators and not computer programmers; therefore, the task of developing their own applications has to be eased as much as possible, enabling them to concentrate on the educational and not on the technical aspects of their applications.

## TECHNOLOGY ACCEPTANCE MODEL AND SELF-EFFICACY BELIEFS

The Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980) hypothesized that human actions can be explained on the basis of the relationship between pre-existing attitudes and behavioral intentions. This theory gave birth to a number of models that all seek to explain one's intention to use technology. Among them, the Technology Acceptance Model (TAM) (Davis, Bagozzi, & Warshaw, 1989) (Figure 1) is widely used and validated. The TAM models the causal relationships between:

- Behavioral intention to use technology (BIU), which is an indicator of the factors affecting the desired behavior (e.g., use of computers). It also specifies how much effort an individual is willing to put in order to perform this behavior (Ajzen & Fishbein, 1980).
- Attitude toward use (ATU), which refers to the degree to which a user likes or dislikes using a certain technological tool (Ajzen & Fishbein, 1977).
- Perceived usefulness (PU), which refers to the extent to which a person believes that using this particular tool would enhance his/her job productivity and performance (Davis et al., 1989).

- Perceived ease of use (PEU), which refers to the degree to which a person believes that the use of the given tool will be free of effort (Davis et al., 1989).

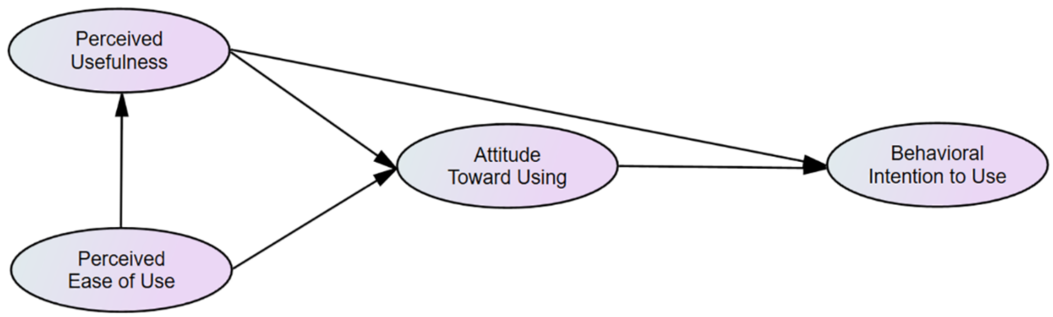


**Figure 1. Technology acceptance model (adapted from Davis et al. 1989)**

There is a substantial theoretical and empirical support in favor of the TAM and it is widely acknowledged as a parsimonious yet robust model. It has been used to assess users' acceptance for diverse technological tools (e.g., Wallace & Sheetz, 2014) across teaching levels (Teo, 2014) and cultures (Teo, Ursavas, & Bahcekapili, 2012). It has also been used in studies involving pre-service teachers (e.g., Teo, 2009; Teo, Lee, Chai, & Wong, 2009). On the other hand, there are only a handful of studies examining the applicability of the TAM in MUVEs (e.g., Bertrand & Bouchard, 2008; Chow, Herold, Choo, & Chan, 2012). What is more, there are no studies utilizing the TAM in order to examine pre-service teachers' intention to use MUVEs when they become practicing teachers. Consequently, the TAM was chosen as the basis for the development of a model to examine exactly this.

Bandura (1986) described self-efficacy beliefs (SE) as how one views his/her ability to perform certain tasks in alignment with the desired goals. Since it is a subjective judgment, the focus is not on the individual's actual skills. Individuals that possess high computer SE beliefs tend to be more persistent when facing usage problems and they are more determined computer users (Compeau & Higgins, 1995). The literature suggests that the computer SE beliefs influence all of the TAM's constructs: BIU (e.g., Teo, 2009), ATU (e.g., Macharia & Pelser, 2014), and PU (e.g., Hsu, Wang, & Chiu, 2009). Consequently, in this study, the TAM was extended by including SE as another construct. Henceforth, SE refers to the beliefs one has about his/her ability to use MUVEs in an educational context.

## Research Model and Hypotheses

The proposed research model, shown in Figure 2, encapsulated the relationships among the variables in the TAM as described in the previous section. Since SE was included as one of the model's constructs, additional relationships were added to account for this inclusion. The study's hypotheses were based on these relationships:

- H1a, b, c: PEU significantly and positively influences PU, ATU, and pre-service teachers' behavioral intention to use MUVEs when they become practicing teachers.
- H2a, b, c: MUVEs SE beliefs significantly and positively influence PU, ATU, and BIU.
- H3a, b: PU significantly and positively influences ATU and BIU.
- H4: ATU significantly and positively influences BIU.

In this study, BIU was used as the dependent variable, while PU, PEU, SE, and ATU were used as independent variables. For the purposes of structural equation modeling, PEU and SE were considered as exogenous variables, while PU, ATU, and BIU were endogenous variables.

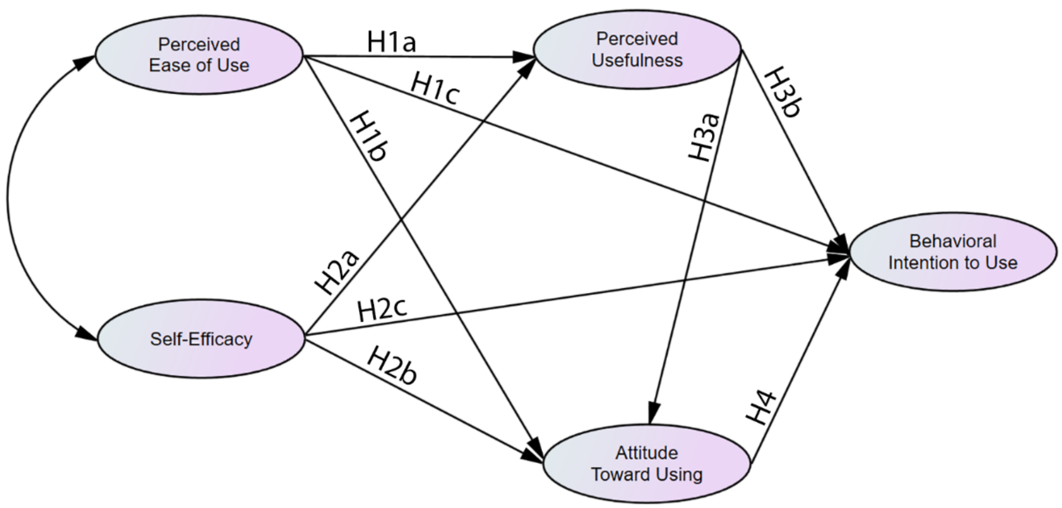


**Figure 2. The proposed research model**

## METHOD

The study's target group was students studying at the Department of Primary School Education, University of the Aegean, having attended both the mandatory and the elective course described in a previous section. Therefore, they are well acquainted with computers, as well as with the educational uses of MUVEs and the software tools which are used for developing them. Thus, it can be assumed that the corresponding behavioral intentions and attitudes have been formed.

A survey questionnaire was used. It comprised of three groups of questions: (a) demographic information (such as age and gender); (b) 24 items measuring the five constructs in the research model; PU (5 items), PEU (5 items), ATU (6 items), SE (4 items), and BIU (4 items); and (c) 6 items (yes-no and multiple choice questions) relating to students' views of the advantages and disadvantages of using MUVEs in education. The second group's items were rated on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree) and formed the MUVEs Attitude Scale (MAS). The backbone of MAS was Selwyn's (1997) Computer Attitude Scale (CAS), though its items were modified to suit the study's needs. This was done because CAS was originally developed for measuring attitude toward computers in general, and not toward MUVEs. The SE's items were selected and adapted from the Computer Self-Efficacy Scale developed by Barbeite and Weiss (2004). Four experts in the field of MUVEs reviewed the questionnaire and minor changes were made in compliance to their comments. The MAS is presented in the Appendix.

The questionnaire was available online for one month (February 2016). An introductory page informed the participants that the survey was conducted on a voluntary basis and that consent to participate was deemed to have been given by completing the questionnaire. No personal information was saved. A total of 339 students responded affirmatively to an email invitation addressed to all students that had attended both courses.

## RESULTS ANALYSES

Prior to conducting any statistical analysis, the data were screened in order to ensure that they were useable, reliable and valid for testing a causal theory. Unengaged (with no variance) responses were deleted. The number of valid questionnaires was 325. Most participants were females ($N$ = 270, 83.1%) and their mean age was 21.02 ($SD$ = 3.72) years, representing, more or less, the actual gender and age distribution of the Department's students. They all owned a computer and, on average, they spend 3.94 (*SD* = 2.3) hours using the computer for work and entertainment. The average mean scores and standard deviations of the model's five constructs are presented in Table 1.

**Table 1. Average mean scores and standard deviations of the model's factors**

| Factor | *M* | *SD* |
|---|---|---|
| ATU | 3.72 | .88 |
| PU | 3.69 | .82 |
| PEU | 3.08 | .77 |
| SE | 3.11 | .92 |
| BIU | 3.25 | .92 |

### *Exploratory Factor Analysis*

Since the MAS was based on a modified version of Selwyn's CAS and additional questions from other sources were used, an Exploratory Factor Analysis (EFA) was conducted in order to establish the underlying dimensions between the variables and the latent constructs. The study's 325 cases satisfied Tabachnick and Fidell's (2007) rule of thumb for at least 300 cases. All 24 items were examined for their mean, standard deviation, skewness, and kurtosis. Skewness and kurtosis indices were small and well below the recommended level of |3| and |10| respectively (Kline 2005).

The data were well suited for factorial analysis, since the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy index was .93, the Bartlett's Test of Sphericity was significant ($p < .001$), and the extraction communalities were above the .5 level (Tabachnick & Fidell, 2007; Hair, Black, Babin, Anderson, & Tatham, 2006). As the study involved human behaviors and structural equation modeling (SEM) was to follow, principal axis factor analysis (PAF) with oblique rotation was used for assessing the underlying structure for the 24 items of the MAS. PAF accounts for the covariation among variables, thus, it is suitable for SEM (Kline, 2005). Oblique rotation is considered to produce more accurate results for research involving human behaviors (Costello & Osborne, 2005).

As hypothesized, five factors were extracted using both the Kaiser's (1960) criterion (eigenvalue > 1) and the more recommended scree test (Costello & Osborne, 2005) (Figure 3).

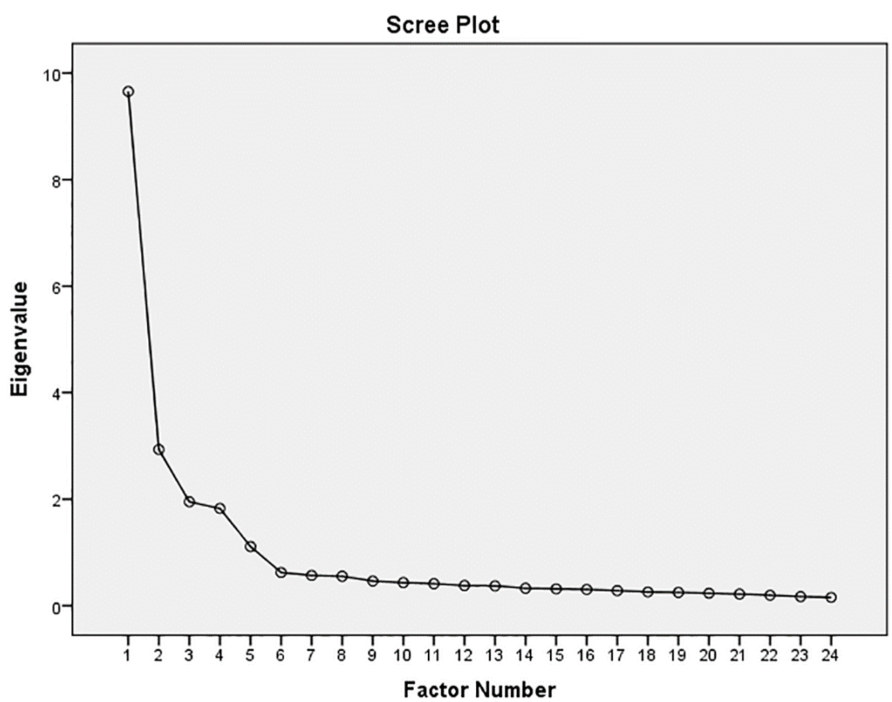


**Figure 3. Scree plot of the eigenvalues**

No variables were dropped and all factors had 4 or more strong loadings (Table 2). All items loaded high on their respective factors (> .6) and each factor averaged above the .7 level, as recommended by Hair et al. (2006). There were no significant cross-loadings between items and there were no correlations between the factors greater than .7. The total variance explained by the five components was 65.70%. The reliability scores of all constructs using Cronbach's alpha was between .85 and .93 and the overall score was .93, exceeding DeVellis's (2003) guidelines (> .70).

**Table 2. Principal axis factor analysis of all items**

| | Factor loadings | | | | | Communalities |
|---|---|---|---|---|---|---|
| | **BIU** | **PC** | **ATU** | **PEU** | **PU** | |
| ATU1 | | | .84 | | | .72 |
| ATU2 | | | .89 | | | .81 |
| ATU3 | | | .69 | | | .62 |
| ATU4 | | | .78 | | | .65 |
| ATU5 | | | .80 | | | .68 |
| ATU6 | | | .80 | | | .73 |
| PU1 | | | | | .73 | .63 |
| PU2 | | | | | .73 | .67 |
| PU3 | | | | | .69 | .65 |
| PU4 | | | | | .90 | .73 |
| PU5 | | | | | .79 | .66 |
| PEU1 | | | | .73 | | .56 |
| PEU2 | | | | .80 | | .1 |
| PEU3 | | | | .69 | | .60 |
| PEU4 | | | | .70 | | .59 |
| PEU5 | | | | .70 | | .51 |
| SE1 | | .66 | | | | .43 |
| SE2 | | .83 | | | | .73 |
| SE3 | | .75 | | | | .60 |
| SE4 | | .80 | | | | .63 |
| BIU1 | .78 | | | | | .70 |
| BIU2 | .74 | | | | | .74 |
| BIU3 | .68 | | | | | .73 |
| BIU4 | .64 | | | | | .70 |
| Eigenvalues | 9.65 | 2.93 | 1.95 | 1.83 | 1.11 | |
| % variance explained (total 65.70) | 38.88 | 10.73 | 6.67 | 6.05 | 3.37 | |
| Cronbach's *a* (total = .93) | .91 | .85 | .93 | .87 | .90 | |

Note: Values < .30 are omitted for clearance of presentation

### *Confirmatory Factor Analysis*

The resulting factor structure was inputted into AMOS 23 to perform Confirmatory Factor Analysis (CFA). Table 3 shows the results of the CFA. The standardized estimates ranged from .65 to .91 and were regarded as acceptable (Hair, Black, Babin, & Anderson, 2010). All but one of the $R^2$ values were above .50, suggesting that items explained more than half the amount of variance of the latent variable that they belong. PEU5's $R^2$ was very close to .50 (.48), therefore it was an acceptable deviation from the recommended value.

From the results of the fit statistics, the initial model, except $\chi^2$, appeared to have a good fit in all the indices (Table 4). As for $\chi^2$, it has to be noted that it is too sensitive when the sample size exceeds 200 cases. If so, there is a great tendency for $\chi^2$ to indicate significant differences (Hair et al. 2006). Therefore, this anomaly was assumed to be applicable in the present study ($N = 325$).

For assessing convergent validity, the average variance extracted (AVE) was calculated and checked whether the measurement items were loaded with significant *t*-values on their theoretical constructs. The AVE in all cases was above the .50 level as suggested by Hair et al. (2010). In addition, all the reflective indicators were significant at the .001 level (Table 3).

**Table 3. Results for the measurement model**

| Item | SE | *t*-value | $R^2$ | AVE |
|---|---|---|---|---|
| ATU1 | .85 | 22.13 | .73 | 0.68 |
| ATU2 | .91 | - | .83 | |
| ATU3 | .79 | 18.87 | .62 | |
| ATU4 | .76 | 17.71 | .58 | |
| ATU5 | .82 | 20.26 | .67 | |
| ATU6 | .82 | 19.90 | .66 | |
| PU1 | .80 | 16.42 | .65 | 0.66 |
| PU2 | .83 | 17.06 | .68 | |
| PU3 | .80 | 16.34 | .64 | |
| PU4 | .82 | - | .67 | |
| PU5 | .80 | 16.38 | .64 | |
| PEU1 | .72 | 14.25 | .51 | 0.59 |
| PEU2 | .83 | - | .69 | |
| PEU3 | .80 | 15.75 | .64 | |
| PEU4 | .80 | 15.79 | .65 | |
| PEU5 | .69 | 13.50 | .48 | |
| SE1 | .65 | 11.99 | .52 | 0.59 |
| SE2 | .85 | - | .72 | |
| SE3 | .77 | 14.76 | .60 | |
| SE4 | .79 | 15.03 | .62 | |
| BIU1 | .82 | 17.74 | .67 | 0.71 |
| BIU2 | .85 | 18.83 | .73 | |
| BIU3 | .85 | 18.89 | .73 | |
| BIU4 | .84 | - | .71 | |

Notes: This value was fixed at 1.00 for model identification purposes.
SE: standardized estimate. AVE: average variance extracted.

**Table 4. Fit indices of the initial research model**

| | Result | Recommendation | Reference |
|---|---|---|---|
| $\chi^2$ | $\chi^2$ (239, $N = 325$) = 426.03, $p < .001$ | ns at $p < .05$ | Hair et al. (2006) |
| $\chi^2$/df | 1.78 | 1 - 3 | Kline (2005) |
| SRMR | .038 | < .05 | McDonald and Ho (2002) |
| TLI | .96 | ≥ .95 | Hu and Bentler (1999) |
| NFI | .92 | > .90 | Bentler and Bonett (1980) |
| RMSEA | .049 | <.05 | McDonald and Ho (2002) |
| CFI | .96 | ≥ .95 | Hu and Bentler (1999) |

Note. ns: not significant

The presence of discriminant validity was evaluated by comparing the square root of the AVE for any given factor with the correlations between that factor and all other factors. The discriminant validity was satisfactory in all cases since the variance shared between a factor and any other factor in the model was less than the variance that the construct shared with its measures (Fornell, Tellis, & Zinkhan, 1982) (Table 5).

**Table 5. Discriminant validity**

| Factor | CR | AVE | SE | ATU | PU | PEU | BIU |
|---|---|---|---|---|---|---|---|
| SE | 0.85 | 0.59 | (0.77) | | | | |
| ATU | 0.93 | 0.68 | 0.33 | (0.83) | | | |
| PU | 0.91 | 0.66 | 0.13 | 0.50 | (0.81) | | |
| PEU | 0.88 | 0.59 | 0.26 | 0.59 | 0.50 | (0.77) | |
| BIU | 0.91 | 0.71 | 0.12 | 0.61 | 0.74 | 0.57 | (0.84) |

Notes: CR: Critical ratio. AVE: Average Variance Extracted. Diagonal in parentheses: square root of AVE extracted from observed variables. Off-diagonal: correlations between constructs

The presence of Common Method Variance (CMV) was also checked. CMV is the variance caused by the measurement method and not by the constructs that the measures represent (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). CMV was a concern since the study was based on perceptual measures from a single source at one point in time. Though it is commonly overlooked -or mentioned as a limitation- in research papers, if it is present but not taken into account measurement errors do occur and the legitimacy of the conclusions is questionable. For that matter, it was checked right after the construct validity was established as suggested by Lowry and Gaskin (2014), by conducting two tests. The first was Harman's single-factor analysis (Podsakoff & Organ, 1986). For the second, a common latent factor (CLF) was added and the standardized regression weights were compared before and after the addition of the CLF, as suggested by Gaskin (2013). There was no evidence of CMV in any factor since: (a) Harman's single-factor analysis was < 50% (37.91%); and (b) the standardized regression weights were not very different when adding the CLF (difference < .2).

### *Structural Equation Modeling*

For testing the fit between the initial research model (Figure 2) and the obtained data, SEM was performed, using AMOS 23. The requirements for SEM were met since the sample size was above 150 ($N = 325$), each construct had four or more items, and the item communality was above .50 (Hair et al., 2006). A curve estimation for all the relationships in the model revealed that in some cases linearity was slightly lower than the strongest relationship between variables but still significant. Therefore, the relationships were sufficiently linear to be tested using a covariance-based structural equation modeling algorithm such as the one used in AMOS. The Variance Inflation Factor (VIF) was used for checking multicollinearity. The highest value of VIF that was observed was 1.85, well below the recommended maximum of 3 (O'Brien, 2007). Since the data were sufficiently linear and multicollinearity was not an issue, it was determined that the multivariate assumptions for conducting SEM were also met.

The results of the SEM analysis of the direct effects in the initial model (Figure 2) are shown in Table 6. The shaded rows identify two effects that were not statistically significant and their path coefficients were also small. All the other direct effects were statistically significant at the .001 level and their path coefficients were considerable. The model fit, although already satisfactory, may be improved if the two not statistically significant effects are removed from the model, resulting in a simpler final model.

All the direct effects were made optional in the model, forming a hierarchy of $2^{10} = 1{,}024$ models which was analyzed using the Specification Search Facility available in AMOS 23. On the basis of the results, the model with the smallest value for $BCC_0$ was selected as the final model ($BCC_0 = 0.00$), as suggested by Burnham and Anderson (1998). Indeed, in this model, the two not statistically significant effects were removed. The fit statistics for the final model were satisfactory and almost identical to those in Table 4 [$\chi^2$ (241, $N = 325$) = 429.34, $p < .001$, $\chi^2$/df = 1.78, SRMR = .039, TLI = .96, NFI = .92, RMSEA = .049, CFI = .96]. A summary of the hypotheses testing results is shown in Table 7, while Figure 4 presents the final model.

**Table 6. Direct effects in the proposed model**

| Path | Path coefficient ($\beta$) | *t*-value | *p* |
|---|---|---|---|
| PEU → PU | .50 | 7.94 | < .001 |
| PEU → ATU | .41 | 6.67 | < .001 |
| PEU → BIU | .15 | 2.84 | .004 |
| SE → PU | -.004 | -.07 | .942 |
| SE → ATU | .19 | 3.77 | < .001 |
| SE → BIU | -.08 | -1.81 | .070 |
| PU → ATU | .27 | 4.62 | < .001 |
| PU → BIU | .53 | 9.06 | < .001 |
| ATU → BIU | .26 | 4.87 | < .001 |

**Table 7. Hypothesis testing results**

| Hypotheses | Path | Path coefficient ($\beta$) | *t*-value | *p* | Result | Confirms TAM |
|---|---|---|---|---|---|---|
| H1a | PEU → PU | .50 | 8.21 | < .001 | supported | yes |
| H1b | PEU → ATU | .41 | 6.67 | < .001 | supported | yes |
| H1c | PEU → BIU | .16 | 2.66 | .008 | supported | no |
| H2a | SE → PU | | Excluded/Not confirmed | | | |
| H2b | SE → ATU | .20 | 3.77 | < .001 | supported | new |
| H2c | SE → BIU | | Excluded/Not confirmed | | | |
| H3a | PU → ATU | .27 | 4.64 | < .001 | supported | yes |
| H3b | PU → BIU | .53 | 9.18 | < .001 | supported | yes |
| H4 | ATU → BIU | .28 | 4.55 | < .001 | supported | yes |

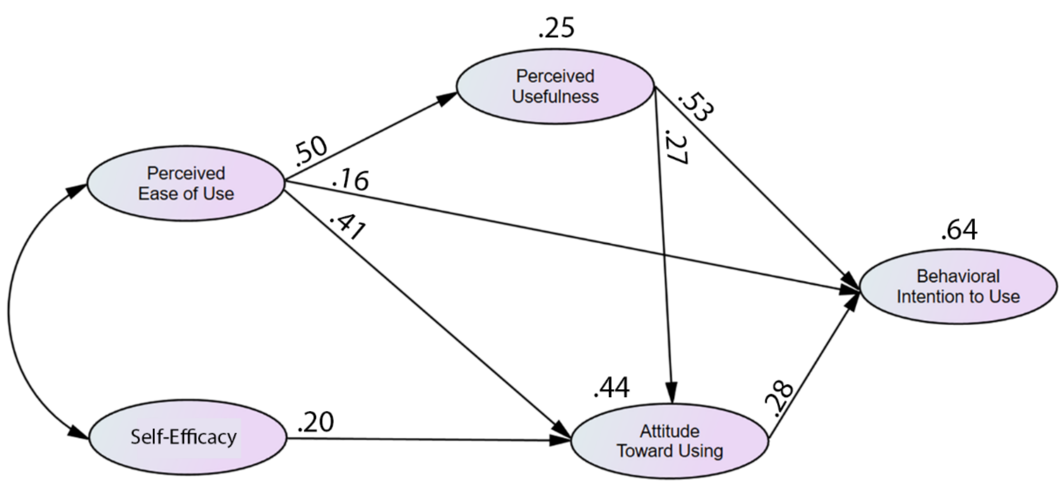


**Figure 4. The final model (non-significant paths were omitted for clearance of presentation)**

The literature suggests that a model's explanatory power is demonstrated by its high $R^2$s and by significant and substantial structural paths (close to .20 and ideally above .30) (Chin, 1988). Although the path between perceived ease of use and behavioral intention to use MUVEs was lower, it can be argued that small but significant interaction terms are also important (Chin, Marcolin, & Newsted, 2003). Seven out of nine hypotheses were supported by the data. The two hypotheses that were not supported are also not reflected in TAM (H2a and H2c). On the other hand, two of the hypotheses that were supported (H1c and H2b) are not reflected in TAM either. The first one was the path between perceived ease of use and behavioral intention to use MUVEs. Contrary to the findings in this study, the path linking them is not present in TAM. The second one was the path between self-efficacy and attitude toward use and that is because self-efficacy is not a construct in the original TAM. Overall, perceived ease of use accounted for 25% ($R^2 = .25$) of the variance in perceived usefulness. Perceived usefulness, perceived ease of use, and self-efficacy accounted for 44% ($R^2 = .44$) of the variance in attitude toward use. Most importantly, a substantial percentage ($R^2 = .64$, 64%) of the variance in the dependent variable in this study (behavioral intention to use MUVEs) was explained by the attitude toward use, perceived usefulness, and perceived ease of use. In the light of the above, it was concluded that the model had a good explanatory power.

As a final note, perceived usefulness and attitude toward use could act as mediator variables (constructs in a causal chain between two other constructs) in explaining behavioral intention to use MUVEs (Figure 2). Mediation models can provide a more accurate explanation for the causal effects the independent variables have on the dependent variable. For that matter, the bootstrapping technique described by Preacher and Hayes (2008) was used and it was found that: (a) the effects of perceived ease of use on behavioral intention to use MUVEs were partially mediated through both attitude toward use and PU, and (b) the effects of self-efficacy on behavioral intention to use MUVEs were fully mediated only through attitude toward use (Table 8).

**Table 8. Mediation results**

| Hypothesis | Direct effect | Indirect effect | Result |
|---|---|---|---|
| PEU → ATU → BIU | .21 (.001) | .13 (.001) | Partial Mediation |
| SE → ATU → BIU | -.09 (.066) | .06 (.002) | Full Mediation |
| PEU → PU → BIU | .16 (.003) | .35 (.001) | Partial Mediation |
| SE→ PU → BIU | -.08 (.066) | .01 (.856) | No effect |

Note. *p*-values reported in parenthesis

### *Results Analysis of the 3rd Group of Questions*

In the first question participants overwhelmingly stated that they are willing to use ready-made MUVEs in an educational context ($N = 270$, 83.08%). This percentage was much lower in the second question regarding their intention to develop, by themselves, educational MUVEs ($N = 177$, 54.45%).

Participants were asked to point out what they liked and disliked while developing their applications. On the positive side, the most common reply was that the virtual worlds can accurately represent reality ($N = 82$), followed by the notion that MUVEs constitute an innovative teaching method ($N = 48$), the many choices that the software has ($N = 44$), and that the graphics were impressive ($N= 43$). On the negative side, participants indicated that the software was quite difficult to learn and that it required advanced computer skills ($N = 136$). A variety of hardware and software problems was also pointed out, the most important being crashing downs and laggings ($N = 76$), installation problems ($N = 21$), that they could not undo a wrong action ($N = 30$), and that the inventory did not have a preview of the 3D items ($N = 21$). Programming was also a negative experience ($N = 29$) as well as the fact that the application was not in Greek ($N = 25$). Then again, 58 participants stated that they had nothing negative to report.

Participants were also asked to state the pros and cons of using MUVEs in an educational context. They pointed out that the realistic illustration of the virtual worlds can enhance students' learning experience (*N* = 108), that they can be entertaining and fun to use (*N* = 103), that they can attract the interest of students (*N* = 69), that they can stimulate students' imagination (*N* = 50) and creativity (*N* = 44). On the other hand, quite a large number of participants (*N* = 158) stated that the development of MUVEs is a time-consuming process. Participants were also afraid that students might find MUVEs difficult to use because they require advanced computer skills (*N* = 139) and that technical problems may arise (*N* = 57). They were also concerned that students might be confused or be cut off from reality (*N* = 70). Nothing negative was reported by 21 participants.

## DISCUSSION

In the present study, the TAM, with the addition of self-efficacy, was employed in order to understand and explain pre-service teachers' intention to use MUVEs when they become practicing teachers. Besides the $R^2$ of .64 for the dependent variable (behavioral intention to use MUVEs), it was found that perceived usefulness, perceived ease of use, and attitude toward use were significant determinants of the intention to use MUVEs, since the paths linking these model's constructs to behavioral intention to use were significant ($\beta$ = .53, $\beta$ = .16, and $\beta$ = .28 respectively). Attitude toward use was influenced by perceived ease of use, perceived usefulness, and self-efficacy beliefs ($\beta$ = .41, β = .27, and $\beta$ = .20 respectively), while perceived usefulness was significantly influenced by perceived ease of use ($\beta$ = .50). Overall, these results demonstrate that the final model adequately represents the relationships among the factors and possesses the power to explain pre-service teachers' intention to use MUVEs in education. Since attitude toward use, perceived usefulness, and perceived ease of use had a direct and significant influence on behavioral intention to use MUVEs, it can be inferred that when pre-service teachers have a positive attitude, believe that MUVEs can improve their work, make them more efficient and that they are easy to use, in all likelihood, they are going to use them. This finding is in line with current research supporting the idea that beliefs (perceived usefulness and ease of use), together with attitude, are significant determinants of students' intentions to use technology (e.g., Macharia & Pelser, 2014).

Research has highlighted the close relationship between attitude toward use and behavioral intention to use a given technology (e.g., Teo, 2010). In turn, pre-service teachers' positive attitude determines the extent to which technology is used because of the strong relationship between attitude and use (e.g., Huang & Liaw, 2005). On the other hand, in the present study, the path coefficient linking attitude toward use to behavioral intention to use MUVEs ($\beta$ = .28) was found to be significantly lower than that in other studies (e.g., Teo, 2012, $\beta$ = .52). This can be attributed to the differences between the depended variables of the studies. As shown in this study, perceived usefulness had a significant influence on behavioral intention to use MUVEs. This finding is in congruence with earlier studies in computer acceptance (Davis et al., 1989), suggesting that, when pre-service teachers understand how useful computers are, they will most likely use them.

Coming to attitude toward use, it was significantly influenced by perceived usefulness ($\beta$ = .27) and perceived ease of use ($\beta$ = .41), as Teo (2011) also suggested. This finding supports the idea that when the use of MUVEs, or any other ICT tool for that matter, is perceived to be an enhancement to one's productivity and is relatively free of effort, he/she will likely develop a positive attitude toward its use (Teo et al., 2009).

Although only 25% of the variance in perceived usefulness was explained, perceived ease of use seems to have a very strong influence on this factor ($\beta$ = .50). This finding is in line with previous studies (e.g., Luan & Teo, 2011). Student teachers will probably consider MUVEs as a productivity enhancement if their use is considered to be relatively effortless. The literature, as well as the initial TAM, suggests that perceived ease of use does not directly influence behavioral intention to use technology, but has an indirect effect on it through perceived usefulness and through attitude toward use (e.g., Teo, 2011). Quite interestingly, and contrary to this, the data analysis demonstrated that perceived ease of use, besides having a strong indirect effect on behavioral intention to use MUVEs through perceived usefulness and attitude toward use, it also had a direct effect on it, although not a strong one ($\beta = .16$). This is probably due to the different nature of the studies which examined the use of computers -in general- and not the use of MUVEs. In any case, taking together the direct and indirect effects on behavioral intention to use MUVEs, the strong effect on attitude toward use ($\beta = .41$), and the even stronger effect on perceived usefulness ($\beta = .50$), it seems that perceived ease of use is a very important construct that requires further and in-depth examination.

Self-efficacy beliefs seem to be the least important construct, having a rather small statistically significant direct effect only on attitude toward use ($\beta = .20$) and an even smaller indirect effect on behavioral intention to use MUVEs through attitude toward use. Actually, the role of self-efficacy beliefs is not very clear. In some studies, it was found to have a direct and significant influence on behavioral intention to use technology (e.g., Chen, Lin, Yeh, & Lou, 2013), or a small one only on perceived usefulness (Teo & Zhou, 2014). Target group differences and/or differences in the type of technology being evaluated are plausible explanations for the discrepancy in the findings.

Though an overwhelming majority of the participants stated that they would like to use ready-made MUVEs in their teaching, only half of them are willing to develop their own. This finding can be explained by viewing the participants' responses on what they disliked in the MUVEs DK. It seems that software and hardware problems, together with difficulties in using the software and the time needed for developing their applications were deemed as the most important disadvantages of MUVEs. These problems have significant implications for practice and it will be further elaborated in the coming section.

Finally, participants' responses to the model's five constructs were interesting per se. Though, on average, they were all above the mid-point, indicating a positive response (Table 1), self-efficacy beliefs and perceived ease of use had the lowest mean scores ($M = 3.11$, $SD = .92$ and $M = 3.08$, $SD = .77$ respectively). Given the problems that participants faced during the courses, it is quite logical not to expect them to respond very positively to the respective questions. On the other hand, attitude toward use and perceived usefulness had the highest mean scores ($M = 3.72$, $SD = .88$ and $M = 3.69$, $SD = .82$ respectively). This can be viewed as an indicator of how successful the courses were in shaping participants' attitude toward MUVEs and in making them understand their usefulness. Responses to the relevant behavioral intention to use MUVEs questions were also positive, though not as much as in attitude toward use ($M = 3.25$, $SD = .92$).

## *Implications for Practice*

There is a gap, a chasm as coined by Moore (1991), between the minority of the early -and enthusiastic- adopters of a technological innovation and the vast -and cautious- majority of its potential users. Then again, a committed minority (around 10% of a given population) is required to reverse the prevailing majority opinion (Xie et al., 2011). If the universities' administrators and educators, as well as the policy makers, are in support of the view that MUVEs, can play an important role in education in the near future, it is their responsibility to plan ahead of their time, to produce and foster that critical mass of passionate and devoted to technology teachers.

One way to achieve the above is to provide increased levels of access to the type of technology (namely MUVEs) that pre-service teachers will use in schools before they become practicing teachers. By doing so, they will gain experiences relevant to that technology, thus, the chance of becoming adept users will be amplified (Yuen, Law, & Chan, 1999). This, in turn, will probably enable them to adjust their instructional strategies and incorporate MUVEs in their teaching.

Most importantly, one has to understand how pre-service teachers' beliefs are formed, given that pre- and in-service teachers are driven by their beliefs in the way they think, teach, and learn (Sugar, Crawley, & Fine, 2004). The study's findings shed some light toward this direction. They suggest that perceived usefulness, perceived ease of use, and attitude toward use, exercise significant direct influence on students' intentions to use MUVEs when they become practicing teachers. Therefore, one has to find ways to positively influence the above factors.

Attitude toward computers, in general, affects the extent of which teachers use technology in their teaching (Teo, 2011). In order to facilitate positive attitudes, student teachers need to undergo discrete ICT training as suggested by Wong, Kamariah, and Tang (2006). Studies have also shown that attitude is very responsive to influences by organizational factors such as strong leadership, positive ethos, collaborative culture, and well-motivated and caring staff (Grainger & Tolhurst, 2005). Moreover, students' attitudes appear to be influenced by their lecturers (Margaryan, Littlejohn, & Vojt, 2011). Therefore, educators in higher education need to become a role model for students, by demonstrating well organized and innovative uses of MUVEs.

The perceived usefulness of MUVEs can be influenced when students see evidence of how they can help them to be more productive and effective in their teaching duties. For that matter, MUVEs, as all other ICT tools, should be linked to practice, providing experiences on how it can be applied to specific content areas (Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer, 2010).

One of the study's most significant findings was that perceived ease of use greatly affects all the other factors. Alas, most participants complained that the MUVEs DK was difficult to use, that the hardware requirements were high, and that, quite often, there were software problems. It is almost certain that these problems had a negative impact on students' views for MUVEs. Indeed, the steep learning curve to function effectively in a virtual environment is a cause of problems as noted by other researchers (e.g., Rhodes & Ralph, 2010). Basic activities are initially challenging and require some technological savvy users. But this seems to be a minor problem compared to that of developing MUVEs. Their development requires skills (e.g., knowledge of a programming language, ability to use software for creating or editing 3D models) that most educators do not have (Titov, Kulmamirov, & Titov, 2014). In addition, the time needed for designing a virtual environment is disproportionately larger compared to other types of computer applications (Fokides & Zampouli, 2016). Under certain circumstances, for example, courses that have very specific learning objectives, the effort involved is probably unjustifiable (Kluge & Riley, 2008). The above suggest that there are implications for software engineers and designers. Since an open source platform was used in the courses, one has to deal with the fact that most open source products have been criticized for having little (or no) emphasis on usability (Andreasen, Nielsen, Schrøder, & Stage, 2015). Given that pre-service teachers are by no means computer experts or power users, software engineers need to design more user-friendly tools. An even more important task is to redesign the whole content creation pipeline and make it more flexible and intelligent, in order to decrease the time of producing, maintaining and evolving these environments by orders of magnitude (Scacchi, 2012).

Research has shown that beliefs and attitudes do not remain static (e.g., Teo, 2012). In addition, due to the endless technological developments, new tools come into play. Users who now perceive technology to be useful and easy to use, may experience difficulties at a later time and develop avoidance behaviors. Since students expect to be engaged with technology at their place of learning (Gu, Zhu, & Guo, 2013), educators and administrators in higher education need to remain responsive to these changes, to constantly introduce new ICT tools, and to provide continuous professional development, in order students to keep abreast of the developments.

As a final note, the way that the courses were set-up, as it was presented in an earlier section, tried to encapsulate at least some of the above suggestions. Therefore, they can serve as an initial organizational model for other courses that examine the educational uses of MUVEs or similar ICT tools (e.g., augmented and virtual reality). Then again, on the basis of the study's findings, it seems that a lot more can and has to be done for improving their effectiveness and, subsequently, in influencing, to the better, students' views regarding how self-efficient they feel they are and how easy the use of MUVEs they think it is. By doing so, students' behavioral intention to use MUVEs might also become stronger.

### *Limitations*

There are limitations to this study that have to be taken into consideration. Since an online questionnaire was used, it is possible that only students who favor this survey method participated in the study. This may have affected the generalizability of the results. The inclusiveness of participants can be improved by collecting data using both online and pen and paper methods. Second, despite being meticulous in methodology, one can never be certain about the accuracy – or honesty – of the participants' answers. Third, data were collected from pre-service teachers in one Department of Education in Greece. Therefore, the study's results cannot be generalized to other samples. Finally, behavioral intention to use MUVEs was explained by four variables by 64%. Although this percentage is more than adequate, still a 36% remained unexplained. It is possible that some crucial factors were left out of the study. For example, beliefs about technology, self-esteem, and computer anxiety, as suggested by other researchers (e.g., Paraskeva, Bouta, & Papagianni, 2008) could have been included.

## Conclusion and Recommendations for Further Research

As mentioned in an earlier section, only a handful of courses instruct the future teachers on how to integrate MUVEs into their teaching. Therefore, the courses presented in this study are at the forefront of this field. Furthermore, and given the importance of the use of technology in the educational milieu, there is a considerable scope for an in-depth scrutiny of the factors that facilitate (or inhibit) the acceptance of various ICT tools among the stakeholders. Despite that, there are no studies examining the effectiveness of courses in shaping pre-service teachers' intention to use MUVEs when they become practicing teachers. Thus, the present study contributes to the existing research by:

- Demonstrating the applicability of the TAM as a model that can adequately explain pre-service teachers' intention to use MUVEs as practicing teachers.
- Determining that perceived usefulness, but primarily, perceived ease of use, are the most significant factors in influencing pre-service teachers' attitude and behavioral intention to use MUVEs.
- Outlining the interventions that need to be realized in order to increase the odds of a successful implementation of MUVEs in education.

On the other hand, further validations are required to examine whether the study's findings hold true under different contexts and thus increase its usefulness to the researchers. Given that pre- and in-service teachers are closely related groups, the model could be applied to both, to examine possible differences or whether the model is invariant in explaining their intentions to use MUVEs during their teaching duties. Since universities' curricula and practices vary, comparative studies across countries are needed to identify curricula invariant variables that influence pre-service teachers' intention to use MUVEs. Future studies may also compare different types of educators (e.g., primary and high school teachers) and different types of software tools. Time is a crucial factor; longitudinal studies may be conducted to trace behavioral changes experienced by pre-service teachers, for example, when they become in-service teachers. Self-efficacy requires further examination, since, in this study, only the one related to MUVEs was taken into consideration. Also, additional factors can be examined that contribute in shaping behavioral intentions. Finally, the applicability of the model suggested in this study can be tested to university courses that examine the educational uses of other types of emerging technologies.

Though researchers have disseminated the findings of innumerable studies demonstrating the significant educational benefits when using MUVEs, educators still continue to flounder alone. Piecemeal research agendas and poor implementation strategies will not affect a lethargic and resistant to changes educational system. By educating the future educators in MUVEs, or in any other technological innovation for that matter, experts and academics are pushing the envelope in education, progressively creating a critical mass of individuals positively inclined toward technology, which will hopefully bring the much needed educational reform. Consequently, despite the limitations mentioned in the previous section, the study's findings might prove to be useful to policy makers and teacher educators for planning and for curriculum development purposes, as well as to software engineers in order to make their tools more accessible to users.

## REFERENCES

Ajzen, I., & Fishbein, M. (1977). Attitude-behavior relations: A theoretical analysis and review of empirical research. *Psychological Bulletin, 84*(5), 888-918. doi: 10.1037/0033-2909.84.5.888

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour*. Englewood Cliffs, NJ: Prentice-Hall.

Andreasen, M. S., Nielsen, H. V., Schrøder, S. O., & Stage, J. (2015). Usability in open source software development: Opinions and practice. *Information Technology and Control*, *35*(3), 303-312.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Barbeite, F. G., & Weiss, E. M. (2004). Computer self-efficacy and anxiety scales for an Internet sample: Testing measurement equivalence of existing measures and development of new scales. *Computers in Human Behavior*, *20*(1), 1-15. doi: 10.1016/S0747-5632(03)00049-9

Barnett, M., Yamagata-Lynch, L., Keating, T., Barab, S. A., & Hay, K. E. (2005). Using virtual reality computer models to support student understanding of astronomical concepts. *The Journal of Computers in Mathematics and Science Teaching, 24*(4), 333-356.

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588. doi: 10.1037/0033-2909.88.3.588

Bertrand, M., & Bouchard, S. (2008). Applying the technology acceptance model to VR with people who are favorable to its use. *Journal of Cyber Therapy & Rehabilitation*, *1*(2), 200-210.

Burnham, K. P. & Anderson, D. R. (1998). *Model selection and inference: A practical information-theoretic approach*. New York: Springer-Verlag. doi: 10.1007/978-1-4757-2917-7

Chen, Y. C., Lin, Y. C., Yeh, R. C., & Lou, S. J. (2013). Examining factors affecting college students' intention to use web-based instruction systems: toward an integrated model. *Turkish Online Journal of Educational Technology, 12*(2), 111-121.

Chin, W. W. (1988). Issues and opinion on structural equation modeling. *MIS Quarterly, 22*, vii-xvi.

Chin, W. W., Marcolin, B. L., & Newsted, P. R. (2003). A partial least squares latent variable modeling approach for measuring interaction effects: Results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. *Information Systems Research*, *14*(2), 189-217. doi: 10.1287/isre.14.2.189.16018

Cho, B. H., Lee, J. M., Ku, J. H., Jang, D. P., Kim, J. S., Kim, I. Y., ... & Kim, S. I. (2002). Attention enhancement system using virtual reality and EEG biofeedback. *Proceedings of IEEE Virtual Reality, 2002*, 156-163. doi: 10.1109/VR.2002.996518

Chow, M., Herold, D. K., Choo, T. M., & Chan, K. (2012). Extending the technology acceptance model to explore the intention to use Second Life for enhancing healthcare education. *Computers & Education*, *59*(4), 1136-1144. doi: 10.1016/j.compedu.2012.05.011

Compeau, D. R., & Higgins, C. A. (1995). Computer self-efficacy: Development of a measure and initial test. *MIS Quarterly, 19*(2), 189-211. doi: 10.2307/249688

Costello, A. B., & Osborne, J. W. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation, 10*(7), 1-9.

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. doi: 10.1287/mnsc.35.8.982

DeVellis, R. F. (2003). *Scale development: Theory and applications* (2nd ed.). Newbury Park, CA: Sage Publications.

Dickey, M. D. (2005). Brave new (interactive) worlds: A review of the design affordances and constraints of two 3D virtual worlds as interactive learning environments. *Interactive Learning Environments, 13*(1-2), 121-137. doi: 10.1080/10494820500173714

Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly, 26*(2), 43-71. doi: 10.1002/piq.21143

Fokides, E. (2016). Pre-service teachers, computers, and ICT courses: A troubled relationship. *International Journal of Information and Communication Technology Education, 12*(4), 25-36. doi: 10.4018/IJICTE.2016100103

Fokides, E., & Zampouli, C. (2016). Content and Language Integrated Learning in OpenSimulator Project. Results of a pilot implementation in Greece. *Education and Information Technologies*. doi: 10.1007/s10639-016-9503-z

Fornell, C., Tellis, G. J., & Zinkhan, G. M. (1982). Validity assessment: A structural equations approach using partial least squares. In B. J. Walker, et al. (Eds.), *An assessment of marketing thought & practice* (pp. 405-409). Chicago: American Marketing Association.

Gaskin, J. (2013, May 2). *SEM series part 5a: Confirmatory factor analysis*. [Video file]. Retrieved from https://www.youtube.com/watch?v=MCYmyzRZnIY

Grainger, R., & Tolhurst, D. (2005). Organisational factors affecting teachers' use and perception of information and communications technology. *Proceedings of the South East Asia Regional Computer Confederation (SEARCC) Conference*, 13-22.

Gu, X., Zhu, Y., & Guo, X. (2013). Meeting the "Digital Natives": Understanding the acceptance of technology in classrooms. *Educational Technology & Society*, *16*(1), 392-402.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: International version* (7th ed.). New Jersey: Pearson.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis* (6th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Hew, K. F., & Cheung, W. S. (2010). Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research. *British Journal of Educational Technology, 41*(1), 33-55. doi: 10.1111/j.1467-8535.2008.00900.x

Hsu, M. K., Wang, S. W., & Chiu, K. K. (2009). Computer attitude, statistics anxiety, and self-efficacy on statistical software adoption behaviour: An empirical study of online MBA learners. *Computers in Human Behavior, 25*, 412-420. doi: 10.1016/j.chb.2008.10.003

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1-55. doi: 10.1080/10705519909540118

Huang, H. M., & Liaw, S. S. (2005). Exploring user's attitudes and intentions toward the web as a survey tool. *Computers in Human Behavior*, *21*(5), 729-743. doi: 10.1016/j.chb.2004.02.020

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement, 20,* 141-51. doi: 10.1177/001316446002000116

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (2nd ed.). New York: Guilford Press.

Kluge, S., & Riley, L. (2008). Teaching in virtual worlds: Opportunities and challenges. *Issues in Informing Science and Information Technology, 5,* 127-135. Retrieved from http://proceedings.informingscience.org/InSITE2008/IISITv5p127-135Kluge459.pdf

Lowry, P. B., & Gaskin, J. (2014). Partial least squares (PLS) structural equation modeling (SEM) for building and testing behavioral causal theory: When to choose it and how to use it. *IEEE Transactions on Professional Communication*, *57*(2), 123-146. doi: 10.1109/TPC.2014.2312452

Luan, W. S., & Teo, T. (2011). Student teachers' acceptance of computer technology. In T. Teo (Ed.) *Technology acceptance in education: Research and issues* (pp. 43-61). The Netherlands: Sense Publishers. doi: 10.1007/978-94-6091-487-4_3

Ludlow, B. L., & Hartley, M. D. (2016). Using Second Life for situated and active learning in teacher education. *Emerging Tools and Applications of Virtual Reality in Education, 96*. doi: 10.4018/978-1-4666-9837-6.ch005

Macharia, J. K. N., & Pelser, T. G. (2014). Key factors that influence the diffusion and infusion of information and communication technologies in Kenyan higher education. *Studies in Higher Education, 39*(4), 695-709. doi: 10.1080/03075079.2012.729033

Margaryan, A., Littlejohn, A., & Vojt, G. (2011). Are digital natives a myth or reality? University students' use of digital technologies. *Computers & Education, 56*(2), 429-440. doi: 10.1016/j.compedu.2010.09.004

Martin, S., Diaz, G., Sancristobal, E., Gil, R., Castro, M., & Peire, J. (2011). New technology trends in education: Seven years of forecasts and convergence. *Computers & Education, 57*(3), 1893-1906. doi: 10.1016/j.compedu.2011.04.003

McDonald, R. P., & Ho, M. R. (2002). Principles and practice in reporting structural equation analyses. *Psychological Methods, 7*(1), 64-82. doi: 10.1037/1082-989X.7.1.64

Meltzoff, A., Kuhl, P. K., Movellan, J., & Sejnowski, T. J. (2009) Foundations for a new science of learning. *Science, 325*, 284-288. doi: 10.1126/science.1175626

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999-2009). Computers & Education, *56*(3), 769-780. doi: 10.1016/j.compedu.2010.10.020

Mintz, R., Litvak, S., & Yair, Y. (2001). 3D-virtual reality in science education: An implication for astronomy teaching. *Journal of Computers in Mathematics and Science Teaching, 20*(3), 293-305.

Moore, G.A. (1991). *Crossing the chasm*. London, UK: Harper Collins.

O'Brien, R. M. (2007). A caution regarding rules of thumb for variance inflation factors. *Quality & Quantity*, *41*(5), 673-690. doi: 10.1007/s11135-006-9018-6

O'Neil, H. F., Wainess, R., & Baker, E. L. (2005). Classification of learning outcomes: Evidence from the computer games literature. *The Curriculum Journal, 16*(4), 455-474. doi: 10.1080/09585170500384529

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

Pan, Z., Cheok, A. D., Yang, H., Zhu, J., & Shi, J. (2006). Virtual reality and mixed reality for virtual learning environments. *Computers & Education, 30*(1), 20-28. doi: 10.1016/j.cag.2005.10.004

Paraskeva, F., Bouta, H., & Papagianni, A. (2008). Individual characteristics and computer self-efficacy in secondary education teachers to integrate technology in educational practice. *Computers & Education, 50*(3), 1084-1091. doi: 10.1016/j.compedu.2006.10.006

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879. doi: 10.1037/0021-9010.88.5.879

Podsakoff, P. M., & Organ, D.W. (1986). Self-reports in organizational research: Problems and prospects. *Journal of Management, 12*(4), 531-544. doi: 10.1177/014920638601200408

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods*, *40*(3), 879-891. doi: 10.3758/BRM.40.3.879

Rhodes, E., & Ralph, L. L. (2010). Information literacy and doctoral students: Avatars and educators collaborate for online distance learning. *Proceedings of the 2010 Informing Science & IT Education Conference, Cassino, Italy,* 227-235. Retrieved from http://proceedings.informingscience.org/InSITE2010/InSITE10p227-235Rhodes754.pdf

Scacchi, W. (2012). *The future of research in computer games and virtual world environments*. Irvine, CA: University of California.

Schneps, M. H., Ruel, J., Sonnert, G., Dussault, M., Griffin, M., & Sadler, P. M. (2014). Conceptualizing astronomical scale: Virtual simulations on handheld tablet computers reverse misconceptions. *Computers & Education, 70*, 269-280. doi: 10.1016/j.compedu.2013.09.001

Seidel, R. J., & Rubin, M. (1977). *Computers and communications: Implications for education*. New York, NY: Academic Press.

Selwyn, N. (1997). Students' attitudes toward computers: Validation of a computer attitude scale for 16-19 education. *Computers & Education, 28*, 35-41. doi: 10.1016/S0360-1315(96)00035-8

Squire, K., Barnett, M., Grant, J. M., & Higginbotham, T. (2004, June). Electromagnetism supercharged!: Learning physics with digital simulation games. *Proceedings of the 6th International Conference on Learning Sciences*, 513-520.

Steed, M. (2014). Virtual reality worlds for teacher education. In M. Searson & M. Ochoa (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 43-48). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Sugar, W., Crawley, F., & Fine, B. (2004). Examining teachers' decisions to adopt new technology. *Educational Technology & Society*, *7*(4), 201-213.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics*. Boston, Massachusetts: Pearson Education.

Teo, T. (2009). Modelling technology acceptance in education: A study of pre-service teachers. *Computers & Education, 52*(1), 302-312. doi: 10.1016/j.compedu.2008.08.006

Teo, T. (2010). Explaining the intention to use technology among volitional users in education: An evaluation of the Technology Acceptance Model (TAM) using structural equation modeling. *International Journal of Instructional Media, 37*(4), 379-389.

Teo, T. (2011). Factors influencing teachers' intention to use technology: Model development and test. *Computers & Education, 57*(4), 2432-2440. doi: 10.1016/j.compedu.2011.06.008

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. doi: 10.1080/10494821003714632

Teo, T. (2014). Unpacking teachers' acceptance of technology: Tests of measurement invariance and latent mean differences. *Computers & Education, 75*, 127-135. doi: 10.1016/j.compedu.2014.01.014

Teo, T., Lee, C. B., Chai, C. S., & Wong, S. L. (2009). Assessing the intention to use technology among pre-service teachers in Singapore and Malaysia: A multigroup invariance analysis of the Technology Acceptance Model (TAM). *Computers & Education, 53*, 1000-1009. doi: 10.1016/j.compedu.2009.05.017

Teo, T., Ursavas, O. F., & Bahcekapili, E. (2012). An assessment of pre-service teachers' technology acceptance in Turkey: A structural equation modelling approach. *The Asia-Pacific Education Researcher, 21*(1), 199-210.

Teo, T., & Zhou, M. (2014). Explaining the intention to use technology among university students: a structural equation modeling approach. *Journal of Computing in Higher Education*, *26*(2), 124-142. doi: 10.1007/s12528-014-9080-3

Titov, I., Kulmamirov, S., & Titov, E. (2014, April). Programming literacy level needed for modern teachers: Fragile border between content creator and a programmer. *Proceedings of the 2014 IEEE Global Engineering Education Conference (EDUCON), Istanbul, Turkey,* 667-669.

Wallace, L. G., & Sheetz, S. D. (2014). The adoption of software measures: A technology acceptance model (TAM) perspective. *Information and Management, 51*, 249-259. doi: 10.1016/j.im.2013.12.003

Wong, S. L., Kamariah, A. B., & Tang, S. H. (2006). Using a Student Centred Learning (SCL) approach to teach a discrete Information Technology (IT) course: The effects on Malaysian pre-service teachers' attitudes toward IT? *Technology, Pedagogy and Education*, *15*(2), 223-238. doi: 10.1080/14759390600769722

Xie, J., Sreenivasan, S., Komiss, G., Zhang, W., Lim, C., & Szymanski, B. K. (2011). Social consensus through the influence of committed minorities. *Physical Review E, 84*(1), 011130. doi: 10.1103/PhysRevE.84.011130

Yuen, H. K., Law, N., & Chan, H. (1999). Improving IT training for serving teachers through evaluation. In G. Cumming, T. Okamoto, & L. Gomez (Eds.), *Advanced research in computers and communications in education* (Vol. 2, pp. 441-448). Amsterdam: IOS Press.

Zheng, D. & Newgarden, K. (2011) Rethinking language learning: Virtual worlds as a catalyst for change. *International Journal of Learning and Media, 3*(2), 13-36. doi: 10.1162/ijlm_a_00067

## APPENDIX

Items in MAS

| Construct | Item | |
|---|---|---|
| Attitude Toward Using (6 items) | ATU1 | I am afraid using the MUVEs Developing Kit (DK) because I might render it inoperable* |
| | ATU2 | I hesitate to use the MUVEs in case I look stupid* |
| | ATU3 | I don't feel hesitant when using the MUVEs DK |
| | ATU4 | When I use the MUVEs DK, I feel uncomfortable/nervous* |
| | ATU5 | I hesitate to use the MUVEs DK for fear of making mistakes I can't correct* |
| | ATU6 | Using the MUVEs DK does scare me* |
| Perceived Usefulness (5 items) | PU1 | MUVEs can help me to improve my work |
| | PU2 | MUVEs can enhance my work to a degree which justifies the extra effort to create one |
| | PU3 | Why use MUVEs in education? There are easier ways to accomplish similar results* |
| | PU4 | MUVEs can allow me to do more interesting and imaginative work |
| | PU5 | MUVEs make my work more productive |
| Perceived Ease of Use (5 items) | PEU1 | Learning to use the MUVEs DK was easy for me |
| | PEU2 | It was easy for me to become skillful at using the MUVEs DK |
| | PEU3 | I find it easy to make the MUVEs DK do exactly what I want it to do |
| | PEU4 | Whenever I use the MUVEs DK, I need help because it is not easy for me to use it* |
| | PEU5 | I found the MUVEs DK easy to use |
| Self-Efficacy (4 items) | SE1 | Overall, I know quite well how to use most features of the MUVEs DK |
| | SE2 | I am able to use the MUVEs DK |
| | SE3 | I feel confident in using the MUVEs DK |
| | SE4 | I am able in making good MUVEs |
| Behavioral Intention to Use (4 items) | BIU1 | I will avoid using any MUVEs when I will work as a teacher * |
| | BIU2 | As a teacher, I will certainly use MUVEs |
| | BIU3 | I will use MUVEs only if l am obliged to* |
| | BIU4 | I will use MUVEs whenever I am given a chance to do so |

Note: * = Item for which scoring is reversed

## BIOGRAPHY

**Dr. Emmanuel Fokides** is a lecturer in the Department of Primary School Education, University of the Aegean, Greece. His courses focus on the educational uses of virtual reality, digital storytelling, augmented reality, and serious games. Since 1994, he has been involved in a number of research projects regarding distance and lifelong learning and the educational uses of virtual and augmented reality. His work is published in several conference proceedings, international volumes, and journals.