Predicting Undergraduate Students' Acceptance of Second Life for Teaching Chemistry

Zahira Merchant
San Francisco State University
momentszahira@gmail.com

Wendy Keeney-Kennicutt
Texas A and M University System - College Station
kennicutt@chem.tamu.edu

Ernest Goetz
Texas A and M University System - College Station
egoetz@tamu.edu

Abstract

This study used the technology acceptance model to explore undergraduate students' perceptions of the virtual world of Second Life (SL) and their intention to use it to learn a chemistry concept. A total of 136 undergraduate students participated in the study by completing a learning task in SL and a self-report measure consisting of 6 variables: perceived ease of use, perceived usefulness, perceived enjoyment, facilitating conditions, attitude, and intention to use. Structural equation modeling was used to test the technology acceptance model. Results supported 6 of the 7 hypothesized relationships. Most notably, perceived enjoyment, perceived usefulness, and attitude towards use predicted students' intention to use. Moreover, perceived ease of use did not influence students' attitude to use the technology. These findings suggest that even if students find SL difficult to use, its educational value and usefulness can overcome its difficulty in motivating them to use it.

Keywords: 3-D virtual world, 3-D virtual environments, chemical education, perceived enjoyment, user's experience, intention to use, attitude to use, perceived ease of use, perceived usefulness, and structural equation modeling analysis

Introduction

Second Life is a 3-D virtual world that allows its users the capability to create immersive simulations (Dawley & Dede, 2014). These simulations are considered to produce captivating experiences by replicating real world settings or creating experiences that are not possible in the real world. This unique pedagogical learning affordance of SL has attracted higher education science instructors to integrate this tool to promote students' engagement and meaningful learning. For example, Antoniou, Athanasopoulou, Dafli, and Bamidis (2014) used the multisensory immersive capability of SL to create virtual dental patients for undergraduate students to learn about periodontology. Menzel, Willson, and Doolen (2014) capitalized on the avatar creation capability of SL to promote the feeling of empathy and social justice among the nursing education undergraduate students in treating underprivileged patients. Beaumont, Savin-Baden, Conradi, and Poulton, (2014) exploited the capability of SL to create authentic scenarios for health care management and paramedic training.

In the field of chemistry education, there has been considerable use of 3-D virtual models to represent abstract chemistry concepts. Bivall, Ainsworth, and Tibell (2010) developed 3-D model of complex molecular interactions coupled with haptic feedback. Barak and Nater (2005) developed a 3-D representation of 150 types of mineral molecules available via a Web-based tool called the Virtual Museum of Mineral and Molecules. Schofield (2012) used a virtual reality simulation called it ViRILE (Virtual Reality Interactive Learning Environment) for undergraduate chemical engineers to absorb the process of configuring and operating a polymerization plant. However, during the literature review process, no studies were located that reported the use of SL for chemical education with the exception of one conducted by the authors. The authors have designed and developed several 3-D molecular simulations in SL demonstrating the concept of valence shell electron pair repulsion theory (VSEPR).

Second Life

Launched in 2003, SL is widely used in higher education for teaching a variety of subject matter (e.g., Merchant, Goetz, Kenney-Kennicutt, Cifuentes, & Davis, 2013, 2012; Burgess, Slate, Rojas-LeBouef, & LaPrairie, 2010; Richardson, Hazzard, Challman, Morgenstein, & Brueckner, 2010). Educators and educational researchers have acknowledged the capability of SL in supporting contemporary teaching approaches such as constructivism, situated learning, and collaborative learning (Dawley & Dede, 2014; De Jong, Savin-Baden, Cunningham, & Verstegen, 2014). Several features of SL lend themselves to promoting the learning process using contemporary teaching approaches. The SL users can create their own virtual digital self-representation, or avatar, that allow them to navigate the environment by walking, running, or flying. The virtual representation of oneself presents a sense of tele-presence—a feeling of almost being there, an experience where users have a sensation of being in the virtual spaces. Avatars have the ability to communicate with other avatars via text chat or voice-enabled chat. Avatars also can build 3-D objects in SL using design tools and Linden scripting language. Therefore, educators have used SL to develop models, simulations, historical recreations, scientific collaboration, and roleplaying scenarios tied to academic content.

The Technology Acceptance Model

Originating in the field of information systems, the technology acceptance model (TAM) is highly acclaimed in the field of human-computer interaction for predicting users' attitude and intention to use a technology. Davis (1989) developed the technology acceptance model adapting from the theory of reasoned action (Ajzen & Fishbein, 1980) and the theory of planned behavior (Ajzen, 1985). According to this model, perceived usefulness and perceived ease of use are the antecedents in predicting user attitudes towards adopting a technology. Further, attitude towards adopting a technology influences the intention to use the technology. According to Davis (1989), perceived ease of use has an indirect effect and perceived usefulness has a direct impact on intention to use, because perceived ease of use is associated with users' perception about the amount of effort it will take to be able to use the technology, and perceived usefulness is related to the contribution of technology in enhancing users' job-related performance.

Although TAM is regarded as a comprehensive model in the field of human computer interaction, Legris, Ingham, and Collerette (2003) recommended that adding external variables could further improve the predictive ability of TAM based on the outcome of their meta-analysis of TAM studies. One of the external variables is facilitating condition, which comprises environmental factors that either support or impede adoption decisions. Researchers have studied a variety of factors such as availability of software in the work environment, technical support, and administrative support as key facilitating conditions in the technology adoption process (Groves & Zemel, 2000; Lim & Khine, 2006). Many researchers have found a significant impact of facilitative condition on the predictive ability of TAM (Martins, Oliveira, & Popovic, 2014; Teo, 2011; Venkatesh & Davis, 2000).

Davis, Bagozzi, and Warshaw (1992) later added perceived enjoyment to the TAM model, identifying it as a factor of intrinsic motivation, with perceived usefulness and perceived usefulness as factors of extrinsic motivation. According to Davis et al. (1992, p. 1113), perceived enjoyment is "the extent to which the activity of using the computer is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated." Therefore, perceived enjoyment, defined as the gratification and satisfaction an individual experience while conducting any specific activity, can be considered a form of intrinsic motivation. According to

Davis et al., perceived enjoyment was complementary to perceived usefulness in influencing the intention to adopt a technology. Researchers have studied the direct and indirect effects of perceived enjoyment; however, there have been inconclusive results (Balog & Pribeanu, 2010; Suki & Suki, 2011; Teo & Noyes, 2011).

Although Davis (1989) first tested this model in the context of using an electronic mail system and text editor, TAM has been validated across several computer technologies including recruitment websites for job seekers, 3G mobile services, and K-12 teacher computer use (Kashi & Zheng, 2013; Suki & Suki, 2011; Teo & Noyes, 2011; Teo & Schaik, 2009). Specifically, at the higher education level, several studies have applied the technology acceptance model to investigate undergraduate students, deans, and faculty members' perception about online education (Gibson, Harris, & Colaric, 2008; Lee, Cheung, & Chen, 2005; Stewart, Bachman, & Johnson, 2010). Several studies have been reported on the acceptance of SL using TAM in higher education. Luse, Mennecke, and Triplett (2013) surveyed Master's of Business Administration (MBA) students enrolled in a graduate-level management information systems introductory course who were exposed to SL during the course activities. Further Singh and Lee (2008), Shen and Eder (2009), Chow, Herold, Choo, and Chan (2012) examined the undergraduate students' perception of accepting SL in their course work. These undergraduates were from the fields of hospitality management, business studies, and nursing. In the studies conducted by Saeed and Sinnappan (2013) and Fetscherin and Lattermann (2008), teachers, researchers, and students who used SL completed a survey to express their intentions to use SL for education in general. Although the technology acceptance model has been applied in the context of higher education and SL, currently, there is a dearth of research on undergraduate student perceptions about the use of SL in the area of chemistry. Thus, the purpose of this study was to explore the undergraduate students' acceptance of and intention to use SL for learning chemistry.

The model depicted in Figure 1 was adopted to test the following hypotheses to examine the validity of the extended TAM in the context of using SL for enhancing first-year chemistry students' learning experience.

H1 Perceived ease of use predicts perceived usefulness

H2 Perceived ease of use predicts attitude toward use

H3 Facilitating condition predicts perceived usefulness

H4 Perceived usefulness predicts attitude to use

H5 Perceived usefulness predicts intention to use

H6 Attitude toward use predicts intention to use

H7 Perceived enjoyment predicts intention to use

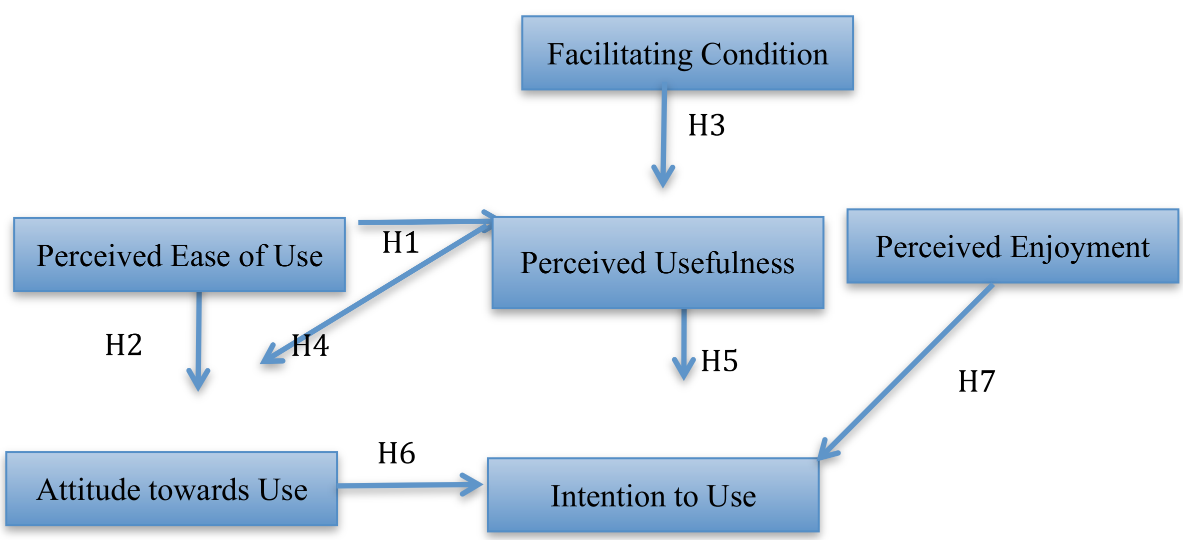

Figure 1: Hypothesized Model.

Method

Participants

Participants were 136 of the 255 undergraduate class students enrolled in a second-semester general chemistry course, Chemistry 102, at a large research university in the Southwest in Spring 2013. The students had first completed a SL activity, called the Molecule Game, earlier in the semester, to help them learn to navigate through the virtual world. The Molecule Game was created for a previous study on the SL environment's effectiveness on learning a chemistry concept (Merchant et al., 2012), The URL for the questionnaire and instruction related to completing the activity in SL was emailed to all participants. Among the participants, 97 (71%) were females and 125 (92%) were in the age range of 18 to 21 yrs. Most of the participants (104, 76%) had no prior experience with using SL before the semester began, and 108 (79%) identified themselves as non-gamers.

Instructional Activity

The students were provided with the instruction sheet to complete a self-paced activity in SL of interacting with the Molecule Builder. A screenshot of the Molecule Builder is shown in Figure 2. The Molecular Builder is open for public access and can be found in SL at http://maps.secondlife.com/secondlife/12th%20Man/223/208/26. The Molecule Builder allows the students to make a molecule of desired geometry appear ("rez") from a menu that consists of the following electronic geometric arrangements: linear, trigonal planar, tetrahedral, trigonal bipyramidal, and octahedral. After rezzing the geometric form of a molecule, students could rotate the molecule to view it from different 3-D perspectives, to change the identity of each atom in the molecule, or to select another electronic geometry from the list.

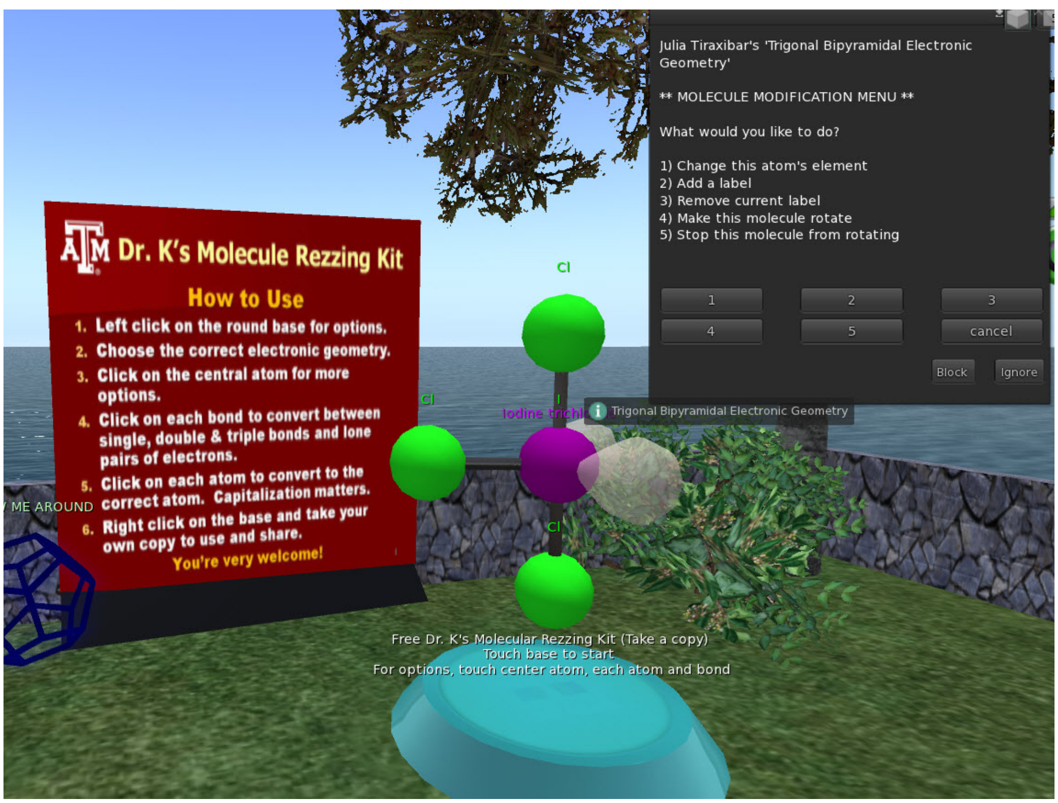

Figure 2. A Screenshot of the Molecule Builder and its Features.

Measures and Procedure

The participants of this study voluntarily completed a self-report questionnaire that included their demographic information and 25 items on perceived enjoyment, facilitating condition, perceived ease of use, perceived usefulness, attitude of use, and intention to use SL that were adapted from the work of previous researchers (Davis, 1989; Davis et al., 1992; Teo & Noyes, 2011). These items**,** which are shown in Table 1, were rated on a 5-point Likert-format scale, ranging from 1 – strongly disagree, to 5 – strongly agree.

Table 1.

Self-report Questionnaire

Construct	Item
Perceived usefulness	PM1 [Using the Molecule Builder in SL would have improved the quality of my understanding of VSEPR theory]
	PM2 [I felt that I was in control of my own learning about VSEPR theory using the Molecule Builder in SL.]
	PM3 [The Molecule Builder in SL would have enabled me to accomplish the task of learning about VSEPR theory easily]
	PM4 [The Molecule Builder in SL would have helped me learn about a very important topic, VSEPR theory]
	PM5 [Using the Molecule Builder in SL is an effective way to learn about VSEPR theory.]
	PM6 [Using the Molecule Builder in SL could have improved my class performance on VSEPR theory if it had been available.]
	PM7 [Using the Molecule Builder would have allowed me to learn more about VSEPR theory than would otherwise be possible.]
	PM8 [Using the Molecule Builder in SL could have enhanced my effectiveness in learning about VSEPR theory.]
	PM9 [Using the Molecule Builder in SL would have made it easier to do my school work on VSEPR theory.]
	PM10 [Overall I found that the Molecule Builder in SL would have been useful in my school work on VSEPR theory.]
Perceived ease of use	PEU1 [I found the the Molecule Builder in SL cumbersome and awkward to use.]
	PEU2 [Learning to interact with the Molecule Builder in SL was easy for me.]
	PEU3 [Interacting with the Molecule Builder in SL was often frustrating.]
	PEU4 [I found it easy to get the Molecule Builder in SL to do what I wanted it to do.]
	PEU5 [The molecular structures created by the Molecule Builder in SL were rigid and inflexible to interact with.]
	PEU6 [It is easy for me to remember how to perform tasks using the the Molecule Builder in SL.]
	PEU7 [My interaction with the the Molecule Builder in SL was intuitive and easy to figure out.]
	PEU8 [Interacting with the Molecule Builder in SL required a lot of mental effort.]
Perceived enjoyment	PE1 [I enjoyed working with Molecule Builder in SL]
Facilitating	FC1 [When encountered with difficulties in using Molecule Builder in SL, I knew

condition	where to seek]
	FC2 [When encountered with difficulties in using Molecule Builder in SL, I was given timely assistance]
	FC3 [When encountered with difficulties in using Molecule Builder in SL, the instructor provided assistance]
Attitude towards use	ATU1 [I expect that when I am introduced to SL again, I will be highly interested in learning about another chemistry concept using SL]
Intention to use	ITU1 [I intend to use the Molecule Builder or a similar program in SL to improve my understanding of chemistry concepts]
	ITU2 [I look forward for other such opportunities to use the Molecule Builder or another activity in SL to help me learn about a chemistry concept]

Data Analysis

The SEM method was used to test the hypothesized relationship between the observed and latent variables included in the model. SEM models random errors in the observed variables, which results in more precise measurements. Another affordance of SEM includes the measurement of each latent variable by multiple indicators (Bollen, 1989). Using the standard two-step approach to SEM (Kline, 2010), the first phase involves estimating measurement models for all the latent variables in the model. The measurement model, also known as confirmatory factor analysis (CFA) model, describes how well the observed indicators measure the unobserved (latent) variables. In the second step, the structural part of SEM is estimated. This part specifies the relationships among the exogenous latent variables. To obtain reliable results in SEM, researchers recommend a sample size of at least 100 – 150 cases (e.g. Kline, 2010).

The Mplus 9 statistical package, which assumes normality of the data, was used in the analysis. A variance, co-variance matrix was used to test the proposed interrelationships among the six variables included in this study (perceived enjoyment, facilitating condition, perceived ease of use, perceived usefulness, attitude of use, intention to use). All the free parameters in the model were estimated and evaluated for statistical significance. We used multiple indices for assessing measurement and structural model fit. These indices are comparative fix index (CFI), root mean squared error of approximation (RMSEA), and standardized root mean square residual (SRMR).

Results

Descriptive Statistics

The descriptive statistics for each item are shown in Table 2. All the mean scores were at or above the midpoint of 2.5, with a range of 2.49 to 3.40, except for the variable of facilitating condition, which had a mean of 2.05. The standard deviations range from 0.90 to 1.19. The skewness index and kurtosis index showed acceptable ranges and followed Kline’s (2010) recommendations that the skew and kurtosis indices should not exceed |3| and |10|, respectively, to ensure normality of the data; therefore, the data in this study were regarded as normal for the purposes of SEM. A correlation matrix including all variables is presented in Table 3.

Table 2.

Descriptive Statistics of the Variables Included in the Measurement Model

Construct	Item	*M*	*SD*	Skewness	Kurtosis
Perceived usefulness					

	PM1	2.69	0.90	0.66	-0.04
	PM2	2.49	1.03	0.70	-0.26
	PM3	2.75	0.98	0.32	-0.73
	PM4	2.62	0.94	0.67	-0.55
	PM5	2.64	0.99	0.58	-0.47
	PM6	2.89	0.90	0.35	-0.51
	PM7	3.00	0.93	0.22	-0.88
	PM8	2.63	0.91	0.75	-0.20
	PM9	2.78	0.97	0.17	-0.63
	PM10	2.73	0.97	0.37	-0.69
Perceived ease of use					
	PEU1	2.71	1.19	-0.01	-1.38
	PEU2	2.73	1.17	0.45	-0.81
	PEU3	3.10	1.19	-0.19	-1.07
	PEU4	2.64	0.95	0.56	-0.41
	PEU5	3.14	0.91	-0.41	-1.11
	PEU6	2.62	0.97	0.57	-0.24
	PEU7	3.40	1.00	-0.60	-0.40
	PEU8	2.74	1.01	0.62	-0.65
Perceived enjoyment					
	PE1	2.88	1.17	0.32	-0.97
Facilitating condition					
	FC1	2.46	1.00	0.26	-0.82
	FC2	2.50	0.90	-0.03	-0.45
	FC3	2.07	0.77	0.07	-0.85
Attitude towards use					
	ATU1	2.87	1.09	0.29	-0.79
Intention to use					
	ITU1	3.18	3.18	-0.15	-0.93
	ITU2	3.04	1.14	0.10	-0.85

Table 3.

Results of Discriminant Validity for Measurement Model

	PEU	PU	FC	ITU
PEU	(0.68)			
PU	0.51	(0.79)		
FC	0.26	0.27	(0.97)	
ITU	0.32	0.62	0.40	(0.85)

Diagonal in parentheses = square root of average variance extracted from observed variables and off diagonal = correlations between constructs.

Evaluation of the Measurement Model

The measurement model was assessed using confirmatory factor analysis (CFA). This was conducted with Mplus using the maximum likelihood estimation procedure (MLE). MLE is a popular and robust procedure for use in the SEM and assumes multivariate normality of the observed variables (Schumaker & Lomax, 2010). Table 4 shows the results of the CFA. All the parameter estimates were significant at $p < 0.001$. The standardized estimates of relationship between each item and the latent factor ranged from 0.43 – 0.99 and were regarded as acceptable following the guidelines of Hair, Black, Babin, and Anderson (2010) and Steven (1992). In addition, most of the R^2 values were above 0.50, suggesting that the items included in each construct had explained more than half the amount of variance of the latent variable (construct) to which they belonged. Of the construct tested in the measurement model analysis phase, we removed one of the three items from the construct of intention to use. We removed the item due to its low and statistically non-significant factor loading value (Bowen & Guo, 2011).

Table 4.

Results of Measurement Model

Factors/Model Fit Indices	Items	Factor Loadings/ *p*-value	R^2	Cronbach alpha
Perceived Usefulness				0.94
	PM1	0.84(0.00)	0.70	
CFI = 0.91	PM2	0.71(0.00)	0.51	
TLI = 0.88	PM3	0.80(0.00)	0.64	
SRMR = 0.04	PM4	0.76(0.00)	0.58	
RMSEA = 0.14	PM5	0.81(0.00)	0.67	
	PM6	0.83(0.00)	0.69	
	PM7	0.76(0.00)	0.57	
	PM8	0.81(0.00)	0.66	
	PM9	0.77(0.00)	0.59	
	PM10	0.80(0.00)	0.64	

Perceived Ease of Use				0.88
	PEU1	0.73(0.00)	0.53	
CFI = 0.93	PEU2	0.79(0.00)	0.62	
TLI = 0.90	PEU3	0.74(0.00)	0.54	
SRMR = 0.05	PEU4	0.67(0.00)	0.47	
RMSEA = 0.14	PEU5	0.43(0.00)	0.18	
	PEU6	0.67(0.00)	0.45	
	PEU7	0.56(0.00)	0.31	
	PEU8	0.79(0.00)	0.62	
Facilitating Conditions				0.82
CFI = 0.93	FC1	0.99(0.00)	0.97	
TLI = 0.90	FC2	0.98(0.00)	0.96	
SRMR = 0.05	FC2	0.96(0.00)	0.93	
RMSEA = 0.14				

Convergent Validity

Convergent validity was tested following Kline's (2010) guidelines of consulting factor loadings to determine whether the observed variables were significantly related to their corresponding constructs. The range of the factor loadings for each construct is presented in Table 4. Hair, Black, Babin, Anderson, and Tatham (2006) recommend that the factor loadings should be 0.50 or higher and ideally should be 0.70 or higher. The factor loadings of all items were statistically significant ($p < 0.01$), and most of the factor loadings ranged between 0.51 and 0.91, indicating an overall high construct validity of the factors. For the item PEU 5, the factor loading was below the threshold established by Hair et al. (2006). However, this can be deemed conservative because Stevens (1992) recommended a lower threshold where factor loadings of 0.40 and above are acceptable. Therefore, because the factors loading for PEU 5 of 0.43 met the criteria established by Steven (1992), we decided to proceed further with the analysis.

Reliability coefficients alpha were calculated for the scores pertaining to each observed variable. As can be seen from Table 4, all the coefficients were above the generally acceptable level of 0.70. The construct of perceived enjoyment and attitude to use are single-item constructs. According to Diamantopoulos, Marko, Fuchs, Kaiser, and Wilczynski (2012), a single-item measurement can adequately represent a concept under certain situations. Several researchers have used single item versus multiple item measures to capture psychological construct such as self-esteem and have found no difference between on the outcome using either measure (Bergkvist & Rossiter, 2007). We believe that the constructs of perceived enjoyment and attitude to use are concrete and uni-dimensional in nature and, therefore, can be represented by a single item. For measurements with a single item (e.g., perceived enjoyment), it is not possible to calculate the reliability coefficient. Therefore, according to Hair et al. (2006), decisions regarding the reliability of a measure with single item can be determined based on researcher's best judgment; thus, the two single-item scales (Perceived Enjoyment and Attitude towards Use) were accepted for use in the analyses. Overall, it was assumed that each measurement model indicated an acceptable level of construct validity.

Discriminant validity

Discriminant validity was examined by comparing the square root of the average variance (AVE) extracted for construct included in the structural model with the correlations between the construct and all other constructs. When the square root of the AVE of a construct is greater than the off-diagonal elements in the corresponding rows and columns, a construct is likely to be more strongly correlated with its indicators than with the other constructs in the model (Fornell, Tellis, & Zinkhan, 1982); thus, it was concluded that the criterion for discriminant validity was met. As presented in Table 4, the diagonal elements in the correlation matrix for all the constructs were larger than were their correlations with other constructs, suggesting the condition of satisfactory discriminant validity was fulfilled.

Evaluation of the Structural Model

A test of the structural model showed a good model fit (χ^2 = 319.246, p < 0.001; CFI = 0.92; SRMR = 0.06; RMSEA = 0.15). Figure 3 shows the results of the hypotheses test and path coefficients of the proposed structural model. All the model estimates were statistically significant and in the hypothesized direction. The results showed that six out of seven hypotheses were supported by the data. The only hypothesis that was not supported was H2, which perceived ease of use would predict attitude to use. Overall, the model explained 59% (R^2 = 0.59) of the variance in intention to use, 48% (R^2 = 0.48) in perceived usefulness, and 24% (R^2 = 0.24) in attitude toward use. As hypothesized: perceived ease of use was a strong, positive, predictor of perceived usefulness (H1); facilitating condition was a strong, positive, predictor of perceived usefulness; perceived usefulness was a strong, positive, predictor of attitude to use (H3); perceived usefulness was strongly and positively correlated with intention to use (H5); attitude to use was strongly and positively correlated with intention to use (H6); and perceived enjoyment was strongly and positively related to intention to use (H7).

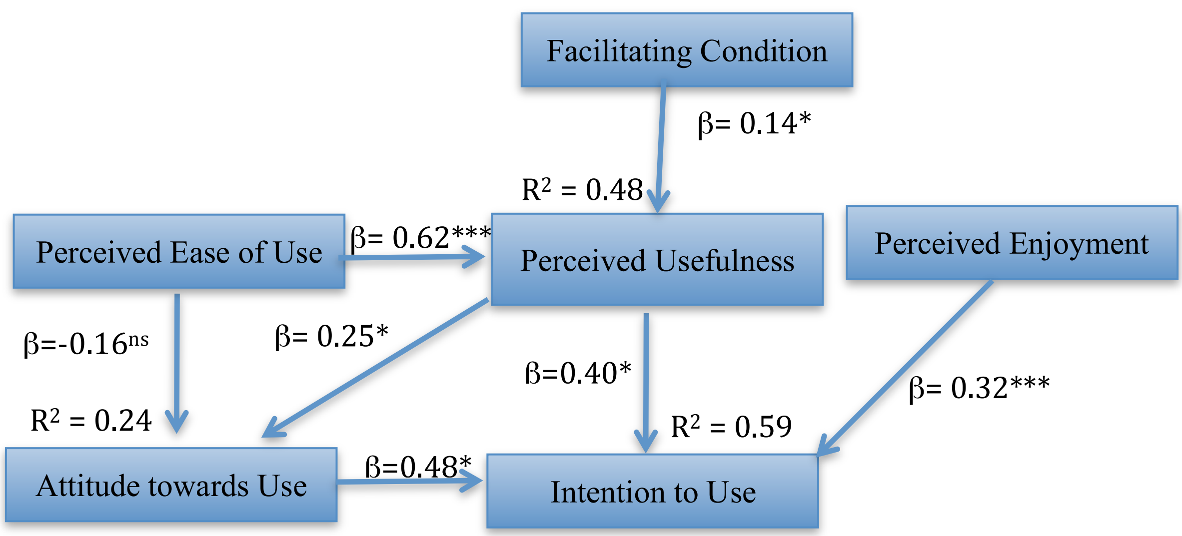

Figure 3. Results of the Tests of the Structural Model.

*** Co-efficient is significant at the 0.001 level (2-tailed)

** Co-efficient is significant at the 0.01 level (2-tailed)

* Co-efficient is significant at the 0.05 level (2-tailed)

ns Co-efficient is non-significant

Discussion

The aim of this study was to explore undergraduate students' intention to use SL for learning chemistry utilizing the technology acceptance model (TAM). Overall, TAM accounted for nearly

60% of the variance in students' intention to use SL. As confirmed by the analyses, perceived usefulness, attitude to use, and perceived enjoyment had direct influence on students' intention to use Second Life for learning chemistry. The variable of intention to use had the strongest relationship with perceived usefulness. These results are consistent with the earlier research conducted using TAM to study end users' intention (Davis, 1989; Davis et al., 1992; Teo, 2011; Venkatesh, & Davis, 2000). A similar validation of this relationship was reported in a comprehensive meta-analysis conducted by King and He (2006) on the technology acceptance model. Perceived usefulness has consistently been a significant antecedent in predicting users' intentions. The chemistry students in this study might have found SL useful because they could visualize 3-D representation of molecules, which were not possible using 2-D images. Moreover, the students were able to manipulate the molecules and this interaction may have enhanced their understanding of the VSEPR theory. Therefore, the students found the SL tool meaningful in learning this chemistry concept.

Attitude toward use was a statistically significant predictor of the students' intention to use, indicating that when students have a positive outlook towards using SL, this outlook can boost their intention to use SL for learning chemistry, which might lead to the use of this technology. In the TAM literature, limited studies have integrated the variable of attitude towards use in the model and the outcome of its influence on intention to use has been inconsistent. While Lee et al. (2005) reported a positive association of attitude and intention of undergraduate students to use Internet-based learning medium technology, Teo and Schaik (2009) reported non-significant association between pre-service teachers' attitude and intention to integrate technology in their teaching. The authors' analysis is reasonable because pre-service teachers assumed integrating technology into teaching as a mandatory component, therefore their attitude did not account for the intention to use, as opposed to Lee et al. (2005) wherein students were volunteering to use the new technology. This result can be further confirmed based on the outcome of this study where a statistically significant relationship was found between undergraduate chemistry students' attitude and intention to use SL.

The hypothesized relationship between perceived enjoyment and intention to use was strong and statistically significant. This indicates that students, along with finding SL useful in enhancing their chemistry learning experience, also found the experience gratifying. This outcome is also consistent with other studies that have included perceived enjoyment as an exogenous variable (Teo, 2011; Venkatesh, & Davis, 2000). Unlike other studies (Agarwal & Karahanna, 2000; Venkatesh, & Davis, 2000), it was assumed in this study that perceived enjoyment has direct effects on intention to use, attitude to use, and perceived usefulness. The results supported the assumption that if users find technology enjoyable, the likelihood that they will use the technology in the future is enhanced.

The variables of facilitating condition and perceived ease of use were hypothesized to have an impact on the intention to use through perceived usefulness and attitude to use, respectively. The outcome suggests that facilitating conditions had an indirect influence through perceived usefulness on the intention to use SL. The variable of facilitating condition was included in this study because SL is known to have a steep learning curve due to its complex environment. The authors particularly scaffolded students' navigational experience in SL such that they were subjected to minimal extrinsic cognitive load (Sweller, 1994). The process of scaffolding was undertaken because the authors wanted to have least impediment in students' learning process by imposing demands on their cognitive resources. Not many researchers have included facilitating condition as one of the predicting variables in the technology acceptance model. Teo and Schaik (2009) hypothesized facilitating condition to positively influence intention through perceived ease of use and attitude to use and found affirming results. This suggests that although users are willing to venture into exploring the technology, facilitating conditions will help alleviate any frustrations caused due to the initial encounter with the interface of the tool.

On the other hand, perceived ease of use was influential in creating its impact on the perceived usefulness but perceived ease of use and attitude to use did not have a significant relationship. The impact of perceived ease of use has been inconsistent in the technology acceptance model research literature where studies have shown strong positive impact (Chow, Herold, Choo, & Kitty

Chan, 2012; Teo & Noyes, 2011; Teo & Schaik, 2009), as well as a weak relationship of perceived ease of use with other variables (Kashi & Zheng, 2013; Singh & Le, 2008; Shen & Eder, 2009). The strong relationship suggests that although users are willing to learn and to integrate new technology, the first encounter could be intimidating and, therefore, if technology appears less complex and cumbersome to use, this might positively influence the users' intention. On the other hand, the weak relationship suggests that complex navigation did not interfere with their positive attitude towards using SL. This is contrary to some of the previous studies that found a positive influence of perceived ease of use as a strong and significant antecedent influencing users' attitudes. It is likely that in the case of this study, students were willing to invest greater efforts in using SL because they found this environment could measurably enhance their learning.

Conclusion

This study made a unique contribution in informing the higher education instructor about the possible acceptance of virtual worlds, e.g. SL, in learning chemistry. The expanded technology acceptance model was adopted to include original variables of perceived ease of use, perceived usefulness, and attitude to use, as well as the external variable of facilitating condition and the emotional variable of perceived enjoyment. These findings suggest that even if students find SL difficult to use, its educational value and usefulness will surpass its difficulty in motivating them to use it. This study's outcome validated results from the previous studies that were conducted using TAM to study the intention of use for SL.

Limitations and Contributions

One possible limitation of the study might be the result of collecting data from second semester general chemistry students at a large southern public Tier 1 research university. This sampling of students might not be representative of all college students within the university as well as across the country. Secondly, this survey was administered online, and students responded voluntarily. It is likely that students who responded had stronger opinions about using SL than did non-respondents. In spite of these limitations, this study makes a significant contribution in examining the students' intentions for using SL in a chemistry undergraduate course. In this study the usual variables were included (i.e. intention to use, attitude to use, perceived usefulness, and perceived ease of use) but other important variables were added: perceived enjoyment and facilitating condition. The results were encouraging for using virtual worlds, such as SL, in higher education. This might revolutionize the methodology used in higher education to teach some of the most abstract concepts that science students have difficulty in understanding. Incorporating virtual worlds might, in turn, help alleviate some of the pressing problems that higher education is facing in the STEM area.

Implication for Practice and Future Research

The implications of these findings can inform those educators who are interested in integrating 3-D virtual worlds such as SL into their educational goals. Higher education instructors should be able to successfully integrate SL into their teachings if its features are capitalized to enhance learning experiences. Higher education students are willing to explore complex 3-D environment such as SL if they perceive the environment meaningful. Another significant component of successfully integrating 3-D virtual worlds technologies in higher education is the element of enjoyment. When students perceive the environment to be enjoyable they become more emotionally vested in the learning process. This might result in prolonged engagement with the learning environment and enriching the learning experience (Smith, Sheppard, Johnson, & Johnson, 2013).

Another noteworthy implication that can inform higher education instructors is that although the SL interface might seem to be complicated, students are willing to surpass the challenge and explore the environment. However, supporting them during the exploration phase is extremely essential. Providing instructional videos, handouts, and consultation with their instructors can help sustain students' motivation in this undertaking.

To validate further the results of this study, future research can be conducted by applying the model tested in this study in the context of teaching other chemistry concepts. These concepts may include but are not limited to those which involve the exploration of 3-D nature of molecules. In addition, further research can be conducted using variables such as computer efficacy, prior experience with virtual worlds, and subjective norm. The research agenda could be further expanded to include moderator variables of gender or computer proficiency level.

References

Merchant, Z., Goetz, E., Keeney-Kennicutt, W., Cifuentes, L., & Davis, T, J. (2014). Effectiveness of virtual reality-based instruction on students learning outcomes in K-12 and Higher Education: A meta-analysis. *Computers & Education, 70,* 29- 40.

Merchant, Z., Goetz, E., Keeney-Kennicutt, W., Kwok, O., Cifuentes, L., & Davis, T, J. (2013). Exploring 3-D Virtual Reality Technology for Spatial ability and Chemistry Achievement. *Journal of Computer Assisted Learning, 29*, 579 - 590.

*Merchant, Z., Goetz, E., Keeney-Kennicutt, W., Kwok, O., Cifuentes, L., & Davis, T, J. (2012). The learner characteristics, features of desktop 3d virtual reality environments, and college chemistry instruction: A structural equation modeling analysis. *Computers & Education, 59,* 551- 568.

Agarwal, R., & Karahanna, E. (2000). Time flies when you're having fun: Cognitive absorption and beliefs about information technology use. *MIS Quarterly, 24,* 665-694.

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckman (Eds.), *Action-control: From cognition to behavior* (pp. 11-39). Heidelberg: Springer. http://dx.doi.org/10.1007/978-3-642-69746-3_2

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

Antoniou, P. E., Athanasopoulou, C. A., Dafli, E., & Bamidis, P. D. (2014). Exploring design requirements for repurposing dental virtual patients from the Web to Second Life: A focus group study. *Journal of Medical Internet Research, 16.* http://dx.doi.org/10.2196/jmir.3343

Balog, A., & Pribeanu, C. (2010). The role of perceived enjoyment in the students' acceptance of an augmented reality-teaching platform: A structural equation modeling approach. *Studies of Informatics and Control, 19*, 319-330.

Barak, P., & Nater, E. A. (2005). The Virtual museum of minerals and molecules: Molecular visualization in a virtual hands-on museum. *Journal of Natural Resources and Life Sciences Education, 34*, 67-71.

Beaumont, C., Savin-Baden, M., & Conradi, E., & Poulton, T. (2014). Evaluating a *Second Life* problem-based learning (PBL) demonstrator project: What can we learn? *Interactive Learning Environments, 22*, 125-141.

Bergkvist, L. & Rossiter, J. R. (2007). The predictive validity of multiple-item versus single-item measures of the same constructs. *Journal of Marketing Research, 44* (2), 175-184.

Bivall, P., Ainsworth, S., & Tibell, L. A. E. (2010). Do haptic representations help complex molecular learning? *Science Education, 95*, 700-719. http://dx.doi.org/10.1002/sce.20439

Bollen, K. A. (1989). *Structural equations with latent variables*. New York, NY: John Wiley & Sons.

Burgess, M., Slate, J. R., Rojas-LeBouef, A., & LaPrairie, K. (2010). Teaching and learning in *Second Life*: Using the community of Inquiry Model to support online instruction with graduate students in instructional technology. *Internet and Higher Education, 13*, 84-88. http://dx.doi.org/10.1016/j.iheduc.2009.12.003

Bowen, N. K., & Guo, S. (2011). *Structural equation modeling*. New York, NY: Oxford University Press.

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

Davis, F. D. (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology, *MIS Quarterly, 13*, 319-340. http://dx.doi.org/10.2307/249008

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1992). Extrinsic and intrinsic motivation to use computers in the workplace. *Journal of Applied Social Psychology, 22,* 1111-1132.

Dawley, L., & Dede, C. (2014). Situated learning in virtual worlds and immersive simulations. *Handbook of Research on Educational Communications and Technology,* 723-734. http://dx.doi.org/10.1007/978-1-4614-3185-5_58

De Jong, N., Savin-Baden, M., Cunningham, A. M., & Verstegen, D. M. L. (2014). Blended learning in health education: Three case studies. *Perspectives on Medical Education*, 278-288. http://dx.doi.org/10.1007/s40037-014-0108-1

Diamantopoulos, A., Marko, S., Fuchs, C., Kaiser, S., & Wilczynski, P. (2012). Guidelines for choosing between multi-item and single-item scales for construct measurement: A predictive validity perspective. *Journal of the Academy of Marketing Science, 40,* 434-449. http://dx.doi.org/10.1007/s11747-011-0300-3

Fetscherin, M., & Lattermann, C. (2008). User acceptance of virtual worlds. *Journal of Electronic Commerce Research, 9,* 231-242.

Fornell, C., Tellis, G. J., & Zinkhan, G. M. (1982). *Validity assessment: A structural equations approach using partial least squares*. Proceedings from the American Marketing Association Educators' Conference.

Gibson, S. G., Harris, M. L., & Colaric, S. M. (2008). Technology acceptance in an academic context: Faculty acceptance of online education. *Journal of Education for Business, 83,* 355-359. http://dx.doi.org/10.3200/JOEB.83.6.355-359

Groves, M. M., & Zemel, P. C. (2000). Instructional technology adoption in higher education: An action research case study. *International Journal of Instructional Media, 27*, 57-65.

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 Education Inc.

Hair, J. F., Black, W. C., Babin, B. J., and Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Upper Saddle River, NJ: Pearson Education Inc.

Kashi, K., & Zheng, C. (2013). Extending technology acceptance model to the E-recruitment context in Iran. *International Journal of Selection and Assessment, 21*, 121-129. http://dx.doi.org/10.1111/ijsa.12022

Kline, R. B. (2010). *Principles and practice of structural equation modeling* (2nd ed.). New York, NY: Guilford Press.

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information Management, 43*, 740-755. http://dx.doi.org/10.1016/j.im.2006.05.003

Lee, M. K. O., Cheung, M. K. C., Chen, Z. (2005). Acceptance of Internet-based learning medium: The role of extrinsic and intrinsic motivation. *Information & Management, 42*, 1095-1104. http://dx.doi.org/10.1016/j.im.2003.10.007

Legris, P., Ingham, J., & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model. *Information & Management, 40,* 191-204. http://dx.doi.org/10.1016/S0378-7206(01)00143-4

Lim, C. P., & Khine, M. S. (2006). Managing teachers' barriers to ICT integration in Singapore schools. *Journal of Technology and Teacher Education, 1*, 97-125.

Luse, A., Mennecke, B., & Triplett, J. (2013). The changing nature of user attitudes toward virtual world technology: A longitudinal study. *Computers in Human Behavior,* 29, 1122-1132. http://dx.doi.org/10.1016/j.chb.2012.10.004

Martins, C., Oliveira, T., & Popovic, A. (2014). Understanding the Internet banking adoption: A unified theory of acceptance and use of technology and perceived risk application. *International Journal of Information Management, 34*(1), 1-13. http://dx.doi.org/10.1016/j.ijinfomgt.2013.06.002

Menzel, N., Willson, L. H., & Doolen, J. (2014). Effectiveness of a poverty simulation in Second Life®: Changing nursing student attitudes toward poor people. *International Journal of Nursing Education Scholarship*.

Richardson, A., Hazzard, M., Challman, S. D., Morgenstein, A. M., & Brueckner, J. K. (2010). A "Second Life" for gross anatomy: Applications for multiuser virtual environments in teaching the anatomical sciences. *Anatomical Science Education, 4*, 39-43. http://dx.doi.org/10.1002/ase.195

Saeed, N., & Sinnappan, S. (2013). Adoption of second life in higher education: Comparing the effect of utilitarian and hedonic behaviors. *International Journal of Virtual and Personal Learning Envrionments, 4,* 1 -18. http://dx.doi.org/10.4018/jvple.2013040101

Schofield, D. (2012). Mass effect: A chemical engineering education application of virtual reality simulator technology. *MERLOT Journal of Online Learning and Teaching, 8,* 63-78.

Schumaker, R. E., & Lomax, R. G. (2010). *A beginner's guide to structural equation modeling* (3rd ed). New York, NY: Routledge.

Shen, J., & Eder, L. B. (2009). Intentions to use virtual worlds for education. *Journal of Information Systems Education, 20*, 225-223.

Singh, N., & Lee, M. J. (2008). Exploring perceptions towards education in 3-D virtual environments: An introduction to "Second Life". *Journal of Teaching in Travel and Tourism, 8*, 315-326.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2013). Pedagogies of Engagement: Classroom-based Practices. *Journal of Engineering Education, 94*, 87-101. http://dx.doi.org/10.1002/1.2168-9830.2005.tb00831.x

Stevens, J. P. (1992). *Applied multivariate statistics for the social sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Stewart, C., Bachman, C., & Johnson, R. (2010). Predictors of faculty acceptance of online education. *MERLOT Journal of Online Learning and Teaching, 6,* 597-616.

Suki, N. M., & Suki, N. M. (2011). Exploring the relationship between perceived usefulness, perceived ease of use, perceived enjoyment, attitude and subscribers' intention towards using 3G mobile services. *Journal of Information Technology Management, 22*, 1-7.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*, 295-312. http://dx.doi.org/10.1016/0959-4752(94)90003-5

Teo, T. (2011). Factors influencing teachers' intention to use technology: Model development and test. *Computers and Education, 57*, 2432-2440.

Teo, T., & Noyes, J. (2011). An assessment of the influence of perceived enjoyment and attitude on the intention to use technology among pre-service teachers: A structural equation modeling approach. *Computers & Education, 57*, 1645-1653. http://dx.doi.org/10.1016/j.compedu.2011.03.002

Teo, T., & Schaik, P. (2009). Understanding technology acceptance in pre-service teachers: A structural equation modeling approach. *Asia-Pacific Education Researcher, 18*, 47-66. http://dx.doi.org/10.3860/taper.v18i1.1035

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*,186-204. http://dx.doi.org/10.1287/mnsc.46.2.186.11926