The Role of Perceived Enjoyment in the Students' Acceptance of an Augmented Reality Teaching Platform: a Structural Equation Modelling Approach

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Abstract: Motivation is an important factor in modern education and it is claimed that a high level of motivation is a prerequisite for success. Augmented reality (AR) technologies are creating a new kind of user experience (UX) able to increase students' interest and engagement in the learning process. This study is one of the few attempts to investigate the role of perceived enjoyment in the students' acceptance of an augmented reality teaching platform (ARTP). Our model captures both extrinsic (perceived usefulness and ease of use) and intrinsic (perceived enjoyment) motivators so that students's intention to use a new learning environment may be explained.. The model was tested by employing structural equation modelling. The results showed that perceived usefulness and perceived enjoyment have a significant impact on the behavioural intention to use ARTP, while perceived ease of use is not a significant direct antecedent. The perceived enjoyment has been proved to be the key influencing factor of intention to use the ARTP.

Keywords: technology acceptance, perceived enjoyment, augmented reality, structural equation modelling, usability

1. Introduction

This work reports on a technology acceptance study of an AR-based teaching platform which was developed in the framework of the ARiSE (Augmented Reality for School Environments) research project. The main objective of this project was to test the pedagogical effectiveness of introducing augmented reality teaching platforms in primary and secondary schools. ARTP is featuring a desktop AR technology (Wind et al, 2007) that creates a new kind of user experience by bringing real life objects into a computing environment. In our study, ARTP has both a pragmatic and hedonic character. On the one hand, it should be easy to use and useful for learning. On the other hand, it should provide with an enjoyable learning experience. An important research goal was to investigate the extent to which this learning environment is enhancing the students' motivation to learn. To address the project's objectives, we developed a usability questionnaire as a measurement model that goes beyond the traditional usability evaluation approaches, by targeting the educational and motivational value of the ARTP.

User experience is an emerging research topic in the area of HCI so there is neither a consensus on its definition nor a mature methodology for evaluation (Law et al., 2009). Several approaches are taking a holistic view by including both pragmatic and hedonic aspects in order to enrich the existing quality models (Hassenzahl & Tractinsky, 2006). For Cockton (2006), UX evaluation is useful in the context of some intended value. Roto (2006) analysed UX as an integrating umbrella that includes worth-centred design, usability, hedonic aspects and acceptance. These approaches suggest that the evaluation of interactive systems should go beyond pragmatic or hedonic aspects measured in isolation and investigate the user acceptance in order to understand the various factors that influence the intention to use. By incorporating user experience constructs, a technology acceptance model could bring useful insights on the causal relations between UX and other factors that are influencing the behavioural intention to use. Of particular interest for the area of educational systems is the relationship between hedonic and pragmatic aspects which are underlying the motivational and educational value of a given e-learning technology.

A well-known model aiming to explain and predict technology acceptance is TAM (Technology Acceptance Model), developed and validated by Davis (1989), and Davis et al. (1989). The TAM model posits that two beliefs, perceived ease of use and perceived usefulness, determine one's behavioural intention to use a technology. In a later study, Davis et al. (1992) introduced perceived enjoyment in the model as an intrinsic motivation and defined perceived usefulness as an extrinsic motivation. Perceived enjoyment was defined as "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" (Davis et al., 1992). On this basis, perceived enjoyment is a form of intrinsic motivation and emphasizes on the pleasure and inherent satisfaction derivated from the specific activity. They found that the perceived usefulness had a large significant effect on the intention to adopt a technology and its influence was complemented by the perceived enjoyment. Other researchers have also distinguished the effects of extrinsic and intrinsic motivation on the individual's acceptance of various information technologies (Agarwal & Karahanna, 2000; Heijden, 2004; Shang et al., 2005; Teo et al., 1999; Venkatesh, 1999, 2000). Although there are many studies targeting learning in virtual environments (Krauss et al, 2009; Thorsteinsson et al, 2010) as well as several studies targeting motivational aspects in e-learning (Keller, 2006; Lee et al., 2005) as far as we know, there is no acceptance model reported for AR-based educational systems.

The purpose of this paper is twofold: (a) to evaluate the validity of the measurement model and (b) to explore the causal relationships between the factors influencing the user acceptance of the ARTP. The rest of this paper is organized as follows. In the next section we will describe the research model and hypotheses. The methodological framework is briefly presented in section 3. The results of the measurement model evaluation and the structural model testing are presented in section 4. The paper ends with discussion, conclusion and limitations in section 5.

2. Research Model and Hypotheses

We hypothesized that the intention to use ARTP in schools is influenced both by extrinsic motivational factors (Perceived Ease of Use and Perceived Usefulness), and intrinsic motivational factors (Perceived Enjoyment). In addition, the extrinsic and intrinsic motivational factors are influenced, both directly and indirectly, by the ergonomics of the ARTP. In this study, the intention to use is a practical approximate measure of acceptance and of actual use. Because all students possess no experience in using augmented reality technology, it is deemed more accurate to measure students' intention rather than their actual use. The proposed research model is illustrated in Figure 1. The relationships between factors are labelled with the number of the corresponding hypothesis. The specific elements of the model and related hypotheses are further detailed below.

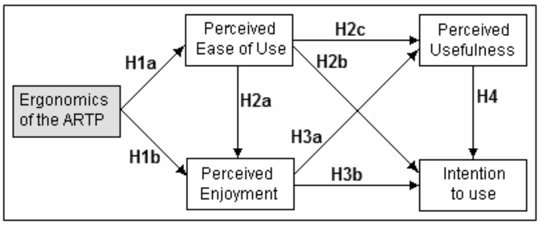

Figure 1. The research model.

The impact of system features on perceived ease of use and perceived enjoyment has been documented in numerous studies in TAM research (e.g., Heijden, 2004; Bruner II & Kumar, 2005). The ergonomics of the ARTP refers to the features related to hardware and accessories that can help students develop favourable (or unfavourable) perceptions regarding the motivational factors. It provides a better understanding of what influences motivational factors and their presence guide the actions required to determine a greater use. From a learner's point of view the ease of use is likely to be influenced by the devices used to perform specific tasks. Although some specific AR accessories and /or devices may be less easy to use than other devices (e.g. mouse), they may provide greater intrinsic motivation to learners, as their novelty and versatility will result in an element of interest and pleasure associated with their usage. Therefore, we propose the following hypotheses:

Hypothesis 1a. Ergonomics of the AR platform has a positive effect on perceived ease of use.

Hypothesis 1b. Ergonomics of the AR platform has a positive effect on perceived enjoyment.

Perceived ease of use (PEOU) has been theorized and empirically validated as either an antecedent or a consequence of perceived enjoyment (PE): PEOU → PE, and PE → PEOU, respectively. PE is a typical UX factor that is contributing to the overall technology acceptance. In their research, Sun & Zhang (2006) showed that "an examination of previous literature reveals that both causal directions between PE and PEOU have been proposed and confirmed". Many researchers suggested that the type of the system (utilitarian or hedonic) and the nature of tasks should be considered in proposing the causal direction between PEOU and PE (Heijden, 2004; Sun & Zhang, 2006; Chesney, 2006; Venkatesh, 2000). PEOU refers to the ease of use of a particular learning application implemented onto ARTP. Therefore, we propose the causal direction from PEOU to PE:

Hypothesis 2a. Perceived ease of use has a positive effect on perceived enjoyment.

The influence of perceived ease of use on perceived usefulness in TAM research has been empirically confirmed in literature (Venkatesh, 2000). Also, there is extensive empirical evidence that perceived ease of use is significantly linked to intention to use, both directly and indirectly via its impact on perceived usefulness (see Sun & Zhang, 2006 for a review). In this study, perceived ease of use is a determinant of perceived usefulness because, assuming other things being equal, students consider ARTP more useful when it is more free-effort. Furthermore, if ARTP is perceived to be easy to use, then the students are more likely to have a higher degree of intention to use it. For this, the following hypotheses are stated:

Hypothesis 2b. Perceived ease of use has a positive effect on intention to use.

Hypothesis 2c. Perceived ease of use has a positive effect on perceived usefulness.

In this study, perceived enjoyment was postulated as an intrinsic motivator for using ARTP and is targeting various aspects that create an enjoyable learning experience: interesting way of learning, captivating exercises, attractive technology, and real objects manipulation, funny and exciting way of learning. An intrinsic motivation variable such as perceived enjoyment is supposed to lead to enhanced perceptions of extrinsic motivation such as perceived usefulness. People with a favourable perception of the enjoyment of a system are more likely to perceive it useful (Sun & Zhang, 2008). Other studies showed that enjoyment had a positive effect on the usefulness in the user acceptance of various systems and technologies: e-learning systems (Yi & Hwang, 2003), search engines (Liaw & Huang, 2003), instant messaging (Li et al., 2005). Thus, we hypothesize that:

Hypothesis 3a. Perceived enjoyment has a positive effect on perceived usefulness.

It has been proposed that perceived enjoyment is able to significantly influence the intention to use. The rationale is that individuals who experience pleasure or enjoyment from using a system are more likely to form an intention to use it than others (Davis et. al., 1992). This relationship has received a good amount of empirical support: Internet learning (Lee et al., 2005), interfaces agents (Serenko, 2008), Second Life virtual platform (Shen et al., 2009), web portal (Van der Heijden, 2004). If students perceive the use of ARTP as enjoyable, they are more likely to have a favourable perception and a higher degree of intention to use it. Thus:

Hypothesis 3b. Perceived enjoyment has a positive effect on intention to use.

Perceived usefulness has been confirmed in numerous previous studies to be a robust determinant of intention to use (e.g., Venkatesh, 2000; Sun & Zhang, 2006). Almost all of the prior studies tested the effect of perceived usefulness on the intention to use. The perceived usefulness explains the educational value of ARTP. This is an extrinsic motivation of using ARTP for e-learning which is targeting specific pedagogical aspects, such as faster understanding, support for learning and usefulness for the learning process. Thus:

Hypothesis 4. Perceived usefulness has a positive effect on intention to use.

3 Research Methods

3.1 Equipment, participants and tasks

ARTP is a "seated" AR environment: users are looking to a see-through screen where virtual images are superimposed over the perceived image of a real object placed on the table (Wind & Bogen, 2007). Two AR-based learning scenarios were implemented on this platform. The test was conducted on the ICI's platform which is equipped with 4 AR modules. A total number of 139 students (13-14 years old), from which 65 boys and 74 girls tested the platform. All were 8th grade students and they were enrolled in 3 general schools in Bucharest. None of them was familiar with the AR technology. The students came in groups of 7-8, accompanied by a teacher.

Each student tested the platform twice: once for the Biology scenario and second time for the Chemistry scenario. Each scenario consists of a demo lesson and a number of exercises. After testing, the students were asked to answer the questionnaire. In order to ascertain the representativeness of the data, we analyzed responses from the first data set (Biology scenario) and then compared the results with the second data set (Chemistry scenario). A simple paired sample t-test analysis showed that there was no significant difference ($p>0.05$) between the two sets of data on the variable utilized in this study. These results suggested that it was appropriate to combine the two data sets.

3.2 Methodology

Based on Hair et al. (2006) and the study of Koufteros et al. (2001), our steps and methods included instrument development, an exploratory study, a confirmatory study, and a test of the structural model, as shown in Figure 2.

The steps (1) and (2) are related to the development of the measurement model which was described in more detail in a previous paper (Balog & Pribeanu, 2009). In the step (1), the instrument development was carried on in a methodological framework for scales development and validation which is grounded on the Churchill (1979) paradigm. In the step (2), exploratory study, the data were gathered by means of a questionnaire. The questionnaire consisted of 28 items measuring the five constructs (Appendix 1). A five-point Likert scale ranging from (1) "strongly disagree" to (5) "strongly agree" was used.

In total, 278 responses were gathered and used for analysis. In order to comply with the statistical hypotheses for multivariate analysis methods (Tabachnick & Fidell, 2007), we carried on an iterative procedure (Balog & Pribeanu, 2009). Data processing resulted in a substantial improvement of normality criteria by a successive elimination of 24 observations with univariate and multivariate outliers. The final sample (N=254) had a moderated deviation from normality and was further used in our study.

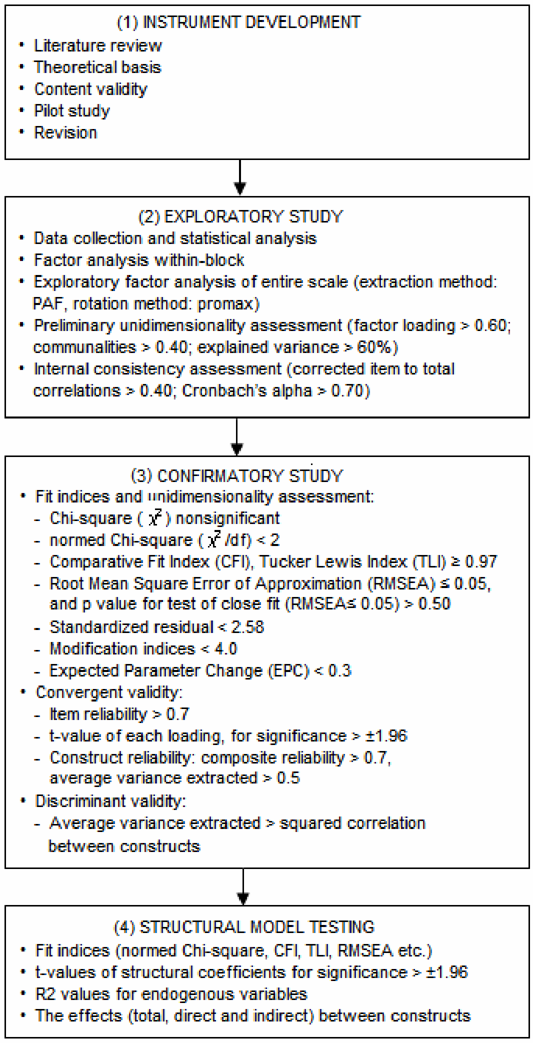

Figure 2. Steps and methods used

The focus of this paper is the evaluation of the measurement properties through Confirmatory Factor Analysis (CFA), the step (3), and the testing of the structural model using Structural Equation Modelling (SEM) approach, the step (4). The five-factor solution generated by exploratory factor analysis (Balog & Pribeanu, 2009) was used as an initial model consisting of 5 latent constructs predicted by 19 indicators. The covariance matrix from the specified measurement model was input into AMOS 16.0 (Arbuckle, 2007). A two-step approach was used, based on Anderson & Gerbing (1988). First, the measurement model was evaluated using confirmatory factor analysis to test the overall fit of the model, as well as its validity and reliability. Second, the hypotheses were analyzed with the structural model. SEM estimation procedure was maximum likelihood estimation.

4 Results

4.1 Measurement model

A number of alternative goodness-of-fit measures are available. In this research we selected indices and cut-off values according to recommendations from Schermellech-Engel et al., (2003), Hair et al. (2006), and Byrne (2001).

The fit indices for the initial model point to conflicting conclusions about the extent to which this model actually matches the observed data (Table 1). The *p*-value of the Chi-square (χ^2=231.825, df=142) was 0.000, and it was statistically significant. A significant χ^2 suggests the model does not fit the sample data. In contrast, a non-significant χ^2 is indicative of a model that fits the data well (Byrne, 2001). The following fit indices suggest a good model fit: χ^2 /df=1.633, SRMR=0.046, and RMSEA=0.05 (90% CI: 0.038-0.061, *p*-value=0.486). The other fit indices suggest only an acceptable fit: TLI=0.951, CFI=0.965. We concluded that the initially hypothesized model does not fit the data well enough. Therefore, it was modified in an iterative process, by examining the standardized residuals and the modification indices, until a good model (for both statistical and theoretical reasons) was achieved.

Based on both statistical results and their relevance, two items were successively eliminated: INT1 ("I would like to have this system in school") and ERG2 ("Adjusting the stereo glasses is easy"). Therefore, the revised measurement model included 17 items describing five latent constructs. The model quality improved as shown in Table 1: a significant decrease of χ^2 (231.825-162.131=69.694), however, *p*-value of the Chi-square (χ^2=162.131, df=109) was 0.000, and was statistically significant. The other fit indices reached their respective good fit levels: χ^2/df=1.487, SRMR=0.038, RMSEA=0.044 (90% CI: 0.029-0.058, *p*-value=0.756), TLI=0.965, CFI=0.972.

Table 1. Fit indices for the measurement model

Goodness of fit measure	Recommended cut-off values (Good Fit)	The initial model	The revised model
Chi square (χ^2)	$0 \leq \chi^2 \leq 2df$	231.825	162.131
p value	$0.05 < p \leq 1.00$	0.000	0.001
Chi square / degree of freedom (χ^2/df)	$0 \leq \chi^2/df \leq 2$	1.633	1.487
Root Mean Square Error of Approximation (RMSEA)	$0 \leq RMSEA \leq 0.05$	0.050	0.044
p value for test of close fit (RMSEA < 0.05)	$0.10 < p \leq 1.00^{*}$ $p>0.50^{**}$	0.486	0.756
Confidence Interval (CI)	left bound of CI=0.00 right bound of CI<0.06**	0.038-0.061	0.029-0.058
Standardized Root Mean Square Residual (SRMR)	$0 \leq SRMR \leq 0.05$	0.046	0.038
Tucker-Lewis Index (TLI)	$0.97 \leq TLI \leq 1.00$	0.951	0.965
Comparative Fit Index (CFI)	$0.97 \leq CFI \leq 1.00$	0.959	0.972

*Schermellech-Engel et al., (2003), **Byrne (2001, p.85).

Convergent validity was assessed by examining the item reliability, the loadings and their statistical significance through *t*-values, composite reliability and average variance extracted. The results are presented in Table 2. An examination of item reliability (R^2) revealed that three items (i.e., ERG5, PEOU2, and PE4) did not meet the 0.50 criterion (Koufteros, 2001). Due to the fact that ERG5, PEOU2, and PE4 are very important items for explaining usability and intention to use of ARTP, none of them was eliminated. Standardized loading for all variables in each construct are in the range 0,695 (PEOU2) - 0,844 (INT3), i.e. over the minimum recommended level of 0.60 (Hair et al., 2006). Table 2 shows that the loadings are statistically significant, each item exceeds the critical ratio ($t>1.96$) at the 0.001 level of significance.

Table 2. Results of convergent and discriminant validity tests

Construct / Item	Std. factor loading	Std. err.	Critical ratio	(R^2)	CR	AVE
ERG					**0.748**	**0.599**
ERG1	0.841	- [a]	-	.708		
ERG5	0.701	.092	9.723	.492		
PEOU					**0.884**	**0.559**
PEOU1	0.725	-	-	.525		
PEOU2	0.695	.093	10.577	.484		
PEOU6	0.712	.089	10.825	.506		
PEOU7	0.799	.085	12.149	.638		
PEOU8	0.768	.095	11.680	.589		
PEOU10	0.781	.079	11.878	.610		
PE					**0.830**	**0.550**
PE1	0.746	-	-	.556		
PE4	0.696	.090	10.312	.485		
PE5	0.763	.085	11.243	.583		
PE6	0.759	.094	11.186	.576		
PU					**0.788**	**0.553**
PU1	0.716	-	-	.513		
PU2	0.717	.091	9.773	.514		
PU4	0.796	.101	10.395	.633		
INT					**0.809**	**0.679**
INT2	0.804	-	-	.647		
INT3	0.844	.147	6.888	.712		

[a] Indicates a parameter fixed at 1.0 in the original solution

As shown in Table 2, the composite reliability (CR) of each construct is above the minimum recommended level of 0.70 (Fornell & Larcker, 1981), ranging from 0.748 for ERG (Ergonomics of the AR platform) to 0.884 for PEOU (Perceived Ease of Use). The values of average variance extracted (AVE) are all above the minimum recommended level of 0.50 (Fornell & Larcker, 1981), ranging from 0.550 for PE (Perceived Enjoyment) to 0.679 for INT (Intention to Use). Among the AVEs of the constructs, intention to use had the highest value of 0.679, indicating that 67.9% of the variance in the specified indicators was accounted for by the construct.

Discriminant validity was evaluated with the test of squared correlations recommended by Anderson & Gerbing (1981): the squared correlation between two constructs should be smaller than the estimation of the AVE of each construct. Table 3 shows the squared correlation of each pair of constructs and the AVE measures.

Table 3. Squared correlations and average variation extracted

	ERG	PEOU	PE	PU	INT
ERG	**0,599**				
PEOU	0,537	**0,559**			
PE	0,340	0,297	**0,550**		
PU	0,294	0,331	0,378	**0,553**	
INT	0,073	0,104	0,161	0,151	**0,679**

The numbers of the off-diagonal represent squared correlations between the constructs.

The numbers of the diagonal (bold) are the AVEs by each construct. The AVEs for all constructs displayed on a diagonal (in bold) exceeded 0.50 as recommended by Fornell & Larcker (1981). Next, all squared correlations between two constructs (off-diagonal elements) were found to be smaller than the average variance extracted measures of both constructs. As a result, each construct shared more variance with its items than it shared with other constructs, thereby fully satisfying the requirements for discriminant validity.

4.2 Structural model testing

Structural equation modelling (SEM) was performed to test the fit between the research model and the obtained data. This technique is chosen for its ability to examine a series of dependence relationships simultaneously, especially where there are direct and indirect effects among constructs within model. The structural model relates the constructs to one another. The path significance of each hypothesized association in the structural model and the variance explained (R^2) by each path are examined. Fig. 3 shows the standardized path coefficients, and the coefficients of determination (R^2) for each endogenous construct.

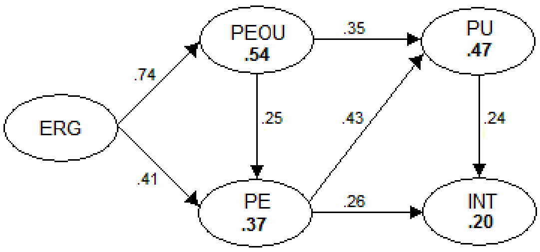

Figure 3. Results of the structural model testing

The same fit indices considered for the confirmatory factor analysis were employed for the structural model testing. The Chi-square value of 163,715 (df=112) is significant at p<0.001. However, the result of the χ^2/df value is within the recommended χ^2/df<2. Given the known problem of the chi square test in SEM (Byrne, 2001) it is more beneficial to use alternative indices. We assessed the model fit using other common fit indices. The results show the evidence of a good model fit: SRMR=0.039, RMSEA=0.043 (90% CI: 0.028-0.056, *p*-value=0.799), TLI=0.967, CFI=0.973.

The analytical results showed that ERG has a positive effect on PEOU (β=0.74, t value=8.64, p<0.001) and PE (β=0.41, t value=3.18, p<0.001), providing support for hypotheses H1a and H1b. PEOU has a significant and positive effect on PE (β=0.25, t value=2.13, p<0.05) and on PU (β=0.35, t value=4.30, p<0.001), supporting H2a and H2c. The path between PEOU and INT is insignificant (β=0.77, t value=0.419), so H2c is not supported. PE has a positive effect on PU (β=0.43, t value=4.99, p<0.001) and INT (β=0.26, t value=2.50, p<0.05). Thus, H3a and H3b are supported. Furthermore, PU was found to have a positive effect on INT (β=0.24, t value=2. 27, p<0.05), this supporting H4. Seven of the eight hypothesized relationship were found to be significant, and were accepted, which means that the model was well conceptualized and demonstrated a good fit with the data.

The model explained substantial variance in PEOU (R^2=0.54), PU (R^2=0.47) and PE (R^2=0.37), and moderate variance in INT (R^2=0.20). ERG explained 54% of the variance contained in PEOU. ERG and PEOU had a significantly positive effect on PE by explaining 37% of the variance. PEOU and PE together explained 47% of the variance in perceived usefulness. However, the perceived enjoyment contributed more to the perceived usefulness than the perceived ease of use.

5. Discussion and Conclusion

5.1 Outcomes

The study's findings add further evidence for the adaptability and applicability of TAM in explaining behaviour, in this case, students' intention to use of ICT in learning. Furthermore, the significance of perceived usefulness shows that TAM can be successfully applied, even when the behaviour in question is not one of pure system usage. From a substantive point of view, we examined how extrinsic and intrinsic motivational factors related to an augmented reality teaching platform can influence the student behaviour, specifically, the intention to use it. Our results show that both perceived enjoyment (an intrinsic motivational factor) and perceived usefulness (an extrinsic motivational factor) are important.

This study found that PE is a stronger determinant of PU than PEOU (β=0.43, and β=0.35, respectively), suggesting that an enjoyable learning experience is increasing the usefulness of the ARTP. Also, the influence of PE was slightly higher than that of PU on INT (β= 0.26, and β= 0.24, respectively). Thus, PE can be as important as, if not more important than, PU in determining the behavioural intention to use ARTP. This finding is consistent with several prior studies (e.g., Heijden, 2004).

From the point of view of measuring the contribution of UX-related factor, this research confirms the robustness of PE in influencing PU and intention to use. PE has a direct impact on the intention to use in addition to an indirect impact via the PU. As regarding the variables which are UX specific, the structural model includes: interesting learning, captivating exercises, enjoyable learning, and exciting system. These are key qualities that are shaping a user learning experience.

The strong positive relationship from ERG to PE (β= 0.41) and the positive relationship from PEOU to PE (β= 0.26) implies that both the ergonomics and ease of use are influencing the user experience. Therefore, developing an AR platform that is easy to use is a prerequisite for an enjoyable learning experience. This finding is consistent to several similar studies (e.g., Ha et al., 2007). The results also show that PEOU positively influences PU. This result is widely accepted because these two constructs were viewed as predictors of intention to use of information systems or innovative products (Wu &Wang, 2005; Bruner et al., 2005). Contrary to our expectations, the effect of PEOU on intention to use was found non-significantly (β=0.07, *t* value=0.42, n.s.), indicating that this relationship is fully mediated by PE and PU. However, PEOU has indirect effects, through PE and PU, on the intention to use.

An important result of this research is a validated model that is targeting several evaluation dimensions for a desktop AR learning platform. The measurement model was confirmed with adequate convergent and discriminant validity with respect to the measurement of the constructs in the research model. This model could be further used to carry on a user centred formative evaluation of various learning scenarios thus providing the developers with a fast feedback on usability, usefulness and user experience. This is important for the deployment of desktop AR technologies in schools where UX is not evaluated in isolation but as a key factor to enhance the motivational value of e-learning systems.

5.2 Limitations and future research

There are some inherent limitations in our study. First, the sample used in this study targeted students chosen only from three schools. Analytical results presented may therefore have limited generalisability. Second, the structural model demonstrated a good fit with the data, although the amount of variance explained by the model in intention to use is only 20%. This shows that other factors excluded in the model also affected ARTP intention to use. This value is acceptable for at least three reasons: the novelty of the platform (there are neither specific usability questionnaires nor similar acceptance models available), the target user population (young and not happy to answer a long questionnaire), and the mixed character of the e-learning system (utilitarian and hedonic). Therefore, we suggest that further research should incorporate other variables into the model.

Third, about 55% of the respondents were girls in this empirical study. Much evidence has shown that gender differences can cause discrepancies in the effects of perceived ease of use and perceived usefulness on intention to use (Ong & Lai, 2006). Accordingly, further research may be needed to examine the moderating effect of gender difference on a student's behaviour intention. Finally, since the sample was collected in Romania, generalisability to other countries might be limited due to cultural differences.

Acknowledgements

This work was supported by the ARiSE research project funded by EU under FP6 027039.

Appendix A. Constructs and measurement items in the research model

Constructs	Items	Variables
Ergonomics of the ARTP (ERG)	ERG1	Adjusting the "see-through" screen is easy
	ERG2	Adjusting the stereo glasses is easy
	ERG3 *	Adjusting the headphones is easy
	ERG4 *	The work place is comfortable
	ERG5	Observing through the screen is clear
Perceived ease of use (PEOU)	PEOU1	Understanding how to operate with ARTP is easy
	PEOU2	The superposition between projection and the real object is clear
	PEOU3 *	Learning to operate with ARTP is easy
	PEOU4 *	Remembering how to operate with ARTP is easy
	PEOU5 *	Understanding the vocal explanations is easy
	PEOU6	Reading the information on the screen is easy
	PEOU7	Selecting a menu item is easy
	PEOU8	Correcting the mistakes is easy
	PEOU9 *	Collaborating with colleagues is easy
	PEOU10	Overall, I find the system easy to use
Perceived usefulness (PU)	PU1	Using ARTP helps to understand the lesson more quickly
	PU2	After using ARTP I will get better results at tests
	PU3 *	After using ARTP I will know more on this topic
	PU4	Overall, I find the system useful for learning
Perceived Enjoyment (PE)	PE1	The system makes learning more interesting
	PE2 *	Working in group with colleagues is stimulating
	PE3 *	I like interacting with real objects
	PE4	Performing the exercises is captivating
	PE5	Overall, I enjoy learning with the system
	PE6	Overall, I find the system exciting
Intention to use (INT)	INT1	I would like to have this system in school
	INT2	I intend to use this system for learning
	INT3	I will recommend to other colleagues to use ARTP

Note: * items deleted in step (2), exploratory study

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