TECHNOLOGICAL SUSTAINABILITY OF MOBILE LEARNING

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Abstract: This study aims to investigate and improve factors affecting technological sustainability of m-learning. In addition to literature review, an investigation based on interviews was conducted with 11 heads and systems experts of distance education centers to obtain the technological sustainability factors of m-learning. In order to understand the significance of these factors on m-learning sustainability, another investigation based on survey research was conducted with 75 system staffs from the universities which have m-learning facilities. The data analyzed and evaluated for a technological sustainability model of m-learning. The study may provide guidelines to m-learning initiatives for a sustainable mobile learning.

Keywords: mobile learning, m-learning, sustainability, technology

Introduction

In the last ten years, many educational institutions have started to give mobile learning which is defined as "intersection of online learning and mobile computing" by William (2003). The mobile devices which are used in m-learning can be listed as mobile device, like cellular phones, Personal Digital Assistants (PDA), smartphones, tablet PC etc. (Andronico et al., 2003). These devices are used for many instructional activities such as downloading and sharing document, collaborating on projects, reviewing coursework, preparing for exams, showcasing their work, sharing project results, reading (listening to) audio books, recording information, presenting projects; conducting research, saving their work, submitting work to the instructor etc. (Corbeil & Valdes-Corbeil, 2007). Although there are more advantages of online learning environments for both students and institutions, high dropout rate is a problem in online education (Bowers & Kumar, 2015).

This study aims to investigate the technologic dimension of m-learning sustainability and seeks to answer such research questions: What are the factors that can affect the technological sustainability of mobile learning? What is the current situation of the technological sustainability of m-learning at universities in Turkey?

Literature Review

Technological perspective of mobile learning sustainability has been handled in few studies. According to Stansfield et al. (2009), appropriate infrastructure & standards (cost effectiveness, systems security, adoption of open-source technologies), support for staff & users/students (adoption of open-source technologies, effective training, maintenance agreements in place), embracing innovation (identifying new trends, integration with mainstream programs, pro-active management) and testing and evaluation (rapid application development, clear technology requirements) are key issues of sustainable e-learning.

Ktoridou and Eteokleous (2005) address the technological aspects on their study. According to them, when mobile devices are compared with PC or desktops, mobile devices have advantages in terms of portability, transfer, usability, battery life, time, familiarity and youth lifestyle but have disadvantages in terms of functionality, expansion and upgrade, connectivity and interoperability, connectivity costs and security. Pea and Maldonado (2006) handled seven device features contributing to the rise in handheld use within schools and beyond: (1) size and portability; (2) small screen size; (3) computing power and modular platform; (4) communication ability through wireless and infrared beaming networks; (5) wide range of available multipurpose applications; (6) ready ability to synchronize and back-up with other computers; and (7) stylus driven interface.

Standards and architecture, tools and technologies, and functionality and uses are important factors from the technological view of e-learning (Conole, 2004). Kukulska-Hulme (2007) pointed out that "m-learning activity continues to take place on devices which are not designed for educational use, and that therefore usability issues are frequently reported". He gave some usability issues related to physical attributes as small screen size, heavy weight, inadequate memory and short battery life, network speed and reliability, and physical environment.

Five broad categories of technology must be considered from technological viewpoint of m-learning; these are transport, platform, delivery, media technologies, and development languages (Attewell, 2005). Cobcroft (2006) handled mobile devices, wireless infrastructure, learning management systems (LMS) in his literature review into mobile learning in the university context. Sánchez and his colleagues (2013) investigated the factors that determine the acceptance of the WebCT learning system among students. The factors they investigated are technical support; computer self-efficacy; perceived ease of use; perceived usefulness; attitude; and system usage. The study revealed the importance of the technical support variable. Oinas-Kukkonen and Kurkela, V. (2003), stated that network accessibility is a main advantage of m-learning. So, it can be taken for inspection of its effect on sustainability.

From a technology viewpoint, restrictions that may impede m-learning sustainability as discussed by Maniar and Bennett (2007), include following eight aspects: small screen size and poor screen resolution, lack of data input capability, low storage, low bandwidth; limited processor speed, short battery life, software issues and interoperability, and lack of standardization. There are some technological challenges and limitation for mobile learning, lack of standards is one of them (Grohmann et al., 2005). Georgiev et al. (2006), also examine the technological challenges of transition from e-learning to m-learning in their study in terms of student, educators and developers. According to them, challenges are for developers:

- *less memory, less computing power, smaller screen size, absence (in most cases) of keyboard, etc.*
- *need to know very well all the abilities and downfalls of the particular mobile devices and communication technologies to successfully design and develop a mobile learning system.*

for educators:

- *need to know very well how to operate mobile devices,*
- *need to know what to require from the developers,*
- *need to know what the limits and abilities of such systems are,*
- *need to be also fluent with the modern communications devices used by their students.*

for students:

the different features of mobile devices compared to the personal computers

Mekuria (2009), studied on sustainability factors in mobile broadband technology and services. Some following questions are handled with the study: (1) Which technology is suitable for designing, activating and affordable delivery of relevant mobile broadband services? (2) Which technology provides easy to tools and protocols to create local mobile content and integrate it to the global web knowledge through mobile IP technologies? (3) Which technology has support to alternative energy usage and provides low power network topologies? (4) What is the contribution of such a technology deployment for the long term mobile-ICT development initiative and digital inclusion? (5) Which technology can give the needed spinoff and employment creation through mobile local content and service provision for social and economic development? (6) Which technology and/or combination of technologies, has the inherent capacity for long term industry support and sustainable service provision. (7) Which technology can provide the maximum spectral efficiency for a given licensed frequency area, by a network operator.

Theoretical Framework and Hypotheses

The sustainability items based on the factors in literature are combined with the items which are obtained from interviews and the factor analyses were applied to the sustainability items in order to group the items under some factors which will be the independent variables (Table 1).

Table 1 Literature-based and Interview-based M-Learning Sustainability Factors

Technological sustainability items of m-learning	Technological sustainability factors of m-learning
system security	Adequacy of Infrastructure & Standards
connectivity	
accessibility	
interoperability	
modularity	
memory adequacy*	
quality standards	Evaluation and Improvements of Infrastructure & Standards
requirement specification	
expansion and upgrade	
maintenance	
testing	

availability of support for system use*	Technical Support for Staff, Instructor and Users
availability of support for connection problems*	
accessibility of support	
effectiveness of support	

*Interview-based sustainability items

After the factor analysis, a theoretical framework was developed to guide the study (Figure 1).

Figure 1 Theoretical Framework

The following hypotheses were established for this study:

H_1: Adequacy of infrastructure and standards will be associated with perceived general technological m-learning sustainability.

H_2: Evaluation and improvements of infrastructure and standards will be associated with perceived general technological m-learning sustainability.

H_3: Technical support for staff, instructors and users will be associated with perceived general technological m-learning sustainability.

H_4: Perceived general technological m-learning sustainability will be associated with perceived general m-learning sustainability.

Methodology

In this study, the literature was reviewed about current sustainability factors and an investigation was made in order to obtain additional sustainability factors from experts. A formal interview which consists of six predetermined and standardized questions, and comment area conducted with 11 heads or system staffs in distance education centers of universities.

Then, factor analysis was applied to group the items handled from both literature and interview. The items are collected under the titles: "Adequacy of Infrastructure & Standards", "Evaluation and Improvements of I&S" and "Technical Support for Staff, Instructors and Users".

In order to obtain data to understand the effects of these factors on technological m-learning sustainability, survey research conducted with system and support staff at distance education centers of universities. First part of the survey includes descriptive items like age and working year in m-learning environment. Another item is for understanding the accessibility to learning system from mobile devices. The second part of the form includes 15 Likert scale items for technological factors, 1 Likert scale item for general technological sustainability and 5 Likert scale items based on the definition of m-learning sustainability in recent study (Coskun-Setirek & Tanrikulu, 2015) for general m-learning sustainability. Totally 75 completed survey forms has been collected and analyzed for understanding the research questions.

Results and Discussion

As a result of data collection process for technological sustainability issues, 75 valid responses have been collected. For the analyses of the data, descriptive analyses, reliability analyses, factor analyses, multiple regression analyses and linear regression analysis techniques were respectively used.

Descriptive Analysis

In descriptive analysis, age and working year of staffs in mobile learning are analyzed. As shown in Table 2, 52% of the respondents of the survey part about technological issues are 20-30 years old and percentages of respondents whose m-learning experience more than 3 years is 44.

Table 2 Demographic Profile of Respondents

Age		<20	20-30	30-40	40-50	50>	Total
	Frequency	2	39	19	9	6	75
	Percent	2.7	52	25.3	12	8	100
Experience		<1	1-3 year(s)	3-5 years	5>		Total
	Frequency	15	27	18	15		75
	Percent	20.0	36.0	24.0	20.0		100.0

When the mean values of the issues are examined, it can be seen that all of them higher than the average value 3 (shown in Table 3). Each issue has value more than 3.5 except the quality standards with 3.41 mean values. The issues quality standards, requirement specification, expansion and upgrade, and maintenance have low mean values so these issues should be solved to increase the technological sustainability of that aspect. The higher mean values belong to accessibility, interoperability, connectivity, and availability of system use support issues. On the other hand, the value of perceived technological m-learning sustainability, 3.69, is higher than the value of perceived general m-learning sustainability, 3.44. It can be said that technological sustainability is in better condition than other dimension of m-learning.

Table 3 Descriptive Statistics of Variables

Technological Issues	N	Mean
system security	75	3.68
connectivity	75	3.84
accessibility	75	4.19
interoperability	75	3.89
modularity	75	3.63
memory adequacy	75	3.80
quality standards	75	3.41
requirement specification	75	3.53
expansion and upgrade	75	3.55
maintenance	75	3.57
testing	75	3.64
availability of system use support	75	3.88
availability of support for connection problems	75	3.60
accessibility of supports	75	3.68
effectiveness of support	75	3.80
Perceived General Technological M-learning Sustainability	75	3.69
Perceived General M-learning Sustainability	75	3.44

Reliability Analysis
Cronbach's Alpha analysis was used for finding the reliability values of each variable. According to Cronbach's Alpha analysis, as shown by Table 4, the overall value of Cronbach's Alpha was found as .925. According to Kline (2013), the reliability of the scale is quite high since it is more than .9.

Table 4 Reliability Statistics

Cronbach's Alpha	N of Items
.925	21

Factor Analysis
In this section, Exploratory Factor Analysis is used to classify the 15 sustainability aspects into certain groups. The reliability of the scale is high with the .925 Cronbach's alpha value. On the other hand, the subjects-to-variables ratio should be at least 5 and preferably 10 (Everitt, 1975). Corresponding ratio for this study is 6 and sample size is adequate for the analysis. When we took a rule of thumb into consideration, sample is found to be highly adequate for factor analysis with the .818 Kaiser-Meyer-Olkin Measure value (Table 5) because it is greater than .50 (a rule of thumb). In addition, the significance level of Barlett's Test (.000 as seen in Table 5) is below .001 therefore it is indicating sufficiently large correlations for principal component extraction and this test showed that the data is suitable for analysis.

Table 5 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.818
Bartlett's Test of Sphericity	Approx. Chi-Square	558.546
	df	105
	Sig.	.000

The Total Variance Explained table (Table 6) shows that 62.157% of the total variance is explained by classifying these 15 aspects into 3 components. Below 50% is interpreted as unsatisfactory by many researchers and 60% or more is preferred as a rule of thumb.

Table 6 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.306	42.041	42.041	6.306	42.041	42.041	3.473	23.153	23.153
2	1.633	10.884	52.924	1.633	10.884	52.924	2.995	19.966	43.119
3	1.385	9.233	62.157	1.385	9.233	62.157	2.856	19.039	62.157
4	1.072	7.144	69.302						
5	.837	5.578	74.880						
6	.677	4.512	79.392						
7	.582	3.882	83.274						
8	.526	3.505	86.778						
9	.384	2.559	89.338						
10	.358	2.384	91.721						
11	.350	2.334	94.055						
12	.289	1.925	95.980						
13	.262	1.748	97.728						
14	.189	1.260	98.989						
15	.152	1.011	100.000						

With the Rotated Component Matrix, it can be determined which variables load together under which factor. According to the Rotated Component Matrix (Table 7), 15 aspects were classified into 3 components as specified in theoretical framework of the study. The first group under component 2 was named as "Adequacy of Infrastructure & Standards". The second group under first component was named as "Evaluation and Improvements of Infrastructure & Standards". The last group under component 3 was named as "Technical Support for Staff, Instructors & Users".

Table 7 Rotated Component Matrix

Technological Items	Component		
	1	2	3
system security	.401	.447	.285
connectivity	.429	.578	.206
accessibility	.397	.602	.180
interoperability	.331	.620	.219
modularity	.061	.827	.016
memory adequacy	.025	.817	.214
quality standards	.673	.398	.000
requirement specification	.770	.068	.230
expansion and upgrade	.732	.107	.268
maintenance	.796	.196	.164
testing	.631	.207	.265
availability of system use support	.291	.087	.771
availability of support for connection problems	.341	.142	.781
accessibility of supports	.037	.203	.800
effectiveness of support	.199	.193	.735

As a result of the factor analysis, the items and the variables of the study are figured out in Figure 2.

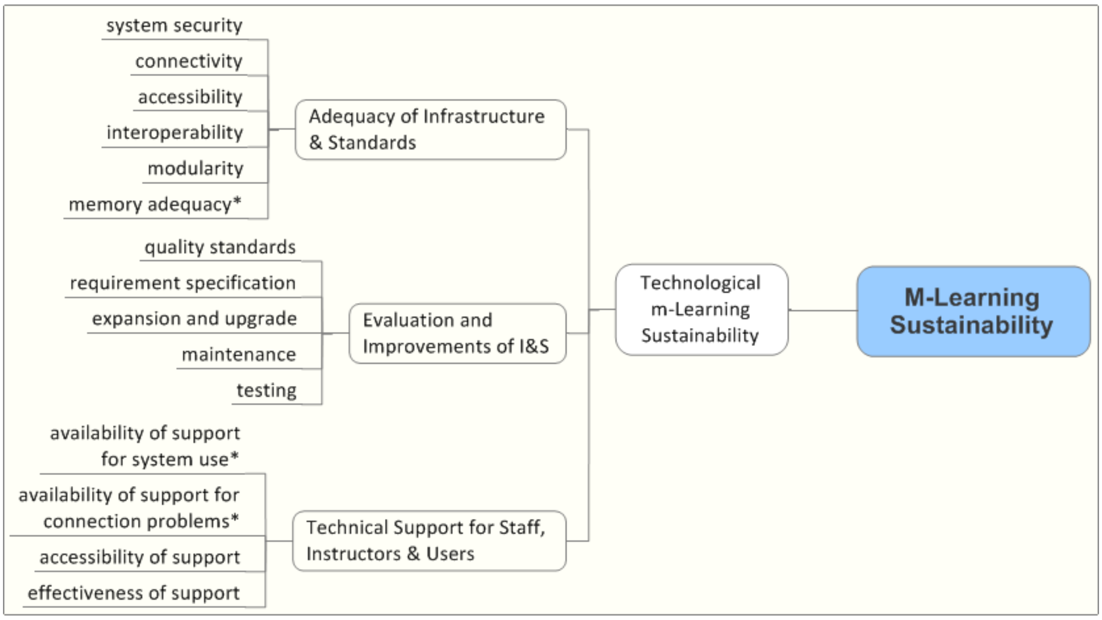

Figure 2 Technological Sustainability Items and Variables

Regression Analyses

For testing hypotheses 1, 2 and 3, a multiple regression analysis was constructed. The three influential variables "adequacy of infrastructure & standards", "evaluation and improvements of infrastructure and standards", and "technical support for staff, instructors and users" were used as independent variables, while perceived general technological m-learning sustainability was used as a dependent variable. The ANOVA table (Table 8) shows that F value of 30.116 having a significance level of 0.000 and the significance value is less than .05.

Table 8 ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.368	3	7.456	30.116	.000[a]
	Residual	17.578	71	.248		
	Total	39.947	74			

As seen in Table 9, the adjusted R^2 is .541 and .541 of the variance in the dependent variable is explained by the independent variables. Durbin-Watson value shows that there is 2.001 auto-correlation between the independent variables and it is between desired range of 1.5-2.5. So we can examine the hypotheses and coefficients.

Table 9 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.748[a]	.560	.541	.498	2.011

a. Predictors: (Constant), adequacy of infrastructure & standards, evaluation and improvements of infrastructure and standards, and technical support for staff, instructors and users

b. Dependent Variable: perceived general technological m-learning sustainability

The results of regression analysis are presented in Coefficient table (Table 10). It shows that P-values of three independent variables are less than .05 and they are considered to have meaningful relationships with perceived general technological m-learning sustainability. Those factors are memory adequacy, investment, expansion and upgrade, and cost effectiveness. Therefore, all variables contribute significantly to the regression equation and hypotheses 1, 2 and 3 are supported by this test. The regression equation is specified as follows: PGTS = .651 + .364 X_1 + .256 X_2 + .272 X_3

Table 10 Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.651	.326		1.998	.050
	adequacy of infrastructure & standards (X_1)	.364	.090	.367	4.064	.000
	evaluation and improvements of infrastructure & standards (X_2)	.256	.088	.271	2.907	.005
	technical support for staff, instructors and users (X_3)	.272	.083	.305	3.261	.002

a. Dependent Variable: Perceived General Technological M-learning Sustainability (PGTS)

For testing hypotheses 4, a linear regression analysis was used. The perceived general technological m-learning sustainability was used as independent variable, while perceived general m-learning sustainability was used as a dependent variable. As shown in ANOVA table (Table 11), F value is 76.475 and it has a significance level of 0.000 which is less than .05.

Table 11 ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	25.827	1	25.827	76.475	.000[a]
	Residual	24.653	73	.338		
	Total	50.480	74			

a. Predictors: (Constant), Perceived General Technological M-learning Sustainability

b. Dependent Variable: Perceived General M-learning Sustainability

As seen in Table 12, R Square is .512 and the adjusted R^2 is .505 and independent variable explains .505 of the variance in the dependent variable. Durbin-Watson value shows that there is 1.769 auto-correlation between the independent variable and the dependent variable, and it is between desired range of 1.5-2.5. Therefore, the hypotheses and coefficients are can be examined.

Table 12 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.715[a]	.512	.505	.5811326	1.769

a. Predictors: (Constant), Perceived General Technological M-learning Sustainability

b. Dependent Variable: Perceived General M-learning Sustainability

Coefficients table (Table 13) presents the results of regression analysis of the Hypothesis 4. It shows that the P-value is less than .05 and there is a meaningful relationship between the perceived general technological m-learning sustainability perceived and the general technological m-learning sustainability. Therefore hypothesis 4 was also supported by the linear regression test.

Table 13 Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.470	.346		1.359	.178
	Perceived General Technological M-learning Sustainability	.804	.092	.715	8.745	.000

a. Dependent Variable: Perceived General M-learning Sustainability

The result of regression analyses were given in Table 16. All three issues which are adequacy of infrastructure & standards, evaluation and improvements of infrastructure & standards, and technical support for staff, instructors and users are considered to have meaningful relationships with the technological m-learning sustainability. In addition, there is a meaningful relationship between perceived general technological m-learning sustainability and perceived general technological m-learning sustainability.

Table 14 Result of Regression Analyses

Hypothesis	Factors	Coefficients Beta	t	Sig.	Significant
	TECHNOLOGICAL M-LEARNING SUSTAINABILITY				
1	Adequacy of Infrastructure & Standards	.367	4.064	.000	Yes
2	Evaluation and Improvements of I&S	.271	2.907	.005	Yes
3	Technical Support for Staff, Instructors & Users	.305	3.261	.002	Yes
4	Perceived General Technological M-Learning Sustainability	.715	8.745	.000	Yes

*Significance at .1 levels.

The model for technological sustainability was developed after the analyses (as presented in Figure 3).

Figure 3 The Final Model for M-learning Sustainability

CONCLUSION

In this study, the aims are specifying the current situation of m-learning and identifying factors affect technological sustainability of m-learning.

The descriptive analysis inform about the current situation of the sustainability of m-learning at universities in Turkey. It is observed that quality standards, requirement specification, expansion and upgrade, and maintenance issues have minimum mean values so these issues should improve to increase the technological and general sustainability of that aspect. The maximum mean value belongs to accessibility, interoperability, connectivity, and availability of system use support issues. On the other hand, the value of perceived technological m-learning sustainability, 3.69, is higher than the value of perceived general m-learning sustainability, 3.44. Therefore, it can be said that technological sustainability is in better condition than other dimension of m-learning.

The result of regression analyses show that all three issues which are adequacy of infrastructure & standards, evaluation and improvements of infrastructure & standards, and technical support for staff, instructors and users are related with perceived general technological m-learning sustainability. Moreover, there is a meaningful relationship between perceived general technological m-learning sustainability and perceived general technological m-learning sustainability. Therefore all hypotheses 1, 2, 3, 4 were supported.

The limitation of this study is that the investigation is geographically limited to Turkey. As a recommendation for future research, other dimension of the m-learning sustainability such as pedagogical, managerial, economical, psychological sustainability, etc. can be studied.

REFERENCES

Andronico, A., Carbonaro, A., Casadei, G., Colazzo, L., Molinari, A., & Ronchetti, M. (2003). Integrating a multi-agent recommendation system into a mobile learning management system. *Proceedings of Artificial Intelligence in Mobile System*, 123-132.

Attewell, J. (2005, October). From research and development to mobile learning: Tools for education and training providers and their learners. In *4th World Conference on mLearning* (pp. 1-6).

Bowers, J., & Kumar, P. (2015). Students' perceptions of teaching and social presence: A comparative analysis of face-to-face and online learning environments. *International Journal of Web-Based Learning and Teaching Technologies (IJWLTT)*, *10*(1), 27-44.

Cobcroft, R. (2006). Literature Review into Mobile Learning in the University Context. Retrieved October 3, 2008.
Conole, G. (2004). E-learning: The hype and the reality. *Journal of Interactive Media in Education*, *11*.
Corbeil, J. R., & Valdes-Corbeil, M. E. (2007). Are you ready for mobile learning?. *Educause Quarterly*, *30*(2), 51.
Coskun-Setirek, A., & Tanrikulu, Z. (2015). Significant Developmental Factors that can Affect the Sustainability of Mobile Learning. *Procedia-Social and Behavioral Sciences*, *191*, 2089-2096.
Everitt, B. S. (1975). Multivariate analysis: The need for data, and other problems. *The British Journal of Psychiatry*, *126*(3), 237-240.
Georgiev, T., Georgieva, E., & Trajkovski, G. (2006, June). Transitioning from e-Learning to m-Learning: Present Issues and Future Challenges. In *SNPD* (pp. 349-353).
Grohmann, G., Hofer, A., & Martin, G. (2005, July). ARIS MOBILE: Helping to define the future of mobile learning. In *International Conference on Mobile Business (ICMB'05)* (pp. 213-219). IEEE.
Kline, P. (2013). *Handbook of psychological testing*. Routledge.
Ktoridou, D., & Eteokleous, N. (2005). Adaptive m-learning: technological and pedagogical aspects to be considered in Cyprus tertiary education. *Recent Research Developments in Learning Technologies. Formatex, Badajoz, Spain*, 676-683.
Kukulska-Hulme, A. (2007). Mobile usability in educational contexts: what have we learnt?. *The International Review of Research in Open and Distance Learning*, *8*(2).
Maniar, N., Bennett, E., Hand, S., & Allan, G. (2008). The effect of mobile phone screen size on video based learning. *Journal of Software*, *3*(4), 51-61.
Mekuria, F. (2009). Mobile Broadband Technology & Services: Sustainability Factors.
Oinas-Kukkonen, H., Oinas, H., Kurkela, V., & Oy, A. (2003). Developing successful mobile applications. *reason*, *394*, 054.
Pea, R. D., & Maldonado, H. (2006). WILD for learning: Interacting through new computing devices anytime, anywhere. *The Cambridge handbook of the learning sciences*, 852-886.
Sánchez, R. A., Hueros, A. D., & Ordaz, M. G. (2013). E-learning and the University of Huelva: a study of WebCT and the technological acceptance model. *Campus-Wide Information Systems*, *30*(2), 135-160.
Stansfield, M., Connolly, T., Cartelli, A., Jimoyiannis, A., Magalhães, H., & Maillet, K. (2009). The Identification of Key Issues in the Development of Sustainable e-Learning and Virtual Campus Initiatives. *Electronic Journal of e-Learning*, *7*(2), 155-164.
William, R. (2003). Handhelds Go to School: Lessons Learned.