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Tiong T. Goh
Victoria University of Wellington, New Zealand, tiong.goh@vuw.ac.nz

Athabasca University, Canada

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Structural equation modelling approach in multiplatform e-learning system evaluation

Tiong T Goh
Victoria University of Wellington, New Zealand
P.O. BOX 600 Wellington, New Zealand
Telephone: 64-04-4636860
E-mail: tiong.goh@vuw.ac.nz

Kinshuk
School of Computing and Information Systems
Athabasca University, Canada

Abstractz

A multiplatform e-learning system is an e-learning system that can deliver learning content to different accessing devices such as PCs, PDAs and mobile phones. The main objective of this paper is to present an evaluation of such a system from the end user (learner) perspective. The evaluation investigates the relationships among the dimensions that influence learner satisfaction while engaged in a multiplatform e-learning system. A total of 36 participants took part in a comparative evaluation. A structural equation model (SEM) was constructed to fit the data. This model indicated that there was a good fit for the resulting model. The SEM identified two groups of factors. Primary factors dominated in the non adaptive e-learning system while secondary factors emerged from the multiplatform e-learning system. The SEM also revealed a suppressor within the system that could possibly negate the contributions from other dimensions.

Keywords

e-learning, mobile devices, mobile learning, multiplatform, learner satisfaction

INTRODUCTION

Mobile devices can provide additional channels of learning opportunities anytime and anywhere. However, using mobile technology for e-learning is not widely adopted. One issue is the adaptation of content from PC to mobile devices (W3C 2001). Content adaptation not only requires the layout, format and structure of the content to be modified, it also faces the problem of adapting interactive multimedia content. Interactive multimedia content is less likely to be accessible via mobile devices without appropriate content adaptation. For example, a traditional PC based e-learning system such as Blackboard using Flash multimedia will not be easily accessible and usable in a mobile phone or PDA without deploying some adaptation or transforming techniques if these devices do not support Flash multimedia. Without appropriate adaptation for various accessing devices, adoption of technology is less likely according to the technology acceptance model (Davis 1989, 1993).

This paper will first provide a brief review of content adaptation techniques and W3C independent access. Subsequently the paper discusses the multiplatform e-learning framework. It should be stressed that the formulation of the framework involves other issues such as device identification, bandwidth estimation, e-learning system architecture and frameworks, mobile learning and many more. Due to space limitations we shall only review the work on content adaptation and W3C independent access. Subsequently we present a comparative evaluation of the multiplatform e-learning system and the traditional Blackboard e-learning system to assess the relationships among dimensions and their influence on learner satisfaction scores. The results and findings based on structural equation modelling are presented. These findings and the process of evaluation can play an important role in helping designers to improve the adaptation process and to enhance the level of learner satisfaction in a multiplatform e-learning system. Finally limitations and recommendations for future research conclude the paper.

RELATED WORK

Content Adaptation

One of the main issues for a multiplatform e-learning system is the requirement to provide meaningful access to an increasing number of accessing devices. Current web-based systems including e-learning systems use server-side designs that are oriented towards clients with standard screens and standard HTML browsers. These designs are unlikely to be acceptable for personal mobile devices such as mobile phones or PDAs. In order to provide meaningful access, the content, structure and navigation must be able to adapt to a multiplatform e-learning system. Thus a multiplatform e-learning system needs adaptivity, i.e., the ability of a system to adapt itself to different client needs. For the case of a multiplatform e-learning system this includes the ability to cope with bandwidth, memory and power limitations, restricted presentation capabilities and different user profiles. A review of content adaptation techniques is essential to understand and appreciate how different techniques can be helpful in the multiplatform e-learning system implementation process. It should be noted that some of these techniques, because of their assumptions, may not always be suitable for the current implementation.

To begin with, the Adaptive Web Content Delivery (AWCD) framework (Chen et al. 2000; Ma et al. 2000) provides a useful overview of the problems that have to be addressed in adaptive systems. Firstly, the system must be able to detect the parameters needed for adaptivity. This includes the automatic measurement of network bandwidth and load and the registration of used end-devices and user preferences. The easiest approach to the latter is to use web forms. More sophisticated inference mechanisms based on user behaviour patterns are under development. And secondly, the system must provide a decision engine for determining when and how to adapt content. The first issue adopted in the multiplatform e-learning system utilised XML document string for each factor. The advantage of using XML string is the ability to provide simple exchange mechanisms with other modules and the potential to transform into other developing standards if necessary. The second issue is included in the coordination dimension.

In general, there are two different classes of approaches to content adaptation. The first class of approaches deals with the problem on the level of pages, i.e. we assume that the web-based service is fully implemented by web pages that can be displayed by a standard browser on a standard computer display. Then adaptation has to take HTML as the format of its input. In the UWA framework (Finkelstein et al. 2002; Kappel et al. 2002; UWA 2002) the adaptation can be expressed by event-condition-action rules. This approach assumes a design has already been made in the PC environment and the adaptation is to transform the PC web page into another device environment. This assumption is not necessary in the multiplatform e-learning system development. We do not assume PC web pages as a starting point but we do recognise that many existing e-learning systems do. Therefore some of the disadvantages of the page level adaptation approach may not be applicable in the multiplatform e-learning system as envisaged.

The second class of approaches handles the problem on a conceptual level, i.e. assuming there will be a generic abstract description of the service's content, from which the actual web pages could be generated. Adaptation now takes the abstract description as its input and derives another abstract description. The pages generated out of this modified specification can be more suitable for specific clients, in particular mobile clients. This approach may not allow other factors such as preferences and interactivity to be optimally incorporated into the cost function (Tretiakov and Kinshuk 2004) which may affect the multiplatform e-learning system implementation.

For content adaptation on the level of pages, the most prominent approaches are re-authoring (Bickmore and Shilit 1997) and transcoding (Bharadvaj, Joshi, and Auephanwiriyakul 1998; Hori et al. 2000; Smith et al. 1999). Reauthoring applies functions to web page descriptions, which will result in new descriptions that are better suited for various kinds of clients. Transcoding aims at direct manipulation of the HTTP stream. Based on these techniques several commercial products and system prototypes have been implemented such as Digestor (Bickmore et al. 1997), Spyglass (1999), Intel QuickWeb (Intel 1998), Mobiware (Angin et al. 1998), TranSend (Fox et al. 1998a), WingMan (Fox et al. 1998b), and Power Browser (Buyukkokten, et al. 2000).

Adaptivity on the level of page descriptions can be achieved more easily if data content, navigation links and presentation are separated from each other, e.g., by using XML, XLink and XSL (Goldfarb and Prescod 1998). In a multiplatform e-learning system experience suggests that content, navigation, presentation and logic should be separated from each other. Also, the work of Chen et al. (2001) presents an interesting approach to detecting objects in pages and their categories using a functional object model. Adaptation rules are then applied to these objects.

Besides page-based techniques, newer techniques focus on paying attention to content adaptivity on the conceptual level (Feyer et al. 2000). The apparent difference between the two classes of approaches is that for page-level adaptivity the adaptation rules will become part of the web-based service, whereas adaptivity on a conceptual level must provide generic rules for adaptivity. Application-dependent adaptivity may be easier to achieve, but it is expensive with respect to development and maintenance.

W3C Device Independence Activities

The motivation of the W3C Device Independence Activities (DIA) (W3C 2001) is closely related to the research in multiplatform e-learning system frameworks. The goal of the DIA is to develop ways for future web content and applications to be authored, generated, or adapted for a better user experience when delivered via many device types. In DIA, user experience is defined as a set of material rendered by a user agent which may be perceived by a user and with which interaction may be possible. The goal of the multiplatform e-learning system framework is to devise a framework for accessing e-learning content via different accessing devices with the aim of analysing the level of influence of the factors within the framework. The current research therefore complements DIA by focusing on basic questions relevant to e-learning and learner satisfaction. In addition, the current adaptive multiplatform e-learning framework takes insights from the DIA perspectives of user, authoring and delivery mechanisms to formulate a competency framework that focuses on content, learner, device, communication, and coordination dimensions that better fits the e-learning environment.

Motivated by future access scenarios, DIA looks at how web content can be accessed from three perspectives: the user perspective, the author perspective, and the delivery mechanism. DIA identifies seven working principles (W3C 2001) to achieve the goal. The seven working principles are device independent access, device independent web page identifiers, functionality, incompatible access mechanism, harmonisation, characterisation of delivery context, and adaptation preferences. The goal of the device independent access and device independent web page identifier principles is to ensure a functional user experience is always possible via any access mechanism. In multiplatform e-learning system implementation this is achieved by matching the devices' capabilities with functional content. In the evaluation process, comparison is made to one that can provide a functional user experience and one that provides a partial user experience to determine the disparity in learner satisfaction. The functionality, incompatible access mechanism and harmonisation principles aim to ensure that functional experience if not met should give appropriate feedback to the user and that harmonised user experience is possible from the author perspective. A harmonised user experience is one that meets the user delivery context and also the quality criteria of the author. In the multiplatform e-learning system, if the user delivery context cannot be met, the lowest version of the functional user experience is rendered. This will normally be text based. The harmonised experience is governed by the coordination dimension which provides harmonised adaptation based on attributes from other dimensions such as bandwidth, device capabilities and environmental factors. Finally the characterisation of delivery context and adaptation preference principles is to ensure that the delivery context is made available to the adaptation process and that a user can change their preference to modify the adaptation process. In the multiplatform e-learning system, the delivery context such as bandwidth, device profiles, learner profiles and preference are either stored in XML files or estimated in real time to allow the adaptation to process. User preference can be changed by the user to be reflected in the adaptation process.

The device independence activities mentioned above strongly demonstrated a vision for the future of a multiple devices accessing scenario in general web service. The current research of a multiplatform e-learning system framework is aligned with the direction of W3C's DIA. This research concentrates on the domain of e-learning and also devises a set of competency principles to operationalise the multiplatform e-learning system framework. E-learning is a revolutionary way of teaching. With the advent of mobile technology e-learning is constantly evolving, thus there is still a need for more research. The multiplatform e-learning research also aims to gain new knowledge by focusing on fundamental factors influencing learners when exposed to a variety of accessing devices. In this regard, the current research goes beyond and complements the DIA activities.

MULTIPLATFORM E-LEARNING SYSTEM

Multiplatform e-learning System Framework

The framework is intended to serve three purposes. First, it provides a preliminary phase for requirement analysis similar to the information system architecture (Zachman 1987) for the construction of future multiplatform e-learning systems. It serves as an initial expandable template that allows system analysis to capture users' and non users' requirements. Second, it serves as a guideline for system implementation. A framework is useful only if it can be operationalised. The multiplatform e-learning system framework has been operationalised to validate its usefulness in an implementation. Third, the framework serves as a resource instrument for evaluating learner satisfaction while using a multiplatform e-learning system. The adaptation framework was first published in Goh and Kinshuk (2002) and subsequently refined in Goh and Kinshuk (2004). The framework also described the competency principles necessary for multiplatform e-learning systems to operate.

The multiplatform e-learning system framework can be organised into five core dimensions: content, learner, device, communication and coordination dimensions as described in Table 1. While some of these dimensions may look similar to those of any input/output devices in general, the adaptation perspective, multiple devices access requirements and context of use such as the learner dimension and device dimension would differ greatly in operation compared with traditional e-learning settings. Each of these dimensions includes various sub-dimensions.

Content Dimension	Learning module	Organisation	Granularity	Pedagogy
	text	modular	beginner	teaching strategy
	multimedia	hierarchy	intermediate	(guideline)
		mixed	advanced	
			expert	
Learner Dimension	**Environment**	**Motivation**	**Learning Profile**	**Preference**
	quietness	urgency	static learning history	presentation preference
	available of help self exploration	(trendy technology)	mobile learning history	learning preference
	multitasking			
Device Dimension	**Presentation Capabilities**	**Operational Capabilities**	**Ergonomic Capabilities**	
	media player	cpu	platform (input)	
	screen	memory	browser	
	browser	power	portability	
		sensor	mobility	
		networking		
Communication Dimension	**Delivery**	**Quality**	**Connectivity**	
	real-time	perceived response	wired	
	synchronised (off-line)	perceived stability	wireless	
	pre-fetch			
Coordination Dimension	**Navigation**	**Interactivity**	**Presentation**	**Software and Algorithm**
	link	forms	display	script
	button	parameters	transform	servlet/ server page
	hot spot	variables		cgi
	option	feed back		agent
	list	cookies		web service

Table 1 Multiplatform e-learning System framework (Goh & Kinshuk 2004)

EVALUATION METHODOLOGY

Evaluation Objectives

The evaluation intends to understand two research questions regarding the influencing dimensions. The research questions are as follows:

RQ1: How do the dimensions impacts on the learner satisfaction score (LSS)?

RQ2: How do the dimensions impact on each other?

The hypotheses resulting from the research questions are as follows:

H1: The content dimension (D1) has a direct impact on LSS.

H2: The learner dimension (D2) has a direct impact on LSS.

H3: The device dimension (D3) has a direct impact on LSS.

H4: The communication dimension (D4) has a direct impact on LSS.

H5: The coordination dimension (D5) has a direct impact on LSS.

H6: D1 has a direct impact on D2.

H7: D3 has a direct impact on D1.

H8: D3 has a direct impact on D5.

H9: D4 has a direct impact on D3

H10: D5 has a direct impact on D4.

Instrument

The Questionnaire for User Interface Satisfaction (QUIS) was developed by Chin et al. (1988) at the University of Maryland. QUIS has been used for evaluating web-based e-learning systems and comparative study of PDA based and paper based quizzes (Johnson et al. 2004; Segall et al. 2005). The original QUIS consisted of five scales, which give overall reactions to the software, screen, terminology and system information, learning and system capabilities. The first scale relating to overall reactions to the software consists of six questions and the other scales include a total of 21 questions. The scaling of items ranges from 1 to 9 and an additional "no answer" option is available. Compared to other instruments, the QUIS was considered to be closer to the current evaluation objective. The current evaluation of the multiplatform e-learning system learner questionnaires (MELQ) is modified and extended from the QUIS. The current questionnaires consist of nine parts. Part 1 of MELQ captures demographic information. Part 2 measures e-learning experience. Part 3 measures previous interaction experience, and has been modified here to include more up-to-date and relevant browsers, mobile games, SMS, PDAs and mobile devices. Part 4 measures the overall learner satisfaction score (LSS) and the statements have been modified for the e-learning context to include different accessing devices. Statement number 5 was changed to gauge the meaningfulness of the system. Part 5 measures the content dimension (D1) with sub parts measuring organisation, granularity, multimedia objects, and pedagogy. Part 6 measures the learner dimension (D2) with sub parts measuring environment, availability of help, motivation, and preferences. Part 7 measures the device dimension (D3) with sub parts measuring presentation capability and ergonomic capability. Part 8 measures the communication dimension (D4) with sub parts measuring perceived response, perceived stability, and mode of delivery. Part 9 measures the coordination dimension (D5) with sub parts measuring navigation, interaction, and presentation.

Evaluations

Evaluating systems is a difficult task and it is even more difficult when the system is adaptive (Hook 1997). The evaluation of adaptive systems remains a challenge (Weibelzahl 2002). Most studies of adaptive systems are comparisons of the same system with and without adaptivity (Boyle et al. 1994; Brusilovsky and Pesin 1994; Hook 1998; Meyer 1994). The current evaluation is also a comparative study. Six scenarios were defined with the intention to vary the interactions between learners and the e-learning systems. Six participants (Nielsen 2000) were enlisted to take part in each scenario. For each scenario each participant has to complete several specific tasks for each system with three different accessing devices. These tasks include login to the respective system, navigate to the respective folder, navigate to the content page, explore individual learning module, explore interactive multimedia, login to exercise, response to exercise, revisit content if necessary, view exercise feedback and exit system. E-learning system A consists of learning and assessment modules implemented in the commercial Blackboard system without adaptive capabilities. E-learning system B consists of an adaptive multiplatform e-learning system with adaptive capabilities. Participants access different modules for each device type. Upon completing each system with a device, participants were asked to complete the survey form. Once all the tasks had been completed, participants were interviewed.

For scenario one, participants assumed that they were in a class room setting and they had just purchased an IPAQ PDA and a Nokia mobile phone. They were keen to explore these devices to learn about a particular physics topic. The scenario encouraged the participant to ask as many questions as possible during the evaluation process. The evaluation environment was made as relaxing as possible. The goal for this scenario was to achieve the best possible result for each device and each e-learning system.

Scenario two also assumed a classroom setting. Participants again used PCs, PDAs and mobile phones to explore the two e-learning systems. In scenario two, participants were made to experience a low bandwidth connection. The adaptive multiplatform e-learning system detected and estimated the delay and offered the participants offline content delivery while the Blackboard system delivered content as usual but with delay. It should be stressed that both systems experienced the same length of delay.

In scenario three participants were made to experience an interruptive environment. Participants were required to read and close a randomly appearing popup window while performing the sequence of required tasks. The objective was to simulate a multi-tasking environment frequently encountered in the mobile environment. The adaptive multiplatform e-learning system made adaptive adjustments to the delivery of content to the learner by adjusting the length of the assessment content while the Blackboard e-learning system remained the same.

In scenario four, participants were made to experience a busy bandwidth connection but not as long a delay as the offline scenario. The adaptive multiplatform e-learning system detected and estimated the bandwidth and presented a pre-fetch delivery solution while the Blackboard system delivered content as usual but with some delay.

In scenario five, participants were assumed to be receiving a call from a friend who wanted help on a particular physic topic. However the participant did not have much time because of an imminent appointment with a doctor. This scenario simulated the condition of working under time constraint. An eight minute countdown clock was deployed to increase the urgency. The adaptive e-learning system provided adaptive content delivery by adjusting the length of the assessment.

In scenario six, participants were made to self explore the e-learning systems without any help from the researcher. In addition they were warned that 10 points would be deducted for every question asked. The objective was to examine the factors that influence learners when absolutely no help is given during self-directed exploration. This scenario is frequently encountered when learners use mobile devices to access an e-learning system outside the classroom environment.

It should be stressed that during all these scenarios the adaptive multiplatform e-learning system can identify the accessing device, determine its capabilities, estimate its bandwidth and provide content adaptation through style sheet transformation.

In the evaluation, e-learning system B included improved link navigations and multimedia with interaction during the adaptation process based on the comments from the pilot evaluation. The PDA used was IPAQ5450 and Pocket PC Internet Explorer 2003 with real time Bluetooth connection. The mobile phone used was Nokia 6600 with an Opera browser and Vodafone GPRS real time connection.

Participant Information

A total of 36 students took part in the evaluation. Six scenarios were used to explore the interaction between the e-learning system, accessing device and learner. Out of the 36 participants 20 (55.6%) were female and 16 (44.4%) were male. The participants were mostly (80%) aged between 16 and 25, while 8% were aged between 26 and 30, and 12% between 31 and 45. The majority (89%) were doing an undergraduate degree while 11% were at post graduate level. The samples used were convenient samples and it matched the university's student population's distribution and profiles.

Validation and Reliability

Correlation statistics for the constructs were generated in our study. The correlations indicate discriminant validity for the constructs. Discriminant validity was assessed by determining the confidence interval around the correlation for each pair of factors. The confidence interval is equal to plus or minus two standard errors of the respective correlation coefficient. If the confidence interval does not include 1.0 then discriminant validity is demonstrated (Anderson and Gerbing 1988). The test indicated a good level of discriminant validity for the measures.

We further conducted separate confirmatory factor analyses for e-learning system A and e-learning system B for all constructs to test their reliability. We assess reliability by computing the composite reliability coefficients for the constructs (Hair et al. 1995); composite reliability values greater than 0.6 are desirable (Bagozzi and Yi 1988). The factor loading for each of the constructs was rather high except for the multimedia factor in the content dimension (CON-MU), and the motivation (LER-MO) and preference factors (LER-PR) in the learner dimension. A slightly low loading suggests that these measures did not capture the construct fully and did not behave in the same direction as other measures within the construct. For other measures, the loadings are high which translates into a high and acceptable composite reliability except for LER-MO, LER-PR and CON-MU in e-learning system A. Nevertheless the overall analysis showed good construct reliability.

Convergent validity was established from a review of the t-tests for the factor loadings. All the t-tests were significant, suggesting that all indicators measure the same construct (Anderson and Gerbing 1988). All of the t-values were greater than 2.0 and significant at P>0.01 (Steenkamp and van Trijp 1991) except for CON-MU due to missing data.

Structural Equation Modelling

Unlike correlation analysis, structural equation modelling allows the entire dimension's relationships to be simultaneously formulated. To establish a neutral model, we first fitted the model using AMOS with all the data combined. For each dimension, we aggregated all the sub-dimension scores to produce a single dimension score for each sample. As our sample size was not very large compared to the number of paths, aggregation helps to reduce system noise. The fit indexes from the combined model achieved a χ^2 =1.917 with DF = 5, N=216 at P=0.861. The ratio of χ^2 /DF = 0.38 which is less than the recommended 3:1. Other fitness indicators were found to be GFI=0.997, AGFI=0.987, NFI=0.999, TLI=1.07, and RMSEA=0.000. Note that because χ^2 /DF <1 thus RMSEA was set to zero in the formula. These indexes provide further support that the overall model fits very well within the established fitness guideline. In the combined model, the path from D3 to LSS was only -0.03 and was not significant. This path was deleted from the model. Once the overall model fitted well with all the data, we performed a group comparison of the model using data from systems A and B. The resulting model is shown in Figure 1 and their fit indexes shown in Table 2. All paths were significant at the 0.001 level unless otherwise stated.

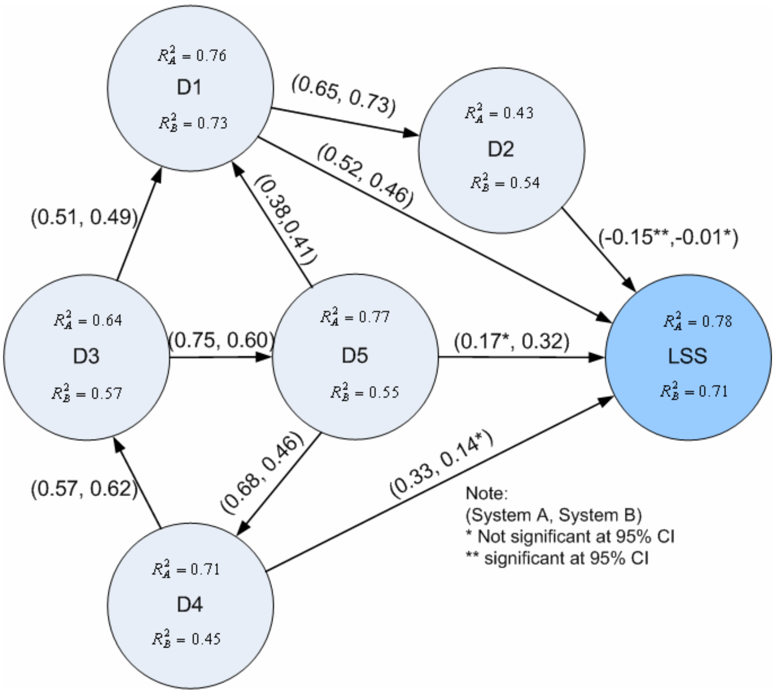

Figure1 Structural equation model (standardised)

Table 2 Fit Indexes for structural equation models

System	CMIN	DF	P	CMIN/DF	RMR	GFI	NFI	RFI	RMSEA
combine	1.91	5	0.86	0.38	0.01	0.99	0.99	0.99	0.00
A	2.95	5	0.71	0.59	0.03	0.99	0.99	0.99	0.00
B	0.94	5	0.97	0.19	0.01	1.00	0.99	0.99	0.00

Table 3 Impact on LSS

	System A			System B		
Dimension	**Direct**	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**
D1	0.524	-0.102	0.422	0.467	-0.013	0.454
D2	-0.155	0	-0.155	-0.017	0	-0.017
D3	0	0.92	0.92	0	0.694	0.694
D4	0.333	0.529	0.862	0.143	0.435	0.578
D5	0.179	0.754	0.932	0.32	0.456	0.776

DISCUSSION

From the structural equation model, only H1 and H5-H10 were supported at the 0.001 level whereas H4 was supported at 0.1 levels for adaptive multiplatform e-learning system B. The implication is that interactions among dimensions were very strong and significant whereas direct impacts were due mainly to D1 and D5. Direct impact due to device dimension D3 cannot be supported in both systems. Direct impact from D2 was supported in system A at the 0.05 level and not supported in system B. From observation it is likely that both D2 and D3 have similar characteristics. Both system A and system B SEM appear to fit well and have good fit statistics. The fit statistics seem slightly better for system B than system A. Because system A is a non adaptive system, this may suggest that measurement from system A has a wider variance than system B. Nevertheless both models can satisfactorily explain the effect of all the dimensions on overall learner satisfaction.

For system B the direct impact on overall learner satisfaction due to learner dimension D2 has been reduced to statically insignificant with a path estimate of -0.01 while for system A the direct impact due to learner dimension D2 on overall learner satisfaction was significant at the 0.05 level with a path estimate at -0.15. The learner dimension has a less negative direct effect in an adaptive e-learning system than a non adaptive e-learning system.

The direct impact on system A was contributed mostly by D1 and D4 while the direct impact on system B was contributed mostly by D1 and D5. The implication is that in system B the communication dimension D4 was perceived positively. A quick response allowed learners' attention to focus on D5 for interaction, navigation and presentation aspects. Conversely in system A the response was slow and D4 was perceived negatively. Learners might not have sufficient time for interaction, navigation and presentation in D5.

The coordination dimension D5 had a strong impact on the communication dimension D4 in system A than in system B. The implication may be that in system B the learner has experienced more consistency in navigation, presentation and interaction and is likely also to be associated with a stable system and suitable form of delivery. Similarly the impact of the device dimension D3 on the coordination dimension D5 was also very strong in system A than in system B. A more consistency experience in D3 was likely to be associated with a consistency experience in coordination dimension D5.

Referring to Table 3, the total impact for D3, D4 and D5 dimensions on LSS have been reduced in system B compared to system A whereas D1 and D2 have been improved. The implication is that the outcome of the adaptation process gave learners better opportunities to experience all the other factors instead of being dominated by a single dimension such as D3 or D5 in system A.

Surprisingly, D2 has a negative path value in both systems. This suggests that D2 might be a suppressor. According to Cohen and Cohen (1975, p. 91), there are three kinds of suppressors. If the predictor variable in question has a zero or very small correlation with the criterion variable, the situation is one of classical suppression. If its beta weight is of opposite sign from its correlation with the criterion, it is serving as a net suppressor. If its beta weight exceeds its correlation with the criterion and is of the same sign, cooperative suppression is indicated.

Further, Darlington (1968) defined a negative suppressor as a variable that has a positive correlation with the dependent variable, but negative beta weight in the regression model. Further analysis shows that D2 itself has a positive correlation with LSS but a negative weight in the full model. This suggests that D2 is a net suppressor. According to Thompson (1998) suppressor variables are important within a regression model because they increase the effect size which shows the extent, strength or effect of a relationship and accounts for the total variance. Further investigation showed that the overall model fit index improved when D2 was present. The suppressing effect was greater in system A than in system B. Thus it is likely that the adaptation process has minimised the suppression, making it more positively correlated.

In summary the model suggests that there are two types of factors – suppressors and non suppressors. D1, D4 and D5 are non suppressor factors whereas D2 (and possibly D3) is a suppressor. The suppressor effect was minimised in system B. The model also suggests that interactions between dimensions were significant in both systems, whereas direct impact from factors to LSS were not all significant. Hypotheses H2 and H3 were not supported at the 0.001 level whereas H4 was only supported at the 0.1 level for system B.

CONCLUSION

This paper has presented a multiplatform e-learning system framework and its evaluation through structural equation modelling. The evaluation focused on the direct impact from various dimensions on LSS and the interaction among them. In order to evaluate the interaction, the systems were explored through six scenarios. The analysis through structural equation modelling revealed that direct impact due to D1 and D5 were supported at the 0.001 level. The analysis also supports a close interaction among the dimensions as in H6-H10. D3 however did not provide a significant direct impact but there were strong relationships between D1, D4 and D5 which should not be treated lightly. Further analysis revealed that D2 is a suppressor and the suppressive effect was reduced in system B. The evaluation and its results come with some limitations. First the evaluation was conducted with learners having short term use of the e-learning systems. Though e-learning system A represents a familiar system with longer term use, its content is somehow not familiar to most learners. Thus further evaluation would need to determine the long term effect when learners are familiar with the e-learning systems and content. Second, while the scenario evaluation intends to vary the interactions between the learner and the system as much as possible, there is no guarantee that all the factors will be equally affected. It is also unlikely that one can control only one particular factor at a time to capture the effect independently as these factors act together. Third, the pedagogy of the implemented e-learning system consists of first exposing learners to theory and principles then multimedia simulation followed by exercises. During the exercises learners were encouraged to revisit the content and multimedia interaction. The evaluation is based on such pedagogy. Lastly, the current research used three different types of accessing devices. It can only generalise to devices with similar capabilities. New devices with very different interaction can be tested with the same instrument.

One area that could benefit from future research with respect to implementation is exploration of other emerging technologies to implement the multiplatform e-learning system. For example comparing the implementation using autonomous agents and web services with respect to performance, adaptivity and extensibility may generate a more robust multiplatform e-learning system.

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