An Empirically Supported Contingent Method for the Usability Evaluation of Web-based Learning Systems

Thao Thi Ngoc Nguyen, Carl Jacob, Vanessa Chang, Elizabeth Chang, Andrew Turk

School of Information Systems,
Curtin University of Technology, Perth 6845
Ng.n.thao@gmail.com, turka@murdoch.edu.au, {jacobc, changv, change}@cbs.curtin.edu.au

Abstract: The research was conducted with the aim to develop a customizable, user-centred method for formative usability evaluation of such systems. The method can be used for usability evaluation of Web-based learning system during its development stages, from screen-based prototypes to near completion. At the heart of the method is a set of empirically-validated usability factors and a set of contingent rules that allow the customization of these factors for different users and context of usage.

Introduction

E-learning refers to any learning done using an electronic medium. E-learning is available in various formats such as computer-based training, online learning, mobile learning, and web-based learning. Computer-based training, the earliest format of e-learning is defined as training activities conducted on computers. Online learning is defined as learning activities conducted over computer networks, including intranets, extranets, or the Internet ((Eklund, Kay & Lynch 2003; Tsai & Machado 2003). Mobile learning is defined as learning activities conducted using mobile devices such as mobile phones, personal digital assistants, and multimedia players such as the ipods. Web-based learning is defined as learning activities conducted using Web-based applications over computer networks.

The evolution of e-learning from computer-based training into a wider range of formats is made possible by the advancement of the Internet and multimedia technologies. However it is the increasing number of learners coupled with the limitation of resources available for education and training that has contributed to its growth (Rutternbur, Spickler & Lurie 2000). It was estimated that e-learning in Australia is growing at an annual compound rate of 22 percent (Payne, 2003 as cited in Eklund, Kay et al. 2003).

The common components available in a web-based learning program include: the learning contents presented in a variety of formats, from plain text to multimedia, discussion board, emails, and other tools that allow the administration of the course from a lecturers' perspective (e.g. gradebook) and the management of personal study from a student's perspective (e.g. calendar).

The usability of web-based learning systems can be evaluated and improved through formative usability evaluation. Formative usability evaluation is conducted during the development process of the product for the purpose of identifying defects and making improvements to the product. Heuristic evaluation is an expert-based formative evaluation method developed by Nielsen (Nielsen & Molich 1990) that can be done at any stage of the design cycle. Heuristics evaluation has been selected as the theory framework for the methodology that this study aims to develop due to its practical value for industry application. Its strength is in its cost-effectiveness and proven ability to capture a substantial number of interface usability problems (Nielsen & Philips 1993).

Motivation

A number of issues have been identified through the literature and the researchers' personal experience of teaching online units at a large university in Australia. These issues have motivated the research and include:

First, Web-based learning systems are complex applications that incorporate technology and education. Yet, at the moment Web-based learning systems are mostly evaluated using usability factors that were either originally

developed for stand-alone applications or Websites or modification of those. The few sets of factors tailored to Web-based learning systems were mostly not validated for their relevance to such systems. A need existed for empirically evaluate the relevance of the existing proposed usability factors for Web-based learning systems.

Second, while it was routinely acknowledged in the literature that not all usability factors apply equally in all situations, there has been no guidance regarding how to account for this variation when conducting usability evaluation. There was a need for guidelines on the variation in importance of usability factors for different context of usage and user characteristics.

Third, one of the common observations from the literature as well as from the researcher's personal experience in participating in e-learning programs at a large higher education institution was that usability evaluation, particularly formative usability evaluation, was either not conducted or conducted informally by the designer based on his or her experience without the learners' perspective. At best usability evaluation was done using existing heuristics with little or no empirical basis. This was often due to a combination of factors, including the urgent development time, the limitations of existing evaluation methods and the shrinking budget for education. There was a need for an resource-efficient and easy to implement usability evaluation method for Web-based learning system.

Research Methodology

The research aimed to develop a contingent, user-centred method for formative usability evaluation of such systems. The method can be used by instructional designers or developers during various stages of the web-based learning system development cycle to improve its usability.

First, the usability factors for web-based learning systems were identified and operationalized using a combination of interviews and literature survey. The outcome of this was also used to develop the instrument for a survey in which the usability factors were to be empirically evaluated. Second, a survey was conducted to investigate (1) the validity of the usability factors identified and defined from the literature, (2) the importance rating of the factors, and (3) the relationships between the independent variables (the learners' characteristics and context of usage) and the dependent variables (usability factors). Due to practical constraints, including accessibility to the sample, time and scope of the project, the survey was limited to web-based learning system used in higher education context. Third, the results of the survey were used to develop a contingent usability evaluation method for web-based learning systems from learners' perspective. The results included the importance rating of (1) usability factors and the relationships between the factors and (2) the learners' characteristics and web-based learning system context of usage from learners' perspective. The method had two components of usability evaluation and usability design, with a focus on usability evaluation of web-based learning system during its development stages, from screen-based prototypes to near completion. At the heart of the method are a set of usability factors and a set of contingent rules that allow the customization of these factors for different users and context of usage.

Learners' and Web-Based Unit Characteristics (the Independent Variables)

There may be relationships between the system's characteristics and the learner's evaluation of its usability. For example, different learners may find the same feature of a system usable or unusable depending on their level of IT proficiency. Prior research suggested that a learner's characteristics such as prior experience with the Internet and computer, cognitive style, culture may affect his or her importance rating of certain usability factors affecting a web-based learning system (Koohang 2004a; Turk 2001; Webster 2002). Additionally, the type of the web-based learning system, most notably its pedagogy, may also be a relevant criterion. Cognitive style was found in Webster's study (2002) to be useful and relevant to the design of interface and content of online learning environment. It is defined as an individual's information representing and processing preferences (Riding and Rayner, 1998 as cited in Webster 2002). It can also be defined by two dimensions: verbal-imaginary and wholist-analytic (Riding and Cheema, 1991 as cited in Webster, 2002). However, it was outside of the scope of this study to explore the impact of cognitive style.

Cultural background was explored within a limited number of dimensions, namely language, country of origin, years in Australia. Culture could be provisionally defined along the dimensions proposed by Hofstede (1986). The pedagogy of Web-based learning system could be defined along the line of learner-centred versus teacher-centred;

and learning-by-doing versus didactic systems. In the survey the respondents were asked about the unit they were studying and the unit would then be analysed for the pedagogy.
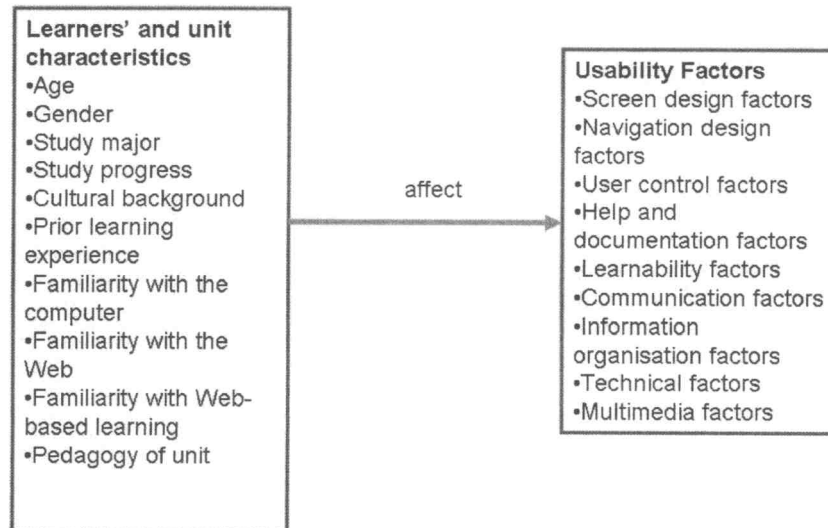

Figure 1: The web-based learning model

The Usability Factors (Dependent Variables)

As web-based learning is a concept that crosses all disciplines, the usability factors from a number of related areas have been combined to form the collection of usability factors that affect web-based learning. Specifically, these encompass: (1) the usability factors affecting web-based applications (Gerhardt-Powals 1996; Kirakowski, Claridge & Whitehand 1998; Turk 2001), (2) the usability factors affecting multimedia applications (Kennedy, Petrovic & Keppell 1998; Najjar 2001), and (3) the usability factors affecting the learning process (Govindasamy 2002; Nokelainen 2005; Reeves 1997; Reeves et al. 2002; Silius, Tervakari & Pohjolainen 2003).

The list of usability factors involving 6 main issues, presented below, has been compiled from the following authors: Gerhardt-Powals (1996), Govindasamy (2002), Kennedy, Petrovic & Keppell (1998), Kirakowski, Claridge & Whitehand (1998), Najjar (2001), Nokelainen (2005) Reeves (1997), Reeves et al. (2002), Silius, Tervakari & Pohjolainen (2003) and Turk (2001).

Interface issues are the characteristics of the web-based learning systems' interface that have an effect on its usability. Examples of the interface issues include the attractiveness, consistency, customizability, error reduction/recovery, help and documentation, internationalization, learner control, recall and recognition improvement, navigation support, and interactivity.

Learnability issues are characteristics of the web-based learning system that facilitates learning. The pedagogical issues may include factors such as learner control, learner activity, applicability, match with pedagogical assumption, added value for learning, motivation, valuation of previous knowledge, and flexibility.

Information organisation issues include characteristics in the structure of the information that have an effect on usability. Examples of the information architecture issues include presentation, names and information organisation, sequencing of information, and search facility.

Accessibility and delivery issues are technical issues relating to the accessibility and delivery of the information. Accessibility and delivery issues may include the factors such as accessibility, download speed, adherence to conventions and standards.

Multimedia issues include characteristics of the multimedia elements of the web-based learning system that affect its usability. The multimedia issues may include coherence of multimedia presentation, suitability of the multimedia used, use of elaborative media, and synchronicity of multimedia presentation.

Communication issues incorporate the communication elements of the web-based learning system that affect its usability. Communication elements include the tools that are synchronous (ie. the messages are sent and received instantaneously, such as the case of online chat) and asynchronous (ie. there is a delay in the time when the message is sent and received, such as in the case of emails or discussion board). Examples of the communication issues include the the availability of the communication tools, issues related to the virtual classroom facilities, issues related to webcams, blogs, personal web page, and file transfer.

Research Study

The sample consisted of 431 respondents and covered a range of age, gender, cultural background, course of study, level of study, language and computer literacy. The students were studying towards commerce degree in the following business disciplines: accounting, business law, marketing, economics and finance, management, information systems. They are also from different countries, with the main groups included Australia, Malaysia, Singapore, Hong Kong, Vietnam. The data was collected online and in class. Online questionnaire was used for students who engaged in pure online learning mode. Written questionnaires handed out in class are for those studying in a mixed mode of class contact and online learning.

Data analysis was conducted to investigate (1) the importance profile of each usability factor so that they could be ranked in order of perceived importance to the learners who used the web-based learning systems; (2) whether there was any relationship between the independent and the dependent variables; and (3) where a relationship existed between the independent and dependent variables, what was the nature of that relationship.

The Survey Results

The results allowed for the ranking of all usability factors in the order of importance from learners' perspective. The usability factors in the category of Technical factors has the highest average importance rating with an Average of Mean Importance of 3.21 out of 4, followed by Navigation at 3.04 and Help and Documentation factors at 3.03.

On an individual basis, the three usability factors that are rated as being the most important are (in decreasing order of importance): The Pages are Quick to Download, Users Can Locate Information Easily and Text is Always Easy to Read. From this, there exist important significance relationships between the Usability Factors and User Characteristics or Context of Usage. A large number of statistically significant relationships were found between the usability factors and the user and contextual characteristics factors. For example, the usability factor Pages are Quick to Download has significant relationships with the following user characteristics and context of usage: Learners' Native Language, Gender, Weekly Hours Spent on the Web, Course of Study, Level of Study, Age, Origin, and the Web-based Unit of Study. These relationships were evidenced by a significance level of 1% when applying the Analysis of Variance (ANOVA) test.

New method for usability evaluation and design of web-based learning systems

The method, a formative usability evaluation is aimed at developing usable system, as opposed to summative usability evaluation method which aimed more at comparing systems on their usability and selecting the most suitable one. The 3 main benefits of this method are in its user-centricity, flexibility, and contingency. At the heart of the method is a heuristic-based set of usability questions that can be used for evaluating online learning systems. This method presented in Figure 2 is used for this study. Heuristics are understood as "sets of questions, principles, or product guidelines" (Geest & Spyridakis 2000). In this method the heuristics have been operationalized as questions so that they can be used effective by evaluators.

The method is user-centred. The foundation of the method (the usability evaluation and guidelines) is based on users' perspectives. The contingent rules used for the methods are based on the target learners' characteristics and their context of usage.

The method is flexible. It can be customized so that the evaluators can be experts of usability, expert of web-based systems, content expert or end users (learners). It can be customised so that the evaluation is a quick one where only top ten usability evaluation questions applying to that particular situation are looked at, or the top fifty percent of the evaluation questions, or a full evaluation of all the ninety eight questions.

The method is "contingent", that is, the usability guidelines and usability evaluation could be adapted depending on the target learners group and their context of usage. Also, it provides the weighting for the factors when overall quantitative evaluation of the system is calculated.
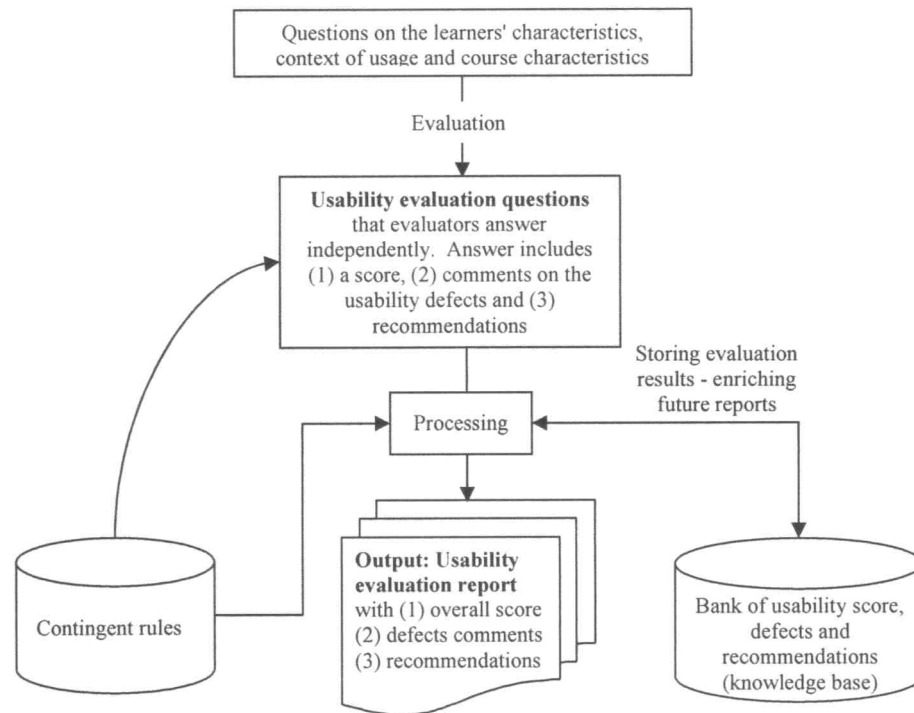

Figure 2: New Method for Usability Evaluation

Four steps are involved in this process. As shown in Figure 2, step 1 of the process starts with the evaluator answering the questions on the learners' characteristics, the context of usage and the web-based learning system characteristics. The data collected are used to implement the contingent rules. The questions on target learners' characteristics and context of usage characteristics are questions essentially created based on the characteristics that were found in the survey results to have a relationship with the usability factors. These characteristics include: the learners' course of study, major area(s) of study, study level, native language, gender, age, origin, the web-based unit they are studying, familiarity with web-based learning, computer literacy, and familiarity with the unit of study.

Step 2 of the process concentrates on the usability evaluation instrument. The usability evaluation questions are created based on the usability factors that were empirically validated in the survey, for example, the usability evaluation question in Table 1 was based on the usability factor Text is easy to read.

The results of the evaluation include (1) a quantitative score which is a weighted average of the scores given on all the usability factors, the weighting is based on the contingent rules applicable to the learners' population of the learning system and (2) qualitative comment on the usability problem (description, severity rating, frequency of usage) and recommendations on how it can be fixed.

USABILITY EVALUATION QUESTION	SCORE (scale of 0-10, give a score of 0 if the feature does not exist)	COMMENTS ON THE USABILTY PROBLEM	RECOMMENDATIONS ON HOW TO FIX THE USABILITY PROBLEM

How easy is it to read the text (font large enough, good contrast with background)?				

Table 1: The usability evaluation instrument

Step 3 of the process is on applying the contingent rules. There are two sets of contingent rules that are used for Usability evaluation. One set is for the customization of the usability evaluation instrument used in this step. The second set is for generation of the Usability evaluation report.

The final step, Step 4 involves generating the usability evaluation reports. Two reports can be generated at this step: (1) Individual expert report, and (2) Combined expert report. The individual expert report that is created in Step 3 can be retrieved from the database of usability score, defects and recommendations, presented in a defined format and printed. The combined expert report is generated by combining all the individual expert reports on the same Web-based learning system by calculating the quantitative score and incorporating all qualitative information. The average quantitative scores given by experts formed the overall quantitative score. This also includes the average significance scores given by expert. The qualitative information includes the usability defects presented in the order given by the averaged significant scores. Under each defect there will be a compilation of all expert comments and recommendations on the defects.

The expert recommendations relating to the usability defects uncovered by each usability question can be stored in the database under that usability question. With time this will be built into an expert knowledge database, so that in the future when an expert answers a usability question he or she can select or modify one of the existing recommendations relating to that question.

Advantages and Limitations

The method developed is an improvement over the standard heuristics evaluation methods that are being applied for e-learning evaluation. Specifically it is based on usability factors that were empirically validated by end users; it is flexible and can be used for short or full evaluation, it can be used by experts (usability expert, web-based learning expert or content expert) or end users. The method is also user-centred that provides usability guidelines and evaluation. It incorporates users' importance rating of usability factors by providing a list of usability guidelines that are ranked in order of importance for the target student population.

It also provides a quantitative evaluation score as well as qualitative comments and recommendations. It semi-automates the evaluation process and generate the usability evaluation reports in standard format. It also has an attached knowledge base that will keep building up which allows evaluators to draw from the knowledge of other experts. Finally it is scalable, that is, new usability factors and contingent rules can be added in the future.

The limitations of the method is that it is better used for formatively identifying usability issues rather than providing a conclusive assessment on the usability of a system, it can be used to identify the majority of usability issues but not all of them. It is also best used by experts who have background knowledge of the good usability practices and it is mainly based on the empirical findings of students who are studying towards a commerce degree.

Conclusions and Future Work

The outcomes of the research were significant for a number of reasons. First, the usability factors that were developed were reasonably comprehensive, covering traditional usability factors and pedagogical factors, and were empirically evaluated. These factors could be the foundation for further research to either expanded upon the usability factors, or to use these usability factors as the foundation for other usability evaluation approaches that are different from the approach developed in this study. Second, the contingent rules developed based on the results of the study enables developers to be aware of issues that matter the most to the users they are designing for. This will help instructional designers and Web-based learning system developers to optimize their resources and design systems that are more usable and user-centred. Third, the usability evaluation method provides designers and developers with a method of evaluating web-based learning systems that are customizable, flexible, based on empirical research and practical. Finally, the online prototype that implements the method can be conveniently used for quick evaluation or comprehensive evaluation as well as evaluation by users or experts. The flexibility of the

tool, coupled with the employment of heuristics evaluation which has already been widely adopted in industry, is expected to maximize its adoption amongst practitioners.

Further research can be conducted to (1) expand the study to students of other disciplines and countries, (2) expand the study to corporate Web-based learning, (3) further develop the method to cover Usability Design, (4) further develop the online prototype into an online tool that implements the Usability Design and Evaluation Method, and (5) develop the knowledge base related to the common usability defects and recommendations so that the process of formative usability evaluation can be further automated.

Reference

Eklund, J, Kay, M & Lynch, H 2003, *E-learning: Emerging Issues and Key Trends - A Discussion Paper*, Australian Flexible Learning Framework. Retrieved June 20 2004, from http://flexiblelearning.net.au.

Elissavet, G, & Economides, A.A. 2003, 'An Evaluation Instrument for Hypermedia Courseware.' *Educational Technology & Society*, vol. 6(2), pp. 31-44.

Geest, TVD & Spyridakis, JH 2000, 'Developing Heuristics for Web Communication: An Introduction to This Special Issue', *Technical Communication*, vol. Third Quarter, pp. 230-239.

Gerhardt-Powals, J 1996, 'Cognitive engineering principles for enhancing human-computer performance,' *International Journal of Human-Computer Interaction*, vol. 8, no. 2, pp. 189-211.

Govindasamy, T 2002, 'Successful implementation of e-learning: Pedagogical considerations', *Internet and Higher Education*, vol. 4, pp. pp 287-299.

Hofstede, G 1986, 'Cultural Differences in Teaching and Learning', *International Journal of Intercultural Relations*, vol. 10, pp. 301-320.

Kennedy, G, Petrovic, T & Keppell, M 1998, 'The Development of Multimedia Evaluation Criteria and a Program of Evaluation for Computer Aided Learning', in *ASCILITE '98*.

Kirakowski, J, Claridge, N & Whitehand, R 1998, 'Human Centered Measures of Success in Web Site Design', in *The 4th Conference on Human Factors and the Web*, AT&T Lab, pp. 24-27.

Koohang, A 2004a, 'A Study of Users' Perceptions Towards E-Learning Courseware Usability', *International Journal of E-learning*, no. April-June 2004.

Koohang, A 2004b, 'A Study of Users' Perceptions Toward E-Learning Courseware Usability', *International Journal on E-Learning*, vol. 3, no. 2, pp. 10-17.

Najjar, LJ 2001, 'Principles of educational multimedia user interface design', in RW Swezey & DH Andrews (eds.), *Readings in training and simulation: A 30-year perspective*, Human Factors and Ergonomics Society, Santa Monica, CA.

Nielsen, J 1993, *Usability Engineering*, Academic Press.

Nielsen, J & Molich, R 1990, 'Heuristic Evaluation of User Interfaces', in *ACM Human Factors in Computing Systems CHI'90*, pp. 249-256.

Nielsen, J & Philips, V 1993, 'Estimating the relative Usability of Two Interfaces: Heuristic, Formal and Empirical Methods Compared', in *ACM/IFIP Human Factors in Computing Systems INTERCHI'93*, pp. 214-221.

Nokelainen, P 2004, 'Designing an Evaluation Tool for Digital Learning Materials', in *Society for Information Technology and Teacher Education International Conference 2004*, AACE, Atlanta, GA, USA, pp. 1810-1817.

Nokelainen, P 2005, 'The technical and pedagogical usability criteria for digital learning material', in *World Conference on Educational Multimedia, Hypermedia and Telecommunications 2005*, AACE, Montreal, Canada, pp. 1011-1016.

Reeves, T 1997, *Evaluating What Really Matters in Computer-Based Education*, Educationau. Retrieved 7 July, from http://www.educationau.edu.au/archives/cp/reeves.html.

Reeves, T, Benson, L, Elliott, D, Grant, M, Holschuh, D, Kim, B, Kim, H, Lauber, E & Loh, S 2002, 'Usability and Instructional Design Heuristics for E-Learning Evaluation', World Conference on Educational Multimedia, Hypermedia and Telecommunications, pp. 1615-1621.

Rutternbur, B, Spickler, G & Lurie, S 2000, *Elearning The engine of the knowledge economy*, Morgan Keegan.

Silius, K, Tervakari, A & Pohjolainen, S 2003, *A Multidisciplinary Tool for the Evaluation of Usability, Pedagogical Usability, Accessibility and Informational Quality of Web-based courses.* Retrieved August 15, from http://www.virtuaaliyliopisto.t.pdf.

Tsai, S & Machado, P 2003, 'E-learning, Online Learning, Web-based Learning, or Distance Learning:' in *Elearn Magazine*,

Turk, A 2001, 'Towards Congingent Usability Evaluation of WWW Sites', in *Proceedings of OZCHI 2001*, Perth, Australia, pp. 161-167.

Webster, R 2002, *Metacognition and the Autonomous Learner: Student Reflections on Cognitive Profiles and Learning Environment Development*, Edith Cowan University, Perth, Australia. Retrieved 9th August, from http://www.csd.uwa.edu.au/iced2002/publication/Ray_Webster.pdf.