A framework for usability evaluation of an offline e-learning tutorial and its application in usability testing

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Abstract: The design of e-learning environments should take into account principles of learning and principles of usability. To achieve this, e-learning applications should undergo usability evaluation and subsequent refinement. The main objectives of this study are (1) to present a synthesised framework of usability evaluation criteria suitable for evaluating a stand-alone offline e-learning tutorial, and (2) to evaluate the tutorial using the usability testing evaluation method and the criteria in the framework. A further aim is to determine the effectiveness of the framework in conducting this task. The framework consists of twelve criteria, each of which has a number of sub-criteria. The use of the framework and usability testing proved to be effective in evaluating the tutorial. The major problems identified were related to the poor structure and navigability of the interactive tutorial, as well as weaknesses in its Help system. These impact negatively on the use of the tutorial for learning.

Introduction

Advances in information technologies have extended the opportunities for designing interactive, learner-centred, engaging and easily accessible e-learning environments (Abdollah, Ahmad and Akhir, 2012; El-Tigi & Branch, 1997; Khan, 2002; Visser & Visser, 2002). However, these developments have come with associated challenges, which cannot be attributed merely to a lack of technical skills among users, but also to issues of interface design and interaction design (White, Wright & Chawner, 2006). Educational applications should have interfaces that simplify communication with the users. In designing e-learning environments such as interactive tutorials, the development of easily usable systems should be a prime goal.

Usability is defined as the effectiveness and efficiency with which users' goals are achieved in a system, to a satisfactory level, for specified users in a specific situation (Dix, Finlay, Abowd & Beale, 2004; ISO 9241-11, 1998; Preece, Rogers & Sharp, 2007). Usability focuses mainly on how the system supports user interaction through appropriate and meaningful interfaces and supportive navigation. Furthermore, the design and implementation of systems should be focused on the users' needs. In addition to the basic usability requirements, usability of e-learning systems should provide the type of interactivity that promotes ease of learning and offers meaningful engagement with the learning content (Masemola & De Villiers, 2006). It is essential that the design should take into account principles both of instructional design and interaction design. Learners must be able to use the system effectively before they can even begin to learn.

To achieve sound usability, products should undergo evaluation and subsequent refinement. This calls for application of adequate and appropriate usability evaluation methods (UEMs). UEMs are techniques used by evaluators to identify usability problems that must be addressed through the design and redesign of a system (Furniss, Blandford & Curzon, 2007). Usability testing (UT) in a human-computer interaction laboratory (HCI Lab) is one of the most effective UEMs for identifying usability problems and measuring product usability. It

involves identifying some of the tasks most commonly done by users, and recruiting typical users to attempt these tasks under controlled observation, while monitoring and recording their usage processes.

To make UT more effective, this paper proposes a synthsized set of criteria as guidelines for evaluating an e-learning tutorial and presents findings from applying this framework in formal usability testing in an HCI Lab.

Research objectives

The main objectives of this study are:

- To present a synthesized framework of usability criteria for evaluation of off-line e-learning tutorials.
- To apply the framework in evaluating a CD-based interactive tutorial, using the usability testing evaluation method and the criteria to identify problems in the tutorial.
- To determine the effectiveness of the framework and the method.

Literature review

E-learning tutorials

Computer-aided instruction, such as an interactive electronic tutorial, presents sets of information and instruction to guide learners, interspersed with examples and interactive exercises (Averill, 2004). Averill stresses the importance of multiple modes of presentation, advocating the incorporation of textual explanations supported by images, animation, sound data and/or video clips for elaboration. Use of these multiple formats can support learners in obtaining cognitive skills. The interactive exercises, usually including multiple-choice questions, should test understanding. Moreover, the system should allow learners to progress to new learning content after demonstrating their understanding of previous units.

Usability evaluation of e-learning systems

Usability evaluation of e-learning systems is different from that of commercial ones. Commercial systems are intended for fast task completion and short execution processes, whereas e-learning applications are intended to support human learning processes through information transfer and to manage educational interaction (Adebesin et al., 2009, Masemola & De Villiers, 2006). Usability of e-learning systems involves both technical usability and pedagogical usability. Technical usability relates to techniques to ensure that interaction with a system is trouble-free, while pedagogical usability intends to support the processes of teaching and learning (Melis & Weber, 2003). To achieve pedagogical usability, the design team of an e-learning application should consider issues of human learning, learning goals and processes, as well as the usual aspects of system requirements and usability.

Controlled usability testing

Usability testing is a usability evaluation method that assesses a product's usability by observing how participants use it and monitoring the problems they encounter (Barnum, 2008; Masemola & De Villiers, 2006; Zazelenchuk, Sortland, Genov, Sazegari & Keavney, 2008). The testing is conducted using sophisticated equipment in the controlled environment of an HCI laboratory (Dix et al., 2004; Rubin & Chrisnell, 2008). According to Nielsen's seminal work (1994b), participants should ideally be real users performing representative tasks. Measurements called usability metrics are taken to quantify performance on aspects such as times taken on tasks, types of errors made, error recovery, etc. This provides the evaluators with direct information on the usability status of the application when in operational use. During a testing session, users are video- and audio-recorded for re-viewing, which facilitates subsequent iterative analysis of the data (Hannafin, Shepherd & Polly, 2010). UT requires sophisticated technology, along with considerable effort and preparation by the researcher. Hence it is an expensive evaluation method (Robertson, 2007).

Research method and processes

The framework of usability criteria for evaluating e-learning tutorials was generated by means of an extensive literature study on learning theories, evaluation, and practical aspects of e-learning.

The next stage of the research, the application study, was conducted on an offline application with the pseudonym *Business English for You (BE-Y). BE-Y* is a CD-based e-learning tutorial that supports learning the English language for business purposes. Due to the location of the usability testing, real-world users of *BE-Y* could not be acquired, but participants in both the pilot and the main UT studies were representative of the typical user population in terms of background, ages (19-40) and occupations as recommended by Davis and Shipman (2011). They were drawn by purposive sampling, from academic and non-academic staff at the University of South Africa (UNISA). The sessions were conducted in the HCI laboratory at UNISA, using observation, protocol analysis ('think-aloud') and recording as data collection techniques.

In line with recommendations by Van Teijlingen and Hundley (2010), a pilot study, with four participants, was conducted prior to the main study. The subsequent main study involved twelve participants. Task selection was based, first, on the frequency of conducting those tasks in the real-world environment and, secondly, to ensure they related to the vital aspects of e-learning applications addressed by criteria in the framework, so that data could be collected for each criterion. The UT process included the following steps: identification of tasks and metrics, preparation for the session, conducting the pilot study, and conducting the main study the next year (Perfetti, 2010; Sperry & Fernandez, 2008). The main study involved welcoming the participants, introducing them to the process and equipment, signing consent forms, and debriefing of participants after the actual testing. The debriefing included a short interview and a post-test questionnaire, which also related to certain criteria in the framework. During the actual testing sessions, the researcher was available to assist participants if required.

The framework

Table 1 presents the framework, which was generated by integrating relevant concepts to synthesize criteria and sub-criteria, comprising learning-related criteria and traditional usability criteria. The two groups are not mutually exclusive, but Criteria 1 to 6 relate mainly to learning, while 7 to 12 are usability aspects. The *Reference* column shows the literature sources from which the criteria were gleaned.

Table 1: Framework of criteria for evaluating offline e-learning tutorials

	Criterion	**References**
1	**Clear learning goals, objectives and outcomes**	
	1.1 An e-learning tutorial should have clear and well-communicated learning goals that a learner is to achieve upon completion of a session.	Albion (1999); Alessi and Trollip (2001); Holzinger (2008); Northrup (2007); Perfetti (2010); Spratt and Lajbcygier (2009).
	1.2 The learning goals and objectives should be clearly evident throughout a learning session.	Alessi and Trollip (2001); Reeves and Reeves (1997).
2	**Presentation of domain in a meaningful and engaging way**	
	2.1 The tutorial and its content should engage learners with practical activities that are interesting and engaging.	Albion (1999); Holzinger (2008); Quinn (1996); Vrasidas (2004); Zaharias (2006).
	2.2 Knowledge should be presented in a way that is appropriate to the learning context.	Jonassen (1994); Shelley, (2001); Squires (1999).
	2.3 There should be a match between the symbols, icons and names used and the learning context in the real world.	Reeves and Reeves (1997); Dix et al. (2004).
3	**Nature of the learning activities**	
	3.1 There should be activities that support learners in comprehending the new knowledge acquired.	Albion (1999); Shelley (2001); Ssemugabi and De Villiers (2010).
	3.2 The system should support active learning in which learners	Alessi and Trollip (2001).

	analyse content, and make deductions.	
	3.3 The learning system should motivate the target users.	Reeves and Reeves (1997); Squires (1997); Vrasidas (2004).
	3.4 The system should promote learners' creativity by including innovative features.	De Villiers (2003); Vrasidas (2004).
	3.5 Learners should be engaged through attractive content and interaction. This should however avoid causing distractions during learning sessions.	Vrasidas (2004).
4	**Elicit learner understanding**	
	4.1 Help should be available to support learners in understanding the learning content and locating what they need.	Albion (1999); Dickinson (2012); Perfetti (2010); Shelley (2001); Zaharias (2006).
	4.2 New learning content should incorporate existing skills and learners' prior knowledge.	De Villiers (2003); Squires and Preece (1999).
5	**Feedback for formative evaluation**	
	5.1 Formative evaluation is important in supporting learning and communicating with learners. The system should provide constructive feedback as part of formative evaluation.	Albion (1999); Northrup (2007); Squires (1997); Vrasidas (2004).
	5.2 Feedback should focus on improving learners' performance and increasing their confidence in learning.	Albion (1999); Squires and Preece (1999); Vrasidas (2004).
	5.3 The tutorial should guide learners through appropriate questions, exercises and/or activities, and provide responses/feedback aligned to the intended learning objectives.	Alessi and Trollip (2001).
6	**Support for skills transfer to the real world**	
	6.1 The learning system should enable transfer of learnt skills to the learners' real world, where they can apply the skills in their everyday activities.	Albion (1999); Dix et al. (2004); Greenwald (2011); Nielsen (1994a); Sharma and Mishra (2007); Squires and Preece (1999).
7	**System status should be visible**	
	7.1 The system should keep the user/learner informed about what is going on.	Dix et al. (2004); Nielsen (1994a); Spratt and Lajbcygier (2009); Squires and Preece (1999).
	7.2 An e-learning tutorial should have built-in feedback mechanisms to respond to learners' answers to learning activities and exercises.	Dickinson (2012); Dix et al. (2004); Greenwald (2011); Spratt and Lajbcygier (2009); Ssemugabi and De Villiers (2010).
	7.3 Every learner-initiated action should have a corresponding visual or audio response by the system so that learners can understand the consequences of their actions.	Squires and Preece (1999); Ssemugabi and De Villiers (2010).
8	**Appropriate learner control**	
	8.1 Learners need freedom to control the pace of their learning. This gives them a sense of ownership of their learning process.	De Villiers (2003); Khan (2002); Shelley, (2001); Squires (1999).
	8.2 Learners should take the initiative for the preferred learning methods, time, place, content (i.e. unit or section), and sequence. This, however, depends on the learning objectives.	De Villiers (2003).
9	**Cognitive error recognition, diagnosis and recovery**	
	9.1 The environment should include some complex situations that require users to construct solutions, since learners learn from their mistakes.	Squires and Preece (1999).

	9.2 The system should provide adequate help to guide learners and help them recover from cognitive errors. 9.3 An e-learning system should permit learners to be innovative in addressing challenges encountered during learning sessions.	Squires and Preece (1999); Ssemugabi and De Villiers (2010). Oliver (2000).
10	**Active learning and learner motivation** 10.1 The system should engage its learners through suitable content.	Vrasidas (2004).
11	**System's flexibility, efficiency and navigation** 11.1 The system should be flexible to the needs of different users, for example novices, intermediate users and experts. 11.2 There should be shortcuts that are not visible to novice users but that are visible to frequent users, so as to increase their paces of interaction and task completion. 11.3 Learners should be able to adjust settings to suit their needs.	Dix et al. (2004); Squires and Preece (1999); Ssemugabi and De Villiers (2010). Dix et al. (2004); Squires and Preece (1999). Squires and Preece (1999).
12	**Help facility** 12.1 Learners should easily be able to access a Help facility. There should be simple and systematic guides to assist learners.	Bernsen and Dybkjaer (2009); Dix et al. (2004); Squires and Preece (1999); Ssemugabi and De Villiers (2010).

Findings of the application study and discussion

The UT and questionnaire in the main study covered a variety of usability aspects, some of which are presented to illustrate usage of the framework. The aspects in the framework contributed to the identification of tasks for the UT sessions. In order to avoid participant fatigue, the time spent on sessions should not be too long and the number of tasks should be realistic, focussing on the most important aspects. For example, with reference to Criterion 9 (Error recognition and recovery) and Criterion 12 (Help facility) in Table 1, a task required participants to use *BE-Y*'s Help facility.

Table 2 shows findings relating to the number of errors that occurred, how participants recovered from their errors, and how often the Help facility was used. It lists the frequency of user errors and indicates whether the participant required assistance from the researcher in recovering. It indicates 39 errors, involving only nine cases of independent recovery from errors, while there were 30 assisted recoveries. For the nine independent recoveries, four participants recovered by using *BE-Y*'s Help facility, while five figured out the solution on their own. In total, twelve participants recovered from errors by using Help, although eight had to be assisted in using it. In most of the 22 cases of assisted error recoveries, where participants did not independently use Help, they were taken through the Help steps by the researcher or the researcher directly provided advice that helped them solve the problems. This data demonstrates that, in general, the Help system was inadequate and not effectively usable.

***Table 2: Comparison of user errors and access to the Help facility* (Main study: n=12)**

Error recovery	Total errors (all participants)	Recovery using *Help*	Did not use *Help* facility
Error with independent recovery	9	4	5
Error with assisted recovery	30	8	22
Total	**39**	**12**	**27**

All twelve participants completed the tasks successfully. This was due to the refinement of tasks after the pilot study, ease of understanding the instructions, and communication between participants and the researcher. The average time taken on all the tasks was 18.9 minutes. The fastest participant took 11 minutes while the slowest took 26. Table 3 shows the usability metrics of the three fastest participants (Participants 7, 10 and 12) and the three slowest (Participants 3, 6 and 11). The slowest took much longer when aggregated – 71

minutes in total, to complete the tasks, in comparison to the three fastest whose times, when aggregated, totalled 41 minutes. The table also shows that although the total number of errors made by the two groups was comparable, 8 errors by the fastest group and 10 by the slowest, the total number of times participants in the slow group was stuck, i.e. 12, was twice as much as the fast group with a total of 6. Because the slow group got stuck more frequently, they required three times as much assistance to recover from errors as the fast group – 12 assisted recoveries, compared to 4. Because the slow group required much more assistance to recover from errors and got stuck more frequently, they took 18 minutes in total to recover from errors while the fast group took only 5 minutes. This was more than 3 times longer for error recovery.

Table 3: Comparison of data for the three fastest and three slowest to complete tasks

	Participant	**P7**	**P10**	**P12**	**Total (fastest)**	**P3**	**P6**	**P11**	**Total (slowest)**
	Usability metric								
1	Time taken to complete tasks (minutes)	15	15	11	**41**	25	26	24	**75**
3	Number of times stuck (user errors)	2	2	2	**6**	4	4	4	**12**
3	Recovery time from errors (minutes)	1	3	2	**5**	4	9	5	**18**
4	Number of assisted recoveries	0	2	2	**4**	4	4	4	**12**
5	Number of errors made	2	4	2	**8**	4	4	2	**10**

In terms of system feedback, the system displayed error messages on only two occasions. This is very poor when considering that a total of 39 errors was made (see Table 2). The lack of feedback in the form of error message is likely to leave learners stuck for longer periods of time without knowing what is required.

Table 4 consolidates the usability problems that were noted in live observation and in re-viewing the video recordings of testing sessions. The frequency column indicates the number of users who encountered that specific problem and the percentage column shows the percentage of users. The table shows that the most frequently encountered problems were poor orientation and navigation and the organisation of menus (Problems 1 and 2). There was also a requirement for the useful audio interface to be available across all interfaces and activities (Problem 3). In general, *BE-Y* has a high number of usability problems emanating from poor organisation of its structure and the complexity in navigation.

Table 4: Problems identified from the sessions in the usability testing

No.	**Problems**	**Frequency**	**Percentage (%)**
1	There is a need to improve navigation and orientation in the system.	11	91.7
2	Menu items are poorly organised.	10	83.3
3	Some interfaces have sound (audio) facilities, but there is a need for the same in all major interfaces, or preferably throughout *BE-Y* for the sake of consistency.	8	66.7
4	Certain functions commonly found in menus are absent; some menu items differ from those of standard generic systems.	7	58.3
5	Some participants were nervous and insecure for the first few moments of their session.	4	33.3
6	There is a need for prompts and clues to guide participants when stuck, to assist them in recovery.	3	25.0

Table 5 provides information obtained from the post-session questionnaires. These were statements that had Likert scale ratings of 2.5 and above (1 = strongly agree, 5 = strongly disagree). They are potential sources of usability problems, since the responses to them tended towards 'Disagree'. Participants preferred classroom learning to using the system, as showed by the mean rating of 3.4 for Statement 5. They appeared not very keen to use *BE-Y* to supplement classroom learning (Statement 4). Since three of the statements in Table 5, namely, Statements 1, 2 and 3, are related to poor organisation of the structure and difficulties in navigating the system (see Problems 1 and 2 in Table 4), the findings are in line with the data obtained from the actual usability testing. Students appeared to have no problems at all with the actual learning content.

Table 5: Statements with poor ratings from usability testing questionnaire

No.	Evaluation statements (that are associated with possible usability problems)	Mean rating [Likert]
1	It is easy to understand the functions of the menu items.	2.7
2	The interface guides the users well (does not mislead users).	2.7
3	This educational tutorial has well-organised menu items.	2.8
4	The system can supplement classroom learning of English language for Business.	2.8
5	I would prefer the system to classroom when learning English language for Business.	3.4

This triangulation of data from the usability testing sessions and from participants' opinions in the post-session questionnaires, enhances reliability of the findings. It also shows the added-value of debriefing after the UT sessions in the controlled laboratory environment.

In the context of learning-related problems, this study established that the main reason for *BE-Y* being poor in its feedback and Help mechanisms, was the lack of error messages. The extent of personal assistance required to support error recovery, was very high, in that the researcher gave personal assistance in 30 out of 39 cases– see Table 2). The inclusion of explicit error messages would expedite recovery from errors. Moreover, the poor organisation of menu items and screens results in the learning content not being optimally presented. The hard-to-navigate and inadequately organised structure of the system means that the tutorial, *BE-Y*, does not support students' learning as effectively as it could, since they spent considerable time trying to understand how to use the system rather than engaging immediately with the good learning content.

Conclusion

This section refers back to the research objectives near the beginning of the study. The first objective was to present a synthesised generic framework of criteria suitable for the evaluation of offline e-learning tutorials. Based on an extensive literature review, a framework was developed, consisting of 12 criteria, each with sub-criteria. The framework was used to guide the determination of appropriate representative tasks, metrics, and questions for the usability testing process. This new framework can also be used with other usability evaluation methods for evaluating e-learning applications, for examples, in contexts such as user surveys, using it as a basis for designing questionnaires, or during heuristic evaluation. The criteria can also be used as guidelines for designers of e-learning applications.

Secondly, the study sought to evaluate a particular offline target tutorial, *BE-Y*, in the context of the usability testing UEM and the synthsized set of criteria. The criteria and the controlled observation of users doing carefully designed tasks helped to identify a number of usability issues and problems in *BE-Y*. In general, the Help system was found to be inadequate. It was also determined that *BE-Y*'s structure was poorly organised and not intuitive to navigate. Usability testing enabled the triangulation of observed data and debriefing data and thus enhanced the reliability of the findings. The UT approach to the evaluation of e-learning applications is useful, since it identified problems which would have been difficult to find using expert- or user-based methods, such as a survey.

Finally, the study aimed to determine the effectiveness of using the new framework, along with the usability testing method, in evaluating an e-learning tutorial. The framework served well in this purpose. Its embedded criteria were effective in investigating system usability and identifying problems in the target application, as well as addressing factors related to learning. The combination of the framework and usability testing proved to be effective in evaluating the offline CD-based e-learning tutorial.

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