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Formal Usability Testing of Interactive Educational Software: A Case Study

Darelle Van Greunen and Janet Wesson

University of Port Elizabeth, South Africa
csadvg@upe.ac.za, csajlw@upe.ac.za

Abstract: As the amount and variety of interactive educational software grows, so does the need to assess the usability of the software. The usability of educational software can be defined as the extent to which the software can be used to achieve specified learning outcomes effectively, efficiently and with user satisfaction. This paper discusses the evaluation of the usability of interactive educational software and proposes a method for formal usability testing of such software that has been successfully used at the University of Port Elizabeth (UPE). After describing the method, it presents a case study to illustrate the implementation of the proposed method.

Keywords: Usability testing, usability methodology, usability, empirical evaluation.

1. INTRODUCTION

The usability of educational software such as tutorial programs is closely related to how much a person learns from using the software. Usability of educational software can be defined as the extent to which the software can be used to achieve specified learning outcomes with effectiveness, efficiency and satisfaction in a specified learning context (Geisert and Futrell, 1995). In this context, effectiveness and efficiency are measures of learner performance. Satisfaction can also affect learning outcomes indirectly, as poorly motivated learners do not use educational software to the best effect (Geisert and Futrell, 1995). These performance measures are best measured by allowing learners to use the educational software. The more they learn from using the software, the more effective it is. The quicker they learn, the more efficient it is. Satisfaction is a more subjective measure, but still

important as satisfaction and motivation are closely related. Standard questionnaires such as Questionnaire for User Interaction Satisfaction (QUIS™) can be used to assess the users' satisfaction with software generally (HCI Laboratory University of Maryland, 2000).

When evaluating educational software, it is important to specify usability objectives that are target levels of effectiveness, efficiency and satisfaction for the particular software package. Usability experts or consultants can assess the usability, but such assessments are rarely as reliable and meaningful as evaluations involving the actual users themselves (Barnum, 2002). There is, however, a lack of expertise in usability testing in South Africa. Most tertiary institutions in South Africa lack usability testing facilities to formally or empirically evaluate system usability. No standard or suggested guidelines currently exist for usability testing in South Africa. This paper will briefly review formal usability testing and discuss a method for conducting a successful formal usability evaluation in a usability laboratory. After describing the formal usability evaluation method, a case study is presented to illustrate the implementation of the method. This case study involved a formal usability evaluation of an educational software package developed at UPE, called Interactive Learner (IAL).

2. INTERACTIVE EDUCATIONAL SOFTWARE

The usability of educational software is heavily dependent on the context in which the software is used (Squires and Preece, 1996). Therefore educational software that is well matched to one learning context may be poorly matched to another context, depending on who the learners are and what their learning objectives are. The environment in which they will learn and the equipment they will be using also play a role.

There are general design guidelines for educational software (based on research in Human-Computer Interaction) that can be applied in a variety of contexts (Squires and Preece, 1996). A key technique is to get feedback from prospective learners and users during the development of educational software (Alessi and Trollip, 2001). Testing prototype educational software with users can be a particularly useful way of getting feedback about usability. To get good feedback, you need a reliable means of assessing and measuring usability.

3. MEASURING USABILITY OF CAL SOFTWARE

A Computer Assisted Learning (CAL) package is both a software artefact and a piece of courseware (Gagne et al., 1992). From its original conception to its production and in-service maintenance, the team working on CAL courseware moves through the lifecycles of both courseware design and software production.

Alessi maintains that CAL software may be evaluated from different perspectives (Alessi and Trollip, 2001). These relate to the different needs of the stakeholders in a CAL system: developers, tutors and students. Usability of educational software can be assessed by measuring each of its components, namely effectiveness, efficiency and satisfaction (Squires and Preece, 1996). Testing the educational software with a group of users and measuring their learning progress via assessments are good ways to measure these. The more users learn from working through the educational software, the more effective it is. The quicker they learn, the more efficient it is. Satisfaction is a more subjective measure, but no less important in assessing educational software since satisfaction and motivation are closely related to achievement of lasting learning outcomes.

4. FORMAL USABILITY TESTING

Formal usability testing is an empirical method that requires the design of a formal usability experiment that is undertaken under controlled conditions in a usability laboratory (Faulkner, 2000). Evaluators give a user a specific task to perform within specific timeframes (Barnum, 2002). The laboratory shown in Figure 1 is typical of those in use today.

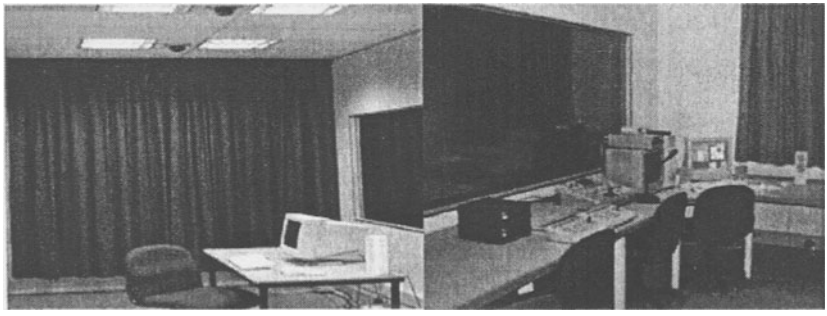

Figure 1. The Participant Room (left) and the Observer Room (right) of the UPE Usability Laboratory

The UPE laboratory consists of two rooms, divided by one-way window in the wall between the two rooms. One room provides a place for the user to perform the tasks required of the test.

The other room, where the test administrator or observer records the activities on videotape for later review, is typically called the observer room.

Evaluators observe the problem(s) the user has, videotape the session and what is happening on the user's computer screen, and then analyze the observational logs and videotapes. Essential components of such an evaluation include a usability laboratory with special-purpose hardware and software; a test plan for the usability experiment; a methodology or technique to conduct the usability experiment and the analysis of the results obtained from the experiment. The results of formal usability testing can provide essential empirical information for the software design process.

5. EVALUATION METHODS

Several guidelines exist in the literature on how to conduct a formal usability evaluation (Rubin, 1994). Most of these are, however, very general and do not give specific guidance on how to conduct the evaluation.

The overall process is simple; get some users and find out how they work with the product. Usually you observe individual users performing specific tasks with the product. You collect data on how they are doing, for example, how long do they take to perform a task, whether they can complete the task successfully, or how many errors they make. Then the data from all the experiments is analysed with the aim of looking for trends.

The above is, however, only a very high-level description of how to conduct a formal usability evaluation and does not represent a complete methodology. Our research into usability testing has shown that an evaluation methodology is needed to successfully design a formal usability evaluation. A decision was made, therefore, to use the methodologies as suggested by Faulkner (Faulkner, 2000) and Rubin (Rubin, 1994) and to supplement these with the additional detail suggested by Dumas and Redish (Dumas and Redish, 1993). Certain aspects of the Common Industry Format Report for Usability Testing were included to present a more detailed, step-by-step descriptive methodology for formal usability testing (Common Industry Format for Usability Test Reports, 2001). An overview of the proposed methodology is given in Table 1 below.

Step	Description of Step
1	Formulate an overall goal of the product to be tested.
2	Formulate objectives for the usability test.
3	Formulate research hypotheses.
4	Determine specific evaluation metrics.
5	Establish the user profile.
6	Select the tasks to be performed.
7	Determine how to analyse the results.
8	Formulate and write the test plan.
9	Create the post-test questionnaire.
10	Select representative participants.
11	Conduct a pilot test.
12	Conduct the usability test.
13	Organise and collate the data.
14	Analyse the findings.
15	Draw evaluation conclusions.
16	Report the results.

Table 1. Basic steps of the proposed methodology

The next section discusses a case study to illustrate the application of this methodology to do a formal usability evaluation of an educational software package at UPE. As discussed above, a test plan is an essential element of such a formal usability evaluation. The following sections are extracts from the test plan.

6. CASE STUDY: INTERACTIVE LEARNER

For the purpose of this research, we did a formal usability evaluation of an educational software package called Interactive Learner (IAL). This tutorial was developed at UPE in 1998 in order to teach and test certain basic computing skills, including keyboard and mouse skills. IAL also produces a simple categorization of the computer expertise of the user as novice, intermediate or expert, based on the time taken by the user to complete the tutorial and the frequency of user errors. IAL is currently being used as part of a model to derive a user classification framework for prospective students at UPE (Streicher et al., 2001).

The usability objectives of IAL were not clearly defined during the development of the tutorial package, but could be summarized as follows:

- Users should achieve the outcomes of being able to successfully use a mouse and keyboard after having completed the tutorial. This could be regarded as a measure of effectiveness of the tutorial.

- It should take users no longer than 25 minutes to achieve the outcomes as mentioned before. This is a measurement of efficiency of the tutorial.
- Satisfaction can be determined by means of questionnaires relating to whether users enjoyed using the tutorial package.

A heuristic evaluation and user observation revealed that IAL contained several usability problems that could affect the user performance. This heuristic evaluation was based on Nielsen's ten usability heuristics (Nielsen, 1994). The key findings of the heuristic evaluation indicated moderate usability problems relating to the visibility of the system status and the use of language in IAL. Johnson defines "unprofessional writing" as "Inconsistent, unclear, and difficult to understand terminology" (Johnson, 2000). Unprofessional writing was used in IAL, which forced the user to reread instructions and text. High usability problems were identified with regard to consistency and standards, as well as error prevention. Inconsistent error messages caused confusion and uncertainty and the user was not always clear how to proceed after the occurrence of a message. The problems revealed by the heuristic evaluation were used as a basis for the planning of the formal usability test.

6.1 The goal of the test

The goal of the usability test was to determine if there were any specific usability problems with IAL that would negatively affect the students' performance. Representative users were asked to complete the tutorial, and measures were taken of effectiveness, efficiency and satisfaction.

6.2 Research Hypotheses

Our research hypotheses were as follows:

H_0: No usability problems exist with IAL.

H_1: Any usability problems that may exist will not affect user performance in IAL.

H_2: Any usability problems that may exist will not affect the different user groups (novice, intermediate, expert) differently.

6.3 User Profile

Background questionnaires were distributed to 350 potential participants who were first-year students at UPE. This questionnaire was used to categorise the potential participants into three different groups based on a

user classification model as developed by Streicher et al (Streicher et al., 2001). This grouping was done on a basis of the different ability groups (i.e. novice, intermediate and expert). Once this grouping was done, a random selection of 7 participants per user group was then made (see Table 2).

	User group	Home Language				Gender		
		Afrikaans	English	Xhosa	Total	Male	Female	Total
1	Novice	0	3	4	7	0	7	7
2	Intermediate	3	3	1	7	4	3	7
3	Expert	0	7	0	7	6	1	7
	Total	3	13	5	21	10	11	21

Table 2. Profile of the participant population

A total of 21 participants were tested. The participants were divided into three groups based on the background questionnaire as follows:

- **Novices:** 7 participants were computer novices. These participants represented the least competent (novice) user who will use IAL.
- **Intermediate:** 7 participants had previous computer experience. Participants in this group had the following characteristics:
  - Work with a computer on a regular basis;
  - Use keyboard keys, cursor keys and mouse; and
  - Spend the majority of computer usage performing word processing tasks.
- **Expert:** 7 participants who had advanced computer experience. Participants in this group had the following characteristics:
  - Work with a computer on a regular basis;
  - Use keyboard keys, cursor keys and mouse;
  - Are familiar with checkboxes and radio buttons; and
  - Spend computer usage time performing tasks ranging from word processing to spreadsheets to desktop publishing tasks.

The above user classification was made based on the intended user population of IAL, as well as the student population at UPE.

6.4 Data Collection

Data was collected and calculated by means of:

- Video recordings with the purpose of capturing the test session (live) on tape so that it could be evaluated at a later stage.
- A preference questionnaire was used to gather feedback and usability metrics using a modified version of the Questionnaire for User Interaction Satisfaction (QUIS™).
- Monitoring of tasks.

7. TEST PLAN

7.1 Performance test

The performance test consisted of the completion of the tutorial within the allocated time period of 25 minutes while being observed.

7.2 Participant debriefing

After the tutorial was completed, the test facilitator debriefed each participant. The debriefing included the following:

- Filling out a brief preference questionnaire pertaining to the usability and aesthetics of IAL.
- Participant's overall comments about his or her performance.
- Participant's responses to probes from the test facilitator about specific errors or problems during the test, e.g. repeating exercises.

7.3 Test environment and equipment requirements

The UPE usability laboratory was used as the test environment with a personal computer (PC) connected to the LAN and loaded with the IAL software and a mouse connected to the PC.

7.4 Evaluation metrics

The objectives of the usability test relate to the measurable goals of the test (Barnum, 2002). These are also called the evaluation metrics and are used to gather information about the performance of the user.

Efficiency:

- **Amount of time spent reading of information on the screen**. This metric involved measuring the time taken to open/enter a screen and then read the instructions/text on the screen before executing the first action.
- **Real-time events**. This metric involved monitoring and filtering events such as the push of a key, click of a mouse or the use of the arrow keys per screen.

Effectiveness:

- **Amount of time spent on an exercise**. This metric consisted of monitoring the time a user spent on reading the instructions for an exercise prior to completing the exercise. This also included the

time spent on the exercise, as well as the number of iterations per exercise.

- **Completion of events.** This metric consisted of monitoring the successful completion of different events on different screens.
- **Error rate and recovery.** This metric consisted of monitoring the number of errors made by the user, as well as the number of errors from which the user could not recover.

Satisfaction:

- **User satisfaction.** This metric was measured using a subjective ratings scale and the modified version of Questionnaire for User Interaction Satisfaction (QUIS™), at the end of the session. The following five factors were measured: overall satisfaction, screen design, terminology and system information, learnability and system capabilities. Each of the specific interface factors consisted of a main question followed by related sub-questions. Each item was rated on a scale from 1 to 5 with 1 representing a negative response and 5 representing a positive response. In addition, "not applicable" was listed as a choice.

8. RESULTS

The first step in evaluating the data was the analysis of the post-test questionnaire. The questionnaire was analysed statistically using MS-Excel and Statistica (Statsoft, 2001). A t-test analysis was performed to analyse the results in the different categories.

The second step in evaluating the data was the analysis of the videotapes taken during the session. The focus here was on the general understanding of the instructions and tasks to see whether the test participants could determine how to complete the tasks. Data from the videos was analysed using the Elementary Statistics function of the Observer Video Pro package (Noldus Technology, March 2001).

8.1 Questionnaire results

The results of the modified version of Questionnaire for User Interaction Satisfaction (QUIS™) were analysed using a t-test analysis. In general, the majority of the responses were positive and only one significant difference in overall user reactions was identified between novice and expert users. This section of the questionnaire posed questions regarding the user's overall reaction to the tutorial, the effectiveness of the tutorial and whether the tutorial tested the users' skills adequately.

8.2 Performance results

The mean extent to which each task was completely and correctly completed, was scored as a percentage. In addition to data for each task, the combined results show the total task time and the mean results for effectiveness and efficiency metrics. These results are discussed in more detail below.

Task Completion: All participants completed the tutorial successfully, but with significantly different completion times. The expert users, as expected, had the shortest mean completion time (10.76 min); followed by the intermediate users (13.29 min) and the novice users (15.47 min). Further analysis of these results was restricted to two groups of users only, namely expert and novice users. The reason for this was that the results of the intermediate user group and the novice user group were very similar (99% significance).

Incidence of errors: In general, very few errors were recorded. The novice user group had one occurrence of an error, whilst the expert user group had two occurrences.

Recovery from errors: All user groups managed to recover from their errors in a very short space of time. They completed the exercises successfully.

Speed of performance: An analysis of the speed of performance is contained in Figure 2. Despite significant differences in actual time spent, it was noted that both novice and expert users spent approximately 45% of their time reading instructions on the various screens of the tutorial. Since the primary goal of IAL is instructional, this can be regarded as acceptable (Alessi and Trollip, 2001).

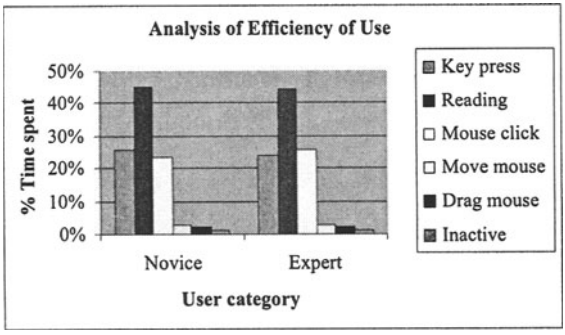

Figure 2. Analysis of user performance

Ease of use: IAL displays a reminder message after a specific time delay to guide the user in navigation between different screens. Both expert and novice users received several reminder messages. Novice users received considerably more reminder messages (93%) than the expert users.

Task closure: IAL displays the message "You have completed the exercise" on the screen on completion of an exercise. The user can, however, continue with the exercise. When the users do continue because they do not recognise or realise that the exercise is completed, a reminder message is displayed which reminds the users how to navigate forward. The frequency of these messages indicates that the task closure for completing an exercise is incorrect and that users should be prevented from redoing an exercise.

9. ANALYSIS OF RESULTS

This section examines the results obtained from an analysis of the performance of the different user groups. No significant usability problems were identified in the post-test questionnaire. The video analysis identified certain specific usability problems (see Table 3). These usability problems identified, were as follows:

Frequency of Reminder Messages			Mean time on screen (in min)			
Screen	Expert users	Novice users	Expert users	Novice users	Mean	StdDev
2	0	1	0.00	10.00	5.00	7.07
3	6	4	3.26	11.96	7.61	6.15
4	1	4	1.08	2.64	1.86	1.10
5	0	1	0.00	2.96	1.48	2.09
6	1	2	4.27	0.78	2.53	2.47
7	0	1	0.00	1.20	0.60	0.85
9	1	4	0.84	3.53	2.19	1.90
10	0	3	0.00	4.84	2.42	3.42
11	1	2	8.80	2.12	5.46	4.72
12	1	0	3.04	0.00	1.52	2.15
13	3	4	6.13	4.39	5.26	1.23
15	1	3	3.08	5.02	4.05	1.37

Table 3. Frequency of Reminder Messages on different types of screens

- The screen titles did not contain a clear classification of the different screen types. IAL consists of 4 different types of screens, namely

General, Information, Exercise and Question screens. The only type of screen that is labeled is the Exercise type screen. Considerable time is spent on the task of reading text and instructions on the screens of IAL (see Figure 2). The main reason for this was determined to be that the user was not always clear what was expected on a particular type of screen. This had a negative impact on the overall speed of performance of not only the novice users but also the expert users.

- Navigation between screens appeared to be a problem together with a lack of task closure at the end of an exercise. This is evident in the fact that both an Exercise Completed message, as well as a Reminder message was often displayed simultaneously on the screen.
- Unprofessional writing resulted in long, unclear and inconsistent lines of text and instructions (Johnson, 2000). This had a negative impact on the overall speed of performance of users as a considerable amount of time was spent on the task of reading and understanding the text and instructions (see Figure 2).
- Inconsistent Error, Reminder and Exercise Completed messages caused users to wonder whether different words or actions meant the same thing. Platform conventions for user interface design were not followed making it difficult for the user to recognize the different messages.
- The system did not always keep the user informed about what was going on. Feedback occurred, but not necessarily within a reasonable time period.

Screens 3, 4, 9 and 13 exhibited specific usability problems. The frequency of Reminder Messages on these screens for both novice and expert users indicated that there were some usability problems. These problems included those mentioned above, but related more specifically to unprofessional and unclear writing and no titles on the screens. The frequency of Reminder Messages indicated that both novice and expert users were unclear as to what was expected of them. This correlates strongly with the usability problems identified in the heuristic evaluation, specifically visibility of system status.

Several usability problems with IAL were therefore identified. We can thus reject H_0 (see Research Hypotheses). Likewise, we can reject H_1 since these usability problems were seen to negatively affect the speed of performance of the users. The increased frequency of reminder messages for novice users is an indication that novice users were affected more than expert users, and thus we can also reject H_2.

10. DESIGN CHANGES

As a result of the formal usability evaluation, the following design changes were proposed:

- All screens must be labeled according to the type of screen they represent. This will enable users to recognize what is expected of them on a particular screen (Visibility of system status).
- All exercise screens must contain a clear task closure and not allow the user to continue with the exercise. This will enable the user to recognize that the exercise has been completed (Error prevention).
- The speed of performance could be improved by rewording the instructions/text displayed on the screens taking into account guidelines on how to shorten text in a graphical user interface (Johnson, 2000). By limiting the instructions and text to the essentials only, the user will not have to spend an excessive amount of time on reading.
- All messages (Error, Reminder and Exercise Completed) should be reworded and designed according to Johnson's guidelines. Messages should be redesigned to adhere to platform conventions (Consistency and standards).
- To improve feedback to the user, the time delay before a message is displayed should be reduced from 25 sec to 5 sec after the user has completed a specific action (Johnson, 2000).

A further usability evaluation was conducted after the suggested changes were implemented to IAL. The test was conducted with 7 participants who were computer novice users (see User Profile in Table 4).

Novice user group	Mean completion time (min)	StdDev (min)
Initial design	15.47	2.6
Improved design	13.96	2.6
% Improvement	9.8 %	

Table 4. Comparison of Efficiency of IAL

Task completion: The mean completion time of the novice user group was reduced from 15.47 minutes to 13.96 minutes. All 7 participants completed the tutorial successfully within the allocated 25 minutes.

Incidence of errors: No instances of error messages were recorded.

Ease of use: In the improved system, Reminder Messages and Exercise Completed Messages were combined into one message that appears at the end of an exercise assisting the student with navigation. The time delay between the completion of an exercise and the message appearing on the

screen was reduced from 25 sec to 5 sec. No Reminder Messages appeared on screen, neither were there any instances of user errors.

Task closure: As task closure was implemented, users could not continue with exercises once these were completed. A user could only repeat an exercise from the beginning if he/she felt the need to do so.

Speed of performance: In some instances, there were significant differences between the two novice user groups. Group 1 (Novice users in initial test) spent approximately 45% of their time reading instructions on the various screens of the tutorial, whilst Group 2 (Novice users in second test) spent only 37% of their time reading instructions on the various screens. Group 2 also spent less time on key presses than Group 1. The percentage time spent on mouse clicks increased by approximately 14% with Group 2 spending 37% of their time on mouse clicks as opposed to the 23% of Group 1. One can thus conclude that as the novice users of group 2 made more use of the mouse than the keyboard, their overall completion time would be significantly reduced. This conclusion is based on the typical times for different operators in the Keystroke-Level Model as proposed by Card, Moran and Newell (Dix et al., 1999).

11. FUTURE RESEARCH

For the purpose of this paper, we only concentrated on formal usability testing of one case study in educational software, i.e. IAL. In order to validate the proposed methodology further, more case studies in formal usability testing will have to be conducted. Such an evaluation should comprise both an evaluation of the methodology and a formal usability evaluation of the software products. The nature of the case studies should be different. The case study in this paper is typical of many interactive educational tutorials. The usability of other types of educational software packages still remains to be fully investigated.

12. CONCLUSIONS

There is no doubt that formal usability evaluation can provide significant results for assessing the usability of interactive software. In addition, there is also a growing need to assess the usability of educational software. In this paper we have discussed a methodology for the formal usability evaluation of interactive educational software packages such as tutorials. The formal usability testing methodologies reviewed were found to give very high-level descriptions of how to conduct a formal usability evaluation and did not

represent a sufficiently complete methodology. The proposed methodology as discussed in this paper, uses the methodologies as suggested by Faulkner (2000) and Rubin (1994) and is supplemented with the detail suggested by Dumas and Redish (1993). Certain aspects of the Common Industry Format Report for Usability Testing were included to produce a more detailed, step-by-step descriptive methodology for formal usability testing.

The case study included a detailed formal usability test of Interactive Learner (IAL) tutorial. The results obtained from the formal usability evaluation of the IAL software highlighted several usability problems and were used to propose several design changes. These design changes resulted in significant improvements in usability. Whilst more research is still necessary, we can conclude that the method developed at UPE can be successfully used to conduct formal usability evaluations of interactive educational software.

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