Learning by Interacting: Comparing the Effectiveness of an Interactive Tutorial with a Standard Electronic Book Interface

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Abstract

Advances in Internet technologies have led Universities to utilise the Internet for delivery of on-line course related material. On-line learning materials are mostly developed as interactive multimedia and are implemented for web delivery. The use of interactive learning has becoming an important component of the on-line teaching and learning experience. These components of the learning experience seem to be successful and well liked by students, but there is little evaluative and experimental evidence to justify the additional resources required to develop interactive learning materials, as opposed to simply providing existing lecture notes on-line, in an electronic book format.This study performed a summative design-evaluation of two types of interfaces, an electronic book and an interactive tutorial. The experiment compared the effectiveness of using the interfaces for web-based computing teaching at tertiary level and determined user reactions to each interface. User preferences were also recorded in this study. User performance data from content tutorials and a preference survey were recorded and analysed using two statistical inference tests. Analysis of these data showed that students achieved improved results when using an

on-line interactive tutorial in comparison to an electronic book. In the survey, students responded in favour of the interactive tutorial.

Keywords
Interface Design, Interactivity, Computer Assisted Learning, Evaluation

Introduction

Advancements in Internet technologies have enabled Universities to have more frequent and progressive contact with students. The realisation that the Internet can provide other services beneficial to distance education led to the concept of using the Internet for delivery of subject related material on-line. Consequently Australian Universities are coming under increasing pressure to deliver on-line courses to all students, to provide a more flexible teaching and learning environment. Using electronic media for education is becoming increasingly cost effective and allows universities to become part of the global market (Ellis et al., 1998).

On-line learning is currently expanding and becoming widely used for educational and business oriented purposes. (Hellwege et al., 1996; Ellis et al., 1998; Love & Gosper, 1995, Gluck et al., 1998) The use of electronic books for education is also becoming increasingly popular. Literature in the area of on-line learning is in abundance and much work has been completed in this area, however, limited research is available in the area of *interactive* on-line learning and the implementation of on-line teaching materials. Evidence shows that the use of on-line course materials to supplement learning of units offered in a university environment have an improved effect upon students (Hellwege et al., 1996; Gluck et al., 1998). Hellwege (1996) provides evidence to show that making course related material available on-line increases the overall pass rate of students studying the course. Due to the fact that so few students, only 16 percent, read on-line materials word by word (Morkes & Nielsen, 1997), researchers and practitioners are having to focus less on the content and more on organising the learning environment and student experience to maximise knowledge construction (Love & Gosper, 1995). The interactive component of interactive multimedia, as defined by Phillips (1997), supports this kind of learning environment by empowering the learner to control the computer environment, and encouraging a student centred learning approach. Phillips (1997) supports the use of interactive multimedia for tutorial material which benefits from simulations, allowing students to "visualise the process and construct mental models". Computer architecture and its associated data flows is one such teaching area where the visualisation of invisible elements, electrical pulses, is important to understanding the concepts of computer operation and data processing.

The interactive on-line learning materials that have been developed to date, using some form of interactive multimedia, are being widely used at various institutions across Australia and seem to be well liked by students.

As an evolving resource in the teaching and learning process, there is little evaluative and experimental evidence to confirm the effectiveness of this interactive coursework, and the acceptance of it by the students who are using it. Most research and data previously obtained in this area is anecdotal. This study aims to make an important contribution by evaluating the performance of students using interactive electronic media for tertiary learning. The purpose of this study was to perform summative design-evaluation of two types of interfaces: an electronic book and an interactive tutorial, for web-based teaching at tertiary level. The aim of the experiment was to compare the effectiveness of the teaching, and determine user reactions to learning using two on-line versions of the existing course material, an electronic book and an interactive tutorial. A second purpose was to record any preferences that the students may express about the form of the course content from which they were expected to learn.

The target users in this study consisted of first-year computing students studying an introductory computer hardware unit, in a Bachelor of Computing. These students were assumed to be representative of typical computing students at first year university level. The content formed part of the compulsory learning material for students enrolled in this unit, being two weeks of tutorial material, designed to reinforce and practise concepts delivered in traditional lecture mode. The interfaces were evaluated by measuring their effect on user performance. User preference was also recorded. User performance was measured through the use of an experiment following the within-subjects design specified by Eberts (1994). The experiment was conducted over a two-week period and involved testing the target users on comprehension of the content in the tutorials. User preference was recorded and examined by a survey that was conducted after the completion of the experiment. The issues being studied included improved student performance, in terms of correct tutorial responses, ease of use of the interface, user satisfaction, ease of content learning, and interest by students in learning on-line. The overall aim of the research was to determine which electronic form of unit content, electronic book or interactive tutorial, produced better student performance and higher user satisfaction ratings.

The Test Interfaces

The process of summative design-evaluation involved constructing two different types of interface: an electronic book design, and an interactive

tutorial design, using the same course content. It also involved producing two tutorials in each design, and evaluating these through the use of an appropriate experimental methodology.

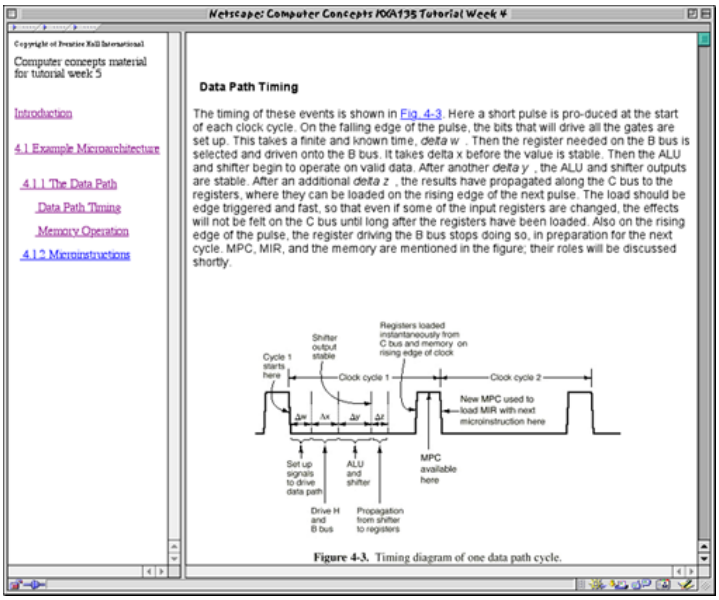


Figure 1: The Electronic Book Interface

The electronic book implementation of the tutorial material was designed according to the recommendations of Paay & Van Den Berg (1999) derived from the evaluation of three representative electronic book interfaces, producing a fourth interface from the experimental findings, and evaluating the effectiveness of the recommended design. This fourth interface, experimentally confirmed as an effective implementation for the teaching of computing concepts to tertiary students, was used as the basis for the electronic book implementation (figure 1). The electronic book uses HTML frames to implement a separate table of contents from the page structure. The table of contents on the left allows users to easily move from one topic to another and is fully expanded. This enables users to read a page and view the table of contents without moving from that page. The bottom of each content page has links to the previous and next sections. Each content document is a chapter length, containing four to five screens of scrollable information. When the user selects a certain topic in the table of contents frame, the relevant information is displayed in the content window. The text in this window has target links to related information and images that are referenced in the text. This design

implements a book-like metaphor while taking advantage of the electronic medium by having hyperlinks within the body of the text for depth of information and a continually visible and hyperlinked table of contents.

The interactive tutorial implementation was developed using Macromedia Director and designed using design recommendations from Phillips (1997) and Boyle (1997). Overall screen and navigational design choices where made based on standard screen layouts and navigational schemas presented by Phillips (1997). The design was also influenced by accepted HCI principles as presented by Mayhew (1992), Hix and Hartson (1993), Galitz (1997) and Shneiderman (1998). The design includes: headers to support orientation and context, positioning of images and text in respect to eye movement around the screen drawing the users eyes to important elements, separate functional areas for content and navigation, and aesthetics through visual balance in screen layout of elements. Recommendations were followed for selection of colour in the interface design. This included the use of a 'cool' colour for the background, a mid-tone blue, and the recommended foreground colours to go with blue, which included yellow for titles and white for the tutorial work area (Mayhew, 1992; Phillips, 1997; Boyle, 1997).

The combinations of colour were visually harmonious, and served the purpose of distinguishing different functional sections of the screen from each other. Educational guidelines for interactive multimedia courseware for Australian schools have also been influential in constructing this interface (Baker, 1995).Phillips (1997) recommends using a constructivist development approach when developing educational interactive multimedia. This provides a guided approach to learning, where the student is guided towards building his or her own structured knowledge of the content. In the interactive tutorial this type of design is evident. Students are given the opportunity to explore and interact with a simulation of a computer component, the arithmetic logic unit (ALU) and a sample central processing unit (CPU) data path. The simulation allows them to experiment with various inputs, and get feedback on the corresponding outputs from the components. According to Van Rosmalen (1994) this fulfils an instructive role in a satisfactory manner, as the simulation in this tutorial is embedded in an instructional environment. Boyle (1997) says that it is important that the student is encouraged to actively explore and is able to control the environment, which adds the element of learning by discovery to this interactive tutorial; something that is not available in the electronic book version of the content material. Both the electronic book interface and the interactive tutorial were supported by

literature in their design as outlined in this section and, as such, were regarded by the researchers as adequate representations of their type for the purposes of this experiment.

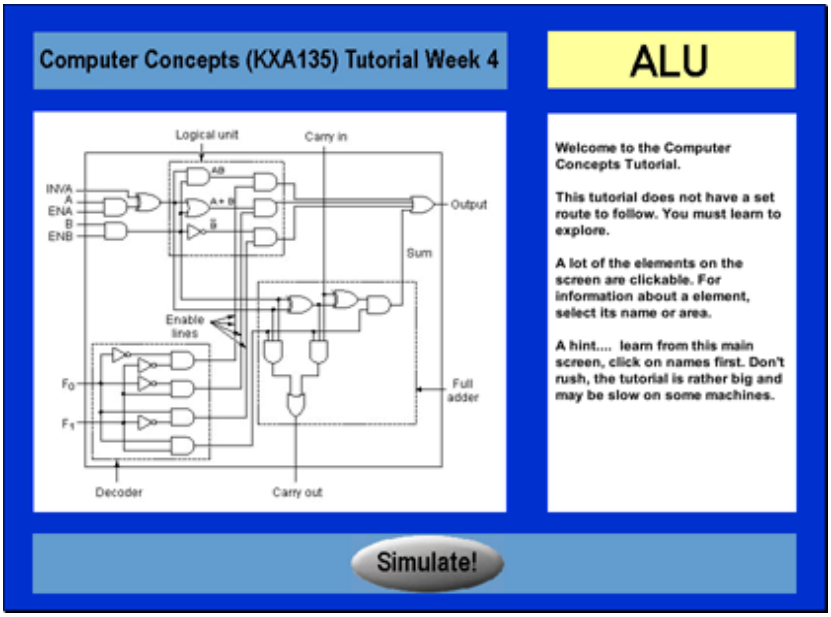


Figure 2: The Interactive Tutorial Interface

The Experiments

A variety of experimental techniques were used to design and evaluate the interfaces, and conduct the experiment. The experimental method is used to establish clear cause-and-effect relationships, by showing that only one factor could have caused the effect observed in the data (Eberts, 1994). The within-subjects design as specified by Eberts (1994) was selected to test the different interfaces. In within-subjects design, test groups use both interfaces which eliminates the interference and complication of participants with diverse abilities because participants experience both interfaces in the experiment. The extraneous variable involved in this experiment occurs because of the fact that the experiment was conducted over two different sets of material. This research was interested in the effect this variable would have upon the results gained from the data, so it was decided to make this variable one of the factors of the experiment. Hence the experiment involved two different factors: the differing interfaces (electronic book and interactive tutorial), and the differing material.

Eight groups participated in the experiment: a total of 119 students, determined by the size of the unit enrolment. These comprised seven allocated tutorial groups at the main campus and an eighth group on a remote campus. The main campus groups each used either an electronic book version or an interactive implementation for two tutorial weeks of the semester. The remote campus group worked through the same tutorial question sheets using the prescribed textbook to find the answers for both experimental weeks, providing benchmark data for comparison purposes. For all other weeks of semester students answered tutorial questions using their textbook as a reference. In the first week of the experiment, three groups were assigned to the electronic book version, and four groups worked with the interactive implementation. This process was then reversed in the following week. The first three groups used the interactive interface, and the other four used the electronic book interface. The problem of the subject material being different over the two weeks, and the fact that the subject material for the second tutorial was more difficult than the first, is an important factor. Statistical analysis using the t-test was done to help exclude the effect of this extraneous factor on the results obtained. The content for the electronic book and the interactive tutorial were drawn from the prescribed text for the unit, “Structured Computer Organisation” by Andrew S. Tanenbaum (1999), used with permission from the publisher, Prentice-Hall. The tutorial exercises completed by the students taking part in the experiment were designed by the lecturer in charge of the unit to achieve unit objectives and were the same tutorial sheets that had been used in the unit in previous years, with students working from the textbook.

The tutorial sheets were given to students at the start of the experimental tutorial class time, and were collected during or at the end of the scheduled class. The time allocated for each experimental session, 50 minutes, represented the time usually allocated for the tutorial exercises to be completed in the equivalent textbook based tutorial sessions. Due to time constraints it had to be assumed that a two-minute explanation before the on-line tutorials was sufficient time to prepare the participants for the experiments. This was deemed acceptable as all participants had prior experience in operating the computers used. In the first week of the experiment 119 tutorial one sheets were completed, and in the second week 108 tutorial two sheets.

Tutorials one and two

The first three tutorial sessions of the week used the electronic book version of tutorial one, covering content on the ALU component of the CPU of the computer, using a sample ALU. The students in the other four sessions of the week were assigned to the interactive tutorial. The eighth group worked on the tutorial exercises using the textbook as a reference, without tutor assistance. The tutorials were self-directed but one of the researchers was available to solve minor technical issues to do with running the software. Students completed their tutorial sheets, using either the electronic book or the interactive version of the content to find the solutions to the questions posed. The completed tutorial sheets were collected and the time of completion recorded for analysis in this experiment. The tutorial sessions in this unit run for 50 minutes, which limited the time that students were able to work on the material to a maximum of 50 minutes.

The second tutorial was conducted in the same way as tutorial one, with the first three tutorial sessions of the week being assigned to the interactive tutorial, and the four groups that used the interactive tutorial in tutorial one were assigned to the electronic book version of tutorial two. The eighth group worked again in textbook mode. Tutorial two covered content dealing with the movement of data on the data path of the CPU, between components of a sample CPU. The material in tutorial two proved more difficult than the previous tutorial and students had difficulty learning the material and completing the tutorial sheet in the permitted time. This was true of all tutorial groups, including the group on the remote campus working from the textbook.

Participant survey

A survey was designed to evaluate user comprehension, user satisfaction and user preference. The survey was distributed in tutorials and lectures in the week following the experiment. Students were not required to complete the survey, but were encouraged to do so. From the 87 surveys distributed only 31 were received after three weeks and much cajoling by the researchers. This response rate was disappointing and can be explained by the fact that students were expected to complete this survey in their own time, not during allocated class time, and could see no personal benefit in doing so.

The survey was designed to gain data about the ease of completion of tutorial sheets, user satisfaction with implementations, and preference of implementation. The survey was divided into three parts. Part One of the

survey dealt specifically with the content of tutorial one, using a set of bipolar semantically anchored items. Shneiderman's (1998) example questionnaires were used as a basis for the development of the survey. The questions in this part related to the difficulty of obtaining information for questions on the tutorial sheet and also involved rating the overall reactions to the system used, and the ease of accessing on-line information. Part Two was similar to Part One, but refers specifically to the content of tutorial two. Parts One and Two investigated three different issues: the difficulty of obtaining correct information to complete the tutorials; the participant's overall reaction to the on-line tutorials; and the participant's ratings using selected criteria for the tutorial. Part Three was used to determine the participant's preference for using the on-line tutorials and included asking the participant to rank in order of preference the interactive tutorial, electronic book and textbook learning.

Summative Evaluation Outcomes

The tutorial sheets and survey results were checked for completeness and correctness and entered into a spreadsheet for analysis. The tutorial sheets were marked using a predefined marking scheme devised by the lecture in charge of the unit. The results were entered into the spreadsheet on a per question basis. Tutorial one had seven distinct parts; tutorial two had nine distinct parts. Student completion times recorded on the tutorial sheets as the participants passed in their completed sheets to the researcher supervising the experiment were also entered into the spreadsheet. The data was analysed by reallocating responses into two main samples: those completed using the interactive tutorial (tutorial 1=62, tutorial 2=34), and those completed using the electronic book (tutorial 1=40, tutorial 2=58). For comparison, the results from the textbook group are also included, although this sample was smaller (tutorial 1=17, tutorial 2=18).

There is no specific way to be certain if the differences observed between the two main samples reflect a true difference, or is a coincidence of random sampling. A t-test was used to determine any significant differences between the two main groups. The type of t-test used was the test using two samples that assumed the variance in the two groups were unequal. This type of test is used to test whether the mean of a variable differs between the two groups and to calculate the probability that an observed difference is significant. The response variables were task completion time and question correctness and these results are presented in sections 4.1 – 4.4, where I = interactive tutorial, e = electronic book,

and n= textbook mode on the graphed results. In combination with the statistical t-test, a different statistical inference was conducted on the user preference data gathered in the survey. This test is known as a two-factor analysis of variance with interaction and was conducted using JMP software. Two-factor analysis of variance performs statistical analysis on two factors rather than one. The two factors are the type of tutorial, (interactive tutorial versus electronic book), and the tutorial material, (tutorial one versus tutorial two). The response variables were task difficulty, user reaction and user preference.

Completion times

From Figure 3 it can be observed that the overall mean completion time for tutorial one, using the interactive tutorial was slightly longer than the electronic book completion time. The mean time for the interactive tutorial was approximately 33 minutes, while that for the electronic book was approximately 30 minutes. The remote students who used the textbook took a mean time of 16.5 minutes which was considerably lower than either of the on-line tutorials. The slight difference in completion times for the on-line tutorials may have been due to students being unfamiliar with an interactive style tutorial, having possibly used electronic text more often than interactive simulations. This did not represent a significant time difference (p=0.1). Ninety percent of those surveyed that experienced both electronic book and interactive tutorials in this experiment said that they enjoyed the simulations and interactivity as part of the learning process. Of these 75% also agreed that the use of simulations and interactivity in the interactive tutorial helped them with learning. These factors may also have affected the time taken.

Figure 3: Tutorial One Completion Time

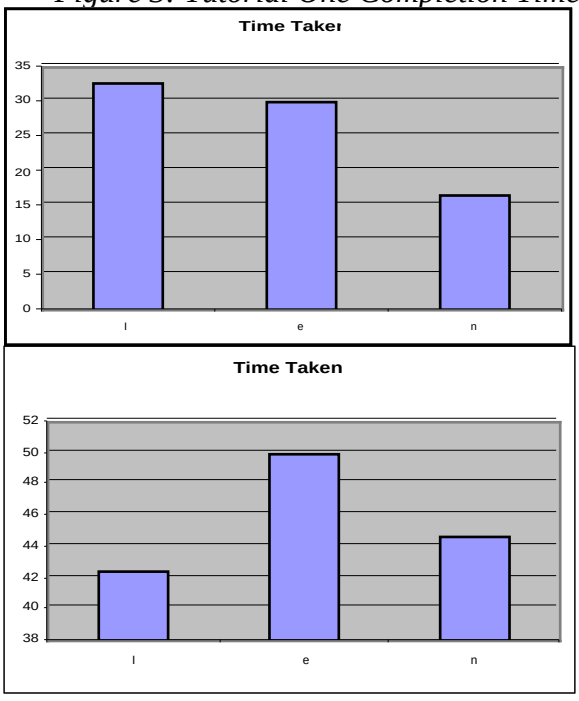


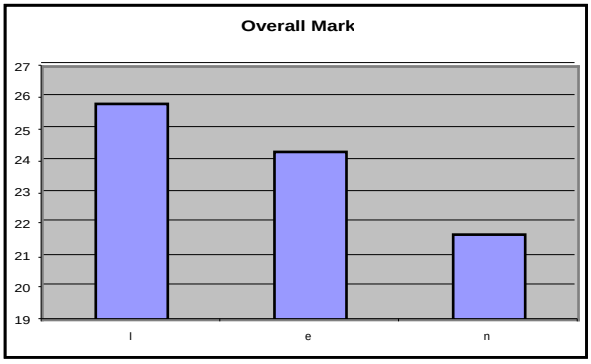
Figure 4: Tutorial Two Completion Time

From Figure 4 it can be observed that there is a great difference between the overall mean times taken to complete the tutorial. The interactive tutorial recorded a mean time of 42.3 minutes, while the electronic book recorded a mean time of 49.8 minutes. This mean score is very near the 50 minute mark, and is due to most students taking 50 minutes to complete the tutorial or not completing it at all, which meant that a maximum time of 50 minutes was recorded. The difference in mean times is approximately seven minutes, and the result is very significant (p= 0.00001). The remote students using the textbook method to complete the tutorial sheet took a mean time of 44.6 minutes. The difference between the on-line tutorials may be due to students having difficulty with the material, hence taking longer to read, view and understand the material. In the survey conducted 73% of participants indicated that the interactive tutorial was easiest to understand, and 80% said that the interactive tutorial was easiest to use. This may also have contributed to the difference in time between on-line tutorials. Based on the analysis of task completion times, the following conclusions can be drawn:

- An increase in the difficulty of the material significantly increases the amount of time spent completing the tutorials, independent of the interface being used;
- The increase in completion times with increasing difficulty level was less noticeable for the interactive tutorial.

Question correctness

From Figure 5 it can be observed that the overall mark for the interactive interface, in regard to the total mark, is greater than the electronic book interface. The interactive tutorial achieved a mean score of 25.86 while the electronic book interface achieved a mean score of 24.26. These scores were out of a total score of 30. The statistical analysis revealed that this result is very significant (p=0.004), providing strong evidence suggesting that the interactive tutorial improved user understanding of the material being presented. The participants using the interactive tutorial also had a lower variance in their score than did the electronic book, which means



that the higher scores were more consistent than the scores of the participants using the electronic book interface. The students using the traditional textbook method achieved a mean score of 21.71. This was considerably lower than both the on-line tutorials.

Figure 5: Tutorial One Question Correctness

From figure 6 it can be observed that the difference between the overall mean scores of the interactive tutorial and electronic book is small and not significant. The interactive tutorial had an overall mean score of 16.79 and the electronic book had an overall mean score of 15.86. These scores were out of a total of 33 possible marks. The traditional textbook method of completing the tutorials achieved a mean score of 15.46. These scores were very low and could be due to the difficulty students had understanding the content material for the tutorial.

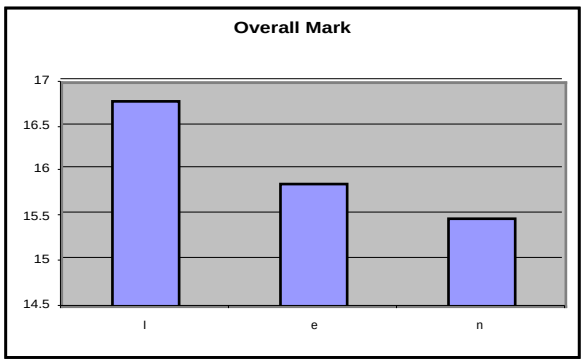


Figure 6: Tutorial Two Question Correctness

Tutorial two was concluded to be much harder for students to learn than previous material. Based on analysis of the question correctness results, the following conclusions can be drawn:

- Participants using the interactive tutorial achieved better scores than those using the electronic book and traditional textbook methods, regardless of material difficulty;
- When using material of greater difficulty, the differences in question correctness scores between interactive, electronic book and traditional textbook tutorials were much less pronounced.

User preference survey

From Figure 7 it can be observed that for tutorial one, the interactive tutorial was rated overall as being the easiest to complete the task. The overall difference ratings have a slight to moderate significance (p=0.05). The interactive tutorial consistently achieves a higher mean rating over the electronic book in the ratings of difficulty. Hence it can be inferred that participants found that it was easier to complete the set of tasks of the tutorial sheet using the interactive tutorials. For tutorial two, the results gained were not statistically significant when the electronic book and interactive tutorial were compared. For tutorial one, the interactive tutorial gained better overall user reaction ratings than the electronic book interface.

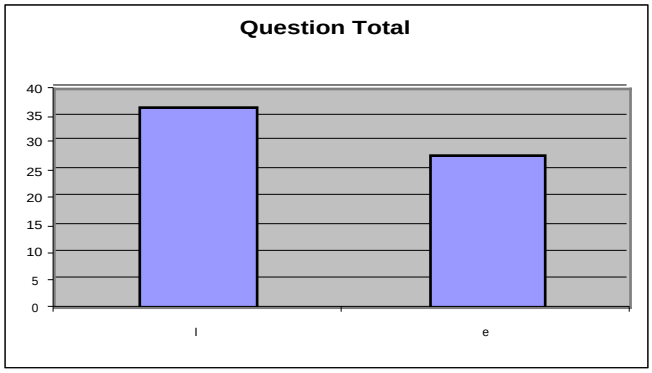


Figure 7: Survey-Tutorial One Mean Difficulty Rating

The results for different aspects have varying degrees of significance but it was found that for tutorial one the interactive tutorial was thought to be best in all aspects covered by the survey. A higher score indicates a better rating and the mean score of the interactive tutorial was nearly 40% greater than that for the electronic book, which is moderately significant (p=0.036). Students were pleased with the interactive tutorial, or considered it to be better than the electronic book when learning the material that was presented in tutorial one. For tutorial two, the interactive tutorial and the electronic book gained very similar results. The difference in ratings between the two was insignificant (p=0.87), signifying that both types of on-line tutorial were rated equally when used with tutorial two content. It is interesting to note that, after applying the two-factor analysis of variance to ascertain whether user reactions to the tutorials were affected by the type or topic of the tutorial, it was found that the topic significantly (p=0.011) affected the results given by participants in the survey in respect to the issue of difficulty with completing tasks. In the survey participants also indicated which type of on-line tutorial they would rather use to learn and revise material. Sixty-five percent of

respondents said they would prefer to use the interactive tutorial to the electronic book or textbook. When asked to select their preferred option between an interactive tutorial or an electronic book, 90% of respondents liked the interactive tutorial best and found it the most interesting and enjoyable. They also indicated that they would prefer to have the interactive tutorial in addition to traditional book based tutorials, rather than a replacement. Overall, students preferred the interactive tutorial to the electronic book, although preference was not nearly so marked in the second tutorial. The interactive tutorial may not have been as suited to the more complex content of tutorial two as the material benefited less from interactivity than the content of tutorial one.

Conclusions

In the user performance evaluation, analysis of the results collected showed the following:

- Students overall performed better using the interactive tutorial in the tutorial sessions;
- Student performance generally decreased in the second tutorial due to the greater difficulty of the material;
- The interactive tutorial produced better results in tutorial one than tutorial two, concluding that the interactive tutorial was better suited to the material content of tutorial one;
- The electronic book produced results that were more consistent than the interactive tutorial over the two different types of tutorial, hence performance with an electronic book is not greatly affected by content difficulty;
- The mean time taken to complete tutorial two was considerably longer than that for tutorial one across all test groups, which is attributed to the difficulty of the material, and not the difficulty of using the interface.

In the user preference evaluation, the results indicate an interactive tutorial is preferred in all aspects that were questioned in the survey. A majority of participants indicated that they liked the interactive tutorial best and that it was more interesting than the electronic book. Many participants indicated that the interactive tutorial was easier to understand and explained the material better. They also thought that the use of simulations and interactivity in the tutorial helped them with learning the content. In conclusion, the interactive tutorial produced better overall task performance than the electronic book for teaching introductory computer

hardware concepts. The experimental findings from the user performance analysis showed that students benefited from using an interactive tutorial and achieved a higher mean score on the tutorial sheets. Students produced results that were correct more often than those who used the other two methods. Results from the survey clearly indicated that the interactive tutorial was preferred over the electronic book in terms of ease of use, user satisfaction, ease of content learning, and interest by students in a tertiary learning environment.

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