An Interactive Computer-Based Tutorial for MATLAB

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Abstract — This paper describes the implementation of an interactive computer-based tutorial for MATLAB. Students are engaged in learning new concepts and syntax with video, audio, and interactive exercises. The interactive exercises, which are a distinguishing feature of the tutorial, use a specially designed exercise window, which has a background software interface to MATLAB. The learner is challenged with problems in the exercise window immediately after covering new concepts. Hints, example solutions, multiple choice quizzes and test problems, requiring the use of proper MATLAB structure and syntax, add to the learning experience.

Student input has played an important role in the development of this tutorial. Student feedback has led to useful improvements, which were integrated into the tutorial. Student evaluation results, which are presented in the paper, indicate great promise for this approach to teaching MATLAB and, by extension, other programming languages.

The paper also describes various difficulties and problems encountered in developing this computer-based tutorial, which may provide some useful guidelines for others who are considering computer-based instruction.

Note that an Internet site, www.m-tutor.usask.ca is available, where the reader can obtain more information on the tutorial. The tutorial has been published by Prentice-Hall (ISBN 0-13-083396-7).

Introduction

MATLAB is a relatively new computer programming environment which is used to perform numerical computations and visualize data. MATLAB's ease of use compared to traditional programming languages has made it very popular in academic and industrial environments. A current list of many textbooks making use of MATLAB is available from the MathWorks Internet web site [1]. This popularity of MATLAB has also resulted in a number of tutorial books [2], [3]. Presently, there are no interactive computer-based tutorials available for learning MATLAB. There exit a number of Internet based tutorials [4], [5], but all of these are basically computer-based textbooks, and lack significant student interaction or feedback.

This paper describes a unique, interactive, computer-based tutorial named, M-tutor, for independent learning of MATLAB. The project to develop M-Tutor was initiated in early 1996 at the University of Saskatchewan. The intent was to develop a tutorial for independent study by learners who had little or no exposure to MATLAB. Some of the goals of this tutorial were to:
1. engage students as active learners in exploring new concepts immediately with interactive exercises;
2. allow students to proceed at their own pace and plan;
3. permit the learning to take place off-campus; and
4. make more effective use of faculty teaching time and student study time.

This paper first describes the details of the implementation of the tutorial, including a description of the direct interface to MATLAB that is used for evaluation of student responses. Next, some results are presented of an evaluation of the tutorial by undergraduate electrical engineering students, followed by a discussion of the difficulties in developing a computer-based tutorial.

Implementation Description

This section describes details of the implementation of the computer-based tutorial, M-Tutor. The following subsections present descriptions of the tutorial content, the user interface, the use of audio, the exercise-MATLAB interface and, finally, the evaluation.

Content

M-Tutor is intended for students who have had little or no exposure to MATLAB, thus it begins with the basic structure of MATLAB. The tutorial then focuses on the strengths of MATLAB, such as basic numerical computation and graphic visualization. The content is divided into the following eight sections:
1. Getting Started
2. MATLAB Variables
3. Scalar Math

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30th ASEE/IEEE Frontiers in Education Conference

4. Vector Math
5. Vectors and Basic Plotting
6. Relational and Logical Math
7. Writing Basic MATLAB Programs
8. Matrix Math

Many of these sections are also divided into a number of subsections which focus on a common topic. A listing of the detailed Table of Contents can be viewed at the Internet site www.m-tutor.usask.ca.

The tutorial content is delivered on 'computer pages', each of which, presents the student with a new concept or with instructions and examples for a set of MATLAB commands. Learners can select highlighted 'Hotwords' to obtain detailed definitions or additional description. Hotwords are also used to request actual MATLAB results for the examples. The majority of the pages have a number of interactive exercises in which students can explore the concepts or commands presented on that page. Note that the amount of information presented on a page has intentionally been kept small so the student can easily digest the material and the exercises can focus directly on that material. An example of one of the computer pages is shown in Figure 1.

User Interface

A comprehensive navigator has been developed to help students manage their path through the M-Tutor MATLAB tutorial. While the tutorial content is organized in a traditional manner, students have the freedom to cover the sections in whichever order suits their needs. The features of this navigator include:

1. On page buttons to easily navigate through the tutorial. These buttons can be seen in the top, left-hand corner of Figure 1. From left to right these buttons are: Go back one page, Go to the main menu, Go ahead one page, Access a list of visited pages, Access the bookmarks list, Jump to the last visited page and Jump to the section contents page.
2. Information, Options and Results menu items which access useful information about the tutorial, change tutorial options and present exercise and quiz evaluation results, respectively. These menus are located at the top, left-hand corner of Figure 1.
3. A Help window which describes how to use the navigator. This help facility is accessible from the Information menu.

The navigator is also responsible for maintaining the record of the student's progress through the tutorial. A database file, keyed to the student's name, keeps an audit trail of the pages the student has visited, the exercises done and the number of attempts made at exercises. The database is used to color code material within the tutorial so the student can easily determine which material has been completed. A record is also kept of the last page visited so when the same student runs the tutorial again, the navigator gives the option of continuing from the last visited page.

An advantage of the database, is that it can also be used for evaluation purposes. For example, it could be automatically submitted to an instructor through an Internet connection. The instructor could use the information to monitor student progress and be alerted to aspects of the content with which the student is having difficulty.

Easy access to the various pages in the tutorial is provided by several methods. The Main Menu is accessed using the on-page navigation button, MAIN, shown in Figure 1. The Main Menu consists of a hierarchical set of color-coded submenus which represent the sections and subsections in the tutorial. This submenu approach reduces the amount of information which is presented to the student, which is beneficial for first time users of the tutorial.

The submenu approach can become tedious once the user becomes familiar with the organization of the tutorial, thus an alternate method to access the pages is also available. This method can be accessed by selecting the TOC button (Table of Contents) located at the bottom left-hand corner of Figure 1 or through the Information menu. Selecting this button displays a window which lists all of the sections, subsections and pages in the tutorial. A scroll bar can be used to move up and down the list. Selecting any of the hotwords in this window will take the student to the corresponding page in the tutorial. Finally, specific pages can be accessed directly by page number with the Go to Page... button, located in the lower left-hand corner of Figure 1.

Audio

Audio, in the form of recorded speech, is used throughout the tutorial to enhance the learning process. The audio used in the tutorial can be classified into two types:

1. Audio which repeats the text on the page, referred to here as verbatim-text audio.
2. Audio which provides further explanations of hotword box contents, referred to here as hotword audio.

Verbatim-text audio is used on all of the computer pages. This feature was added, since student feedback indicated that some students preferred the audio to reading the text. Hotword audio is used for examples and results that need more explanation.

The students have considerable control over the audio using a number of on-screen controls and user selectable options. Many of these options and features have been added as a result of the student feedback. Students had varied, sometimes strong, preferences regarding the usefulness of the audio tracks. The on-screen controls are shown in the bottom right-hand corner of Figure 1. Stu-

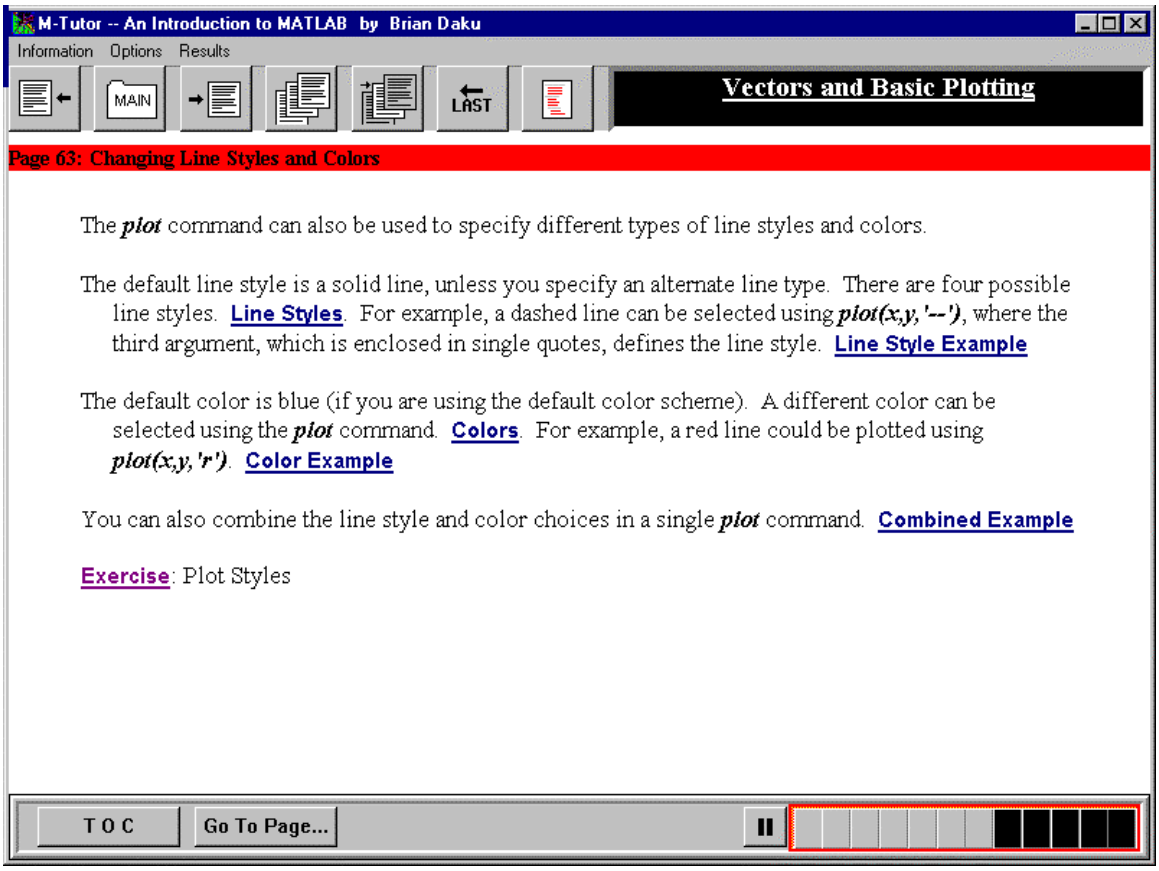

Fig. 1. Example page from the MATLAB Tutorial.

dents can pause and continue the audio, or replay specific paragraphs of the audio by selecting rectangles in the status indicator bar. The user selectable options can be viewed by selecting Audio in the Options menu. A dialog box will appear, which gives the user the option of turning the audio on or off and changing the speed and type of audio delivery.

Exercise-MATLAB Interface

In the Getting Started section of the tutorial the student uses the MATLAB command window to perform some simple exercises. This first exposes the student to the actual MATLAB interface. In all of the subsequent sections the student uses a specially designed exercise window to perform the exercises, an example of which is shown in Figure 2. The exercise problem to be solved is displayed in the top left-hand corner of the window. The user can select the Hints button, which progressively displays a list of hints to aid the student in solving the problem. Students enter their solutions to the problem (MATLAB language expressions) in the center subwindow, which is labeled Enter MATLAB Commands Here. This window has the full functionality of the MATLAB command window, including previous command access using the arrow keys. The student enters a MATLAB command and the result is displayed in the MATLAB Response subwindow. This response is the exact response that would be seen if the command were executed in MATLAB's own command window. This is done by evaluating the commands using the MATLAB engine.

The exercise window uses a DLL (C engine routines) interface to the MATLAB engine to execute the MATLAB commands entered by the student. The student selects the Evaluate button after entering the MATLAB commands and is then informed of whether the proposed solution is correct or incorrect. The evaluation method uses the MATLAB engine to compare the workspace contents and variables of a correct solution with those of the student's proposed solution. The student can access an example of a correct solution from the Hints menu, after using the Evaluate button.

The main advantage of the exercise window is the direct interface to MATLAB, which allows the student to use MATLAB and get instant feedback from within the tutorial. The exercise window is also used to guide the student through the problems using hints. The student is informed if the proposed solution is correct or not and

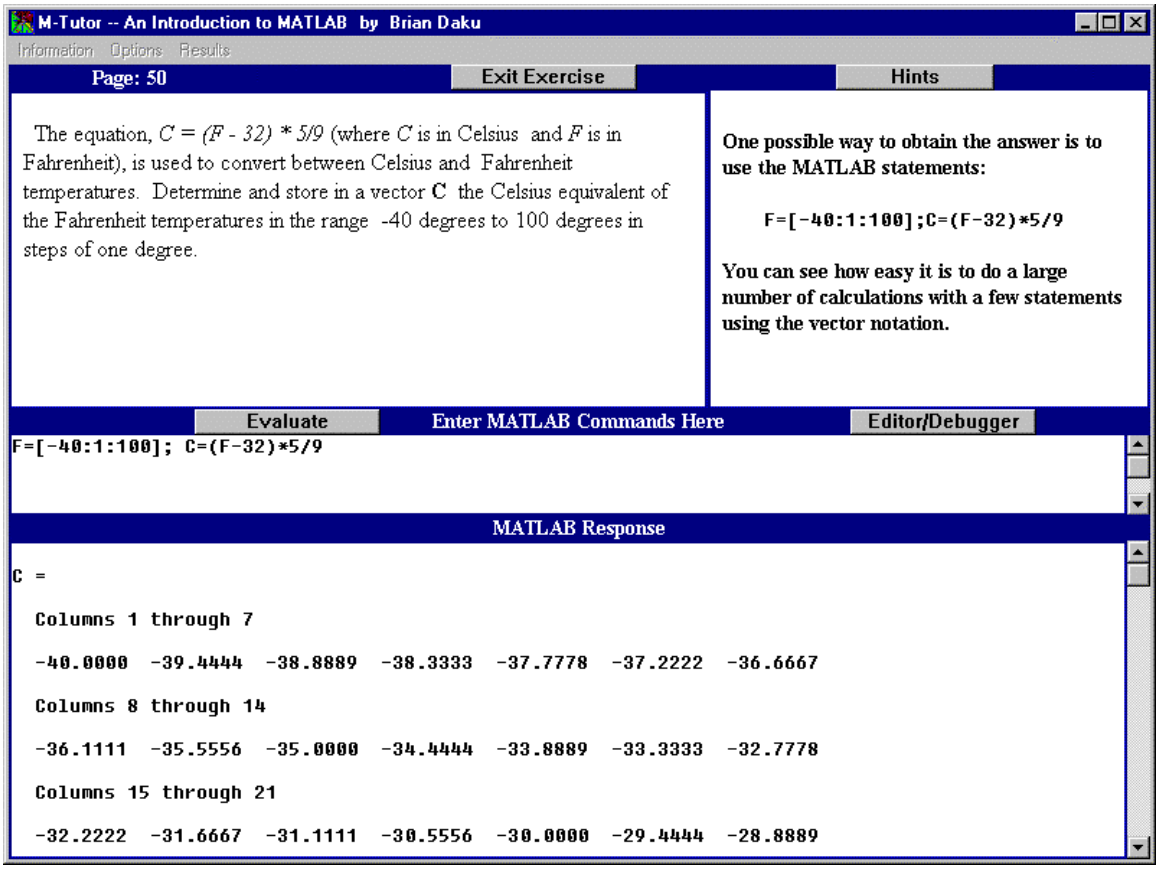

Fig. 2. Exercise Window from the MATLAB Tutorial.

then the student is given access to the actual solution to the problem. Another advantage of the exercise window is that a record can be kept of the students progress through the exercises, this could be used to route the student through remedial exercises if necessary, though this has not yet been implemented in the present version of the tutorial.

End of Section Evaluation

Evaluation of students' mastery of the content occurs at the end of each subsection of the tutorial. This is done using two forms of quizzes: a Summary Quiz and an Exercise Quiz. Each Summary Quiz consists of a number of short questions, the majority of which are multiple choice. These questions review the information presented in the subsection.

The Exercise Quiz consists of problems that use the exercise window. There is one exercise for each page in the subsection. The exercises in the Quiz do not provide hints, but they do provide the answer after students have attempted the solution. The results of the Summary Quiz and the Exercise Quiz are tabulated and displayed using the Results menu item. Keeping a record of the quiz results, which the student can access, provides motivation for the student to seriously attempt the questions.

Student Tutorial Evaluation

Student input has played an important part in the development of the M-tutor MATLAB tutorial. Along with feedback from individual students the following two major evaluations were conducted:

1. Sixty second year Electrical Engineering students evaluated the tutorial in March 1997.
2. Thirty-nine second year Electrical Engineering students evaluated the tutorial in March 1998.

This section presents some of the results from these two evaluations.

The main purpose of these tests was to evaluate the effectiveness of the tutorial for students considered to be part of the target learner population: learners with some mathematical and computer literacy who are motivated to learn MATLAB. The evaluation was done on-campus in a computer lab. These students spent between three and five hours going through a portion of the tutorial (55 pages).

The survey questionnaire consisted of 29 multiple-choice questions which were divided into three sections:

Background, Overall Impressions and Detailed Impressions. The results of some of the survey questions are presented below and the complete survey results can be accessed at the Internet site, www.m-tutor.usask.ca.

The survey had a number of questions, which related to how receptive the students were to this approach in teaching as opposed to classroom lectures. These questions were presented as statements and the students selected one of five choices, which gives a relative indication of whether they agree with the statement or not. The results of two of these questions are presented in Figures 3 and 4.

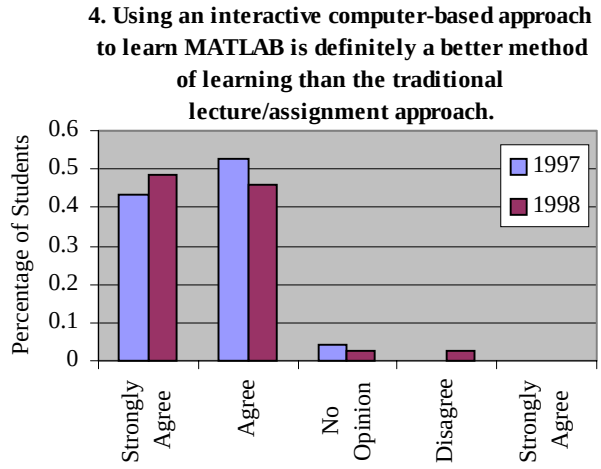

Fig. 3. Survey Question 4.

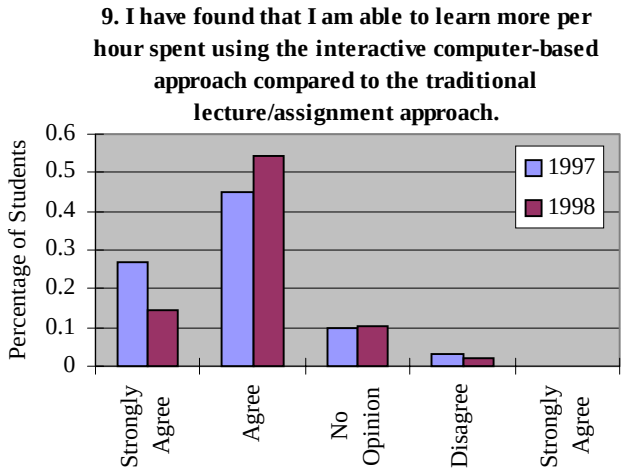

Fig. 4. Survey Question 9.

The results in Figure 3 demonstrate, that for this group of students, learning MATLAB using a computer-based approach is preferable over a traditional lecture/assignment approach. Discussions with some of the students indicate the major reasons for this positive response are:

1. Immediate application of the MATLAB concepts using the Exercise window, which is not possible in a lecture/assignment approach. They also felt that having hints and the answer available for each of the exercises were very beneficial.
2. Freedom to go through the tutorial at their own pace as opposed to the lecture presentation, which is defined by the instructor.

The results in Figure 4, which relate to the rate of learning, indicates that the majority of students felt they could learn more per hour spent using the computer-based approach as opposed to the lecture/assignment approach.

There were also a number of questions which focused on the details of the tutorial implementation. The statement in Figure 5 obtains some feedback to determine whether using audio to repeat the text on the page was useful. The results, which likely reflect different learning styles, are spread across all of the possible responses, with more students disagreeing than agreeing. Thus it appears that including verbatim-text audio is worthwhile for some students, but for others, having the option to disable the audio is a requirement.

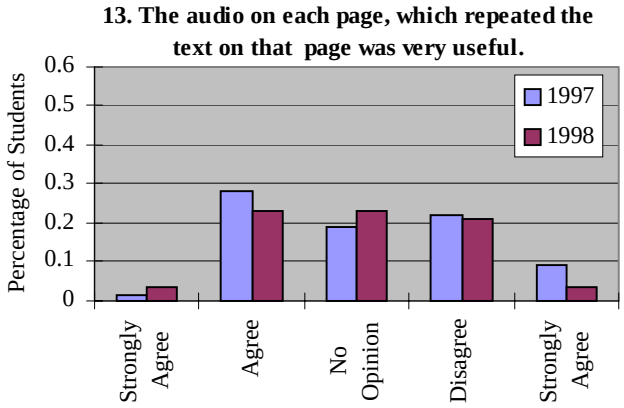

Fig. 5. Survey Question 13.

The approach used in the interactive exercises was also evaluated in the student survey by comparing it with the traditional method of just assigning questions. The results of this statement are shown in Figure 6. The response here is very positive, the students definitely prefer the method used in the specially designed exercise window. The approach used in delivering the exercises is one of the unique advantages of this computer-based tutorial over textbook or minimally interactive Internet tutorials.

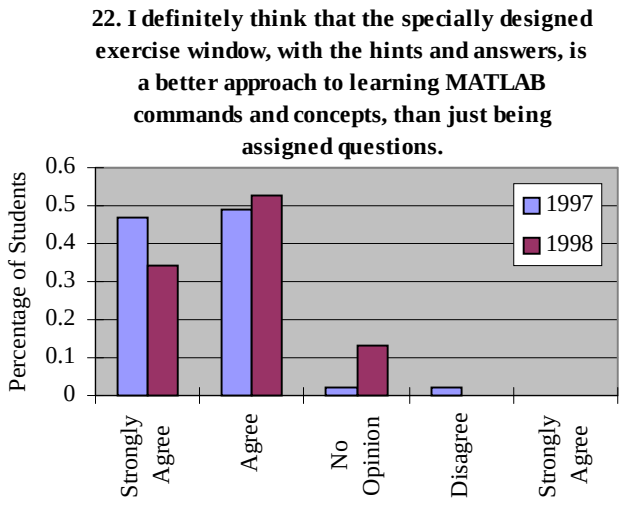

Fig. 6. Survey Question 22.

Development Issues

This section details some of the development issues and problems associated with producing an interactive, multimedia tutorial. A project such as this requires a significant commitment of time and resources. This was difficult to do in a research-intensive university environment, where these type of activities are not well supported.

The elapsed development time for this project was approximately two and one-half years, finishing in June 1998. The majority of the work was done by the developer, Brian Daku, who maintained research and other teaching activities during that period. An undergraduate student, Karl Lehmann, was hired for nine months to enter the content into the pages. The authoring environment was IconAuthor from Authorware. The tutorial was produced for CD-ROM, although it could be adapted to be accessed over a network. The Peter N. Nikiforuk Innovative Teaching and Learning Centre in College of Engineering provided facilities and financial assistance for the development. Experimenting with various approaches for delivering the content was a high priority for this project, and this required extra time from the developer, Brian Daku. Obviously, any future projects can build on this base of pedagogical and logistical experience.

Some of the major challenges in this project were related to version changes in MATLAB and the Windows operating system. The tutorial is heavily reliant on the integration of the MATLAB engine, the operating system and the tutorial. This project spanned more than two years and a new operating system, Windows 98, was released and a new version of MATLAB was released during this period. These new versions required significant modifications to the tutorial. To keep the tutorial useable over a reasonable number of years, long term software maintenance and support become a major issue and significant costs may be involved. Certainly it is in the best interest of a developer to use operating system independent tools where possible. That was not possible in this project since the exercise window interface had to use the operating system to access MATLAB.

Another difficulty with a project such as this, which is suitable for both academic and industrial markets, is choosing the best way to deliver the product to the markets. Traditional academic publishers have some difficulty with this type of product, since their marketing and distribution channels focus on supplying textbooks in large quantities. A multimedia tutorial like M-Tutor is viewed as supplementary material, and does not receive the same attention. On the other hand they are not well structured to sell single units to individuals in industry who wish to learn a new skill quickly.

Conclusions

This paper describes the implementation of an interactive computer CD-ROM based tutorial for the MATLB programming language. It presents some student evaluation results, which report students' opinions about the learning approach and various features of the tutorial. Finally, some of the development issues are discussed.

The unique feature of the tutorial implementation is the exercise window which includes hints, the answer, and a background software interface to MATLAB. The exercise window was well received by the students. They felt that studying MATLAB with the interactivity provided through the exercises was a much better approach for reinforcing the concepts than completing traditional assignments.

An important result of this work is that most students appear to prefer this computer-based approach to learning (of this type of subject content) when compared to the traditional lecture/assignment approach. They also feel that it is a more efficient way of learning.

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