EXPANDING HORIZONS FOR WOMEN AND MINORITIES: STIMULATING INTEREST IN ENGINEERING THROUGH WEB-BASED MODULES

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Abstract

Recent studies indicate that while the majority of those entering the labor force will be women by the year 2005, those choosing engineering are too few and far between. A variety of reasons have been offered for this phenomenon, and despite many interventions designed to encourage talented females and minorities to pursue careers in engineering and other sciences, the participation rate is not drastically changing. Clearly additional avenues must be pursued.

Based on the thesis that reaching students through the Internet enhances the educational process, Texas Womans' University formulated a project designed to develop independent, interactive web-based learning modules for use with mathematics and computer science courses. These modules offer *always-available* and convenient tutorial support to students enrolled in supported courses, while at the same time exposing them to applications from science and engineering. The objective of such exposure throughout the curriculum is to catch the interest of students at an early stage, and thus encourage them to pursue those career paths.

The project uses web-based modules to address its goals at two levels. One is to increase interest in science and engineering at the lower level courses for majors and non-majors. The other is to improve retention by offering support for upper level courses. While some modules are course specific, others are deliberately planned to be independent, allowing for maximum flexibility. All modules are available over the Internet.

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A Brief History

According to the Hudson Institute's report[7] *Workforce 2020: Work and Workers in the 21st Century*, the latest available national demographic trends project that more than 60% of those entering the US work force will be women by the year 2005. The data also show that women are not choosing to pursue careers in engineering and other hard sciences in any great numbers. For example, currently, fewer than 20% of the students studying engineering in college are women[1, 16], while less than 30% of those enrolled as computer science majors are women[16].

An abundance of research publications have suggested a variety of reasons for this phenomenon, including lack of female role models, male domination of classrooms, and a need for social relevance. Many researchers have suggested possible interventions to remedy the situation. However, despite the implementation of interventions designed to encourage talented females and minorities to pursue careers in engineering and other sciences, the latest figures show that the participation rate is not drastically changing. For further discussion of these and related issues, see [8]. Clearly there is room to explore different avenues in addition to existing efforts.

To address the concerns stated above, Texas Womans' University (TWU) established unique partnerships with industry and other universities across Texas. These partnerships each have a mission to increase the participation of traditionally under-represented populations in mathematics, computer science, and engineering[8]. In one such partnership, TWU, Texas Tech University (TTU), and Texas Instruments, Inc. (TI), recognize that innovative instruction techniques play a large role in supporting that mission. Together, they have formulated a project[1] designed to develop independent, interactive web-based learning modules for use with mathematics and computer science courses. The idea is based on the thesis that reaching students through the Internet enhances the educational process. For many underrepresented groups, access to university resources outside of the regular classroom hours represents a barrier, and even when available, the stresses associated with use of university resources within a context of commuting, daytime family and work responsibilities exacerbate an already potentially negative experience. Previous research by the authors indicates that many at-risk students require the flexible scheduling that distance-learning avenues afford. At the same time, they need to feel a connection with the material, the instructor, and other students that is commonly not associated with such distance education. These web-based modules offer *always-available* and convenient tutorial support to students enrolled in a variety of courses in the Department of Mathematics and Computer Science at TWU, while at the same time exposing them to applications from science and engineering. The objective of such exposure throughout the curriculum is to catch the interest of students at an early stage, and thus encourage them to pursue those career paths.

The project uses web-based modules to meet three goals. One is to increase interest in computer science and engineering at the lower level courses for majors and non-majors. A second goal is to improve retention by offering support for upper level courses. The third goal is to provide support to the partnership project with TTU and TI. While some modules are course specific,

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others are deliberately planned to be independent, allowing for maximum flexibility in their use. All modules are accessible over the Internet.

The associated objectives of the proposed project are to develop a set of web-based interactive tutorial modules that

- support the traditional classroom by providing additional resources and access to those resources,
- serve as an effective remedial tool through interactive examples that produce immediate feedback,
- increase student understanding at all levels of student ability through increased variety, flexibility, exposure to the subject matter, and learner control,
- enhance the educational experience of students with limited access to the traditional university resources outside of the classroom, and
- increase student comfort levels with technology through continuous exposure, thus promoting increased interest in pursuing computer science and engineering careers.

The anticipated final outcomes of the project include a continuously improving and growing set of independent web-based interactive modules that present a wide variety of topics, related to mathematics, statistics, computer science and engineering, flexible enough that they can be use in a majority of classes in the department, at all levels, and by majors as well as non-majors.

Web-Based Modules

The authors are currently developing self-contained tutorial modules with mathematics, computer science and engineering related content, designed to supplement traditional courses. They are designed as self-contained, on-line, student-centered, interactive tutorial modules. They introduce terminology, concepts, applications and problems within the context of the classroom course. Students will thus have the opportunity to supplement the traditional courses with materials that introduce them to engineering and science. The tutorial modules will supplement traditional courses offered in mathematics and computer science departments. Courses that are standard to most programs in mathematics and computer science include Calculus I (Cal I), Calculus II (Cal II), Differential Equations (DE), Digital Logic (DL), and Probability and Statistics I (PS). The initial plan is to develop two web-based modules for each course listed above. Other modules are intended for students in lower level classes, both majors and non-majors.

To make the on-line modules as effective and flexible as possible, a variety of approaches are used. Each module incorporates most or all of the following elements.

- A concise presentation of the appropriate materials.
- Examples that use real or realistic data, and are based on real life.
- Interactive comprehension questions with immediate feedback interspaced in the text. Their intent is to continuously check the level of understanding.
- Interactive applets to illustrate and/or demonstrate concepts. Appropriate pre-existing applets are used if possible.
- Comprehensive testing modules at the end of a module or sub-module.
- A comprehensive problem at the end of a unit or module.

- Other features include a glossary of terms, frequently asked questions, contact information, links, interesting facts and historical background information.

The rationale for the design of these modules is based on previous research by Holt and Demuynck[9] in the context of statistics education (NSF DUE #9972494). Because the modules are web-based, advantages and disadvantages of using this medium were carefully considered.

Many publications, such as [2], [4], [5], [6], [10], [13] and [15] discuss a number of ways in which reaching students through the Internet may enhance the educational process. Some of the more interesting findings are:

- An increased participation of students inside and outside of the classroom: Our web-based modules give students the opportunity to go over the material again on their own, as many times as they wish. The interspaced self-evaluation questions give them feedback on their understanding of the materials discussed in the modules.
- An increased interest: There is ample anecdotal evidence to suggest that young students of all backgrounds really enjoy working with computers. As reported by [3] for example, using interactive applets in the classroom seems to generate a positive reaction from students and results in increased attentiveness, enthusiasm and participation.
- Increased flexibility: This is a necessity, as more and more mature students are returning to college. They often have family or work obligations and need to find study time at non-traditional hours. As our web-based modules are accessible through the Internet, they are accessible at any time.
- Increased expectations from students: Students are expecting more attention, more and different learning resources, feedback, etc., from their instructors. Web-modules help in this respect as they provide a student with an additional learning resource, which also offers more feedback through the interactive testing and frequently asked questions sections.
- Increased exposure: Continuous exposure to computer applications, of which web-based modules are a good example, results in increased comfort with computer technology, which in turn generates an increased interest in computer and technology. Ultimately, this leads to increased access to careers in computer science, mathematics and engineering.
- Changed nature of the acquisition of knowledge: The amount of knowledge is growing at an increasing rate of speed, making it more and more likely that people will need retraining several times during their careers; even those staying on the same career path will need to update and upgrade their skills regularly. Ultimately, the type of modules presented here can be a vehicle for upgrading and retraining, continuing and adult education.
- Increased independence: The modules will afford the students a measure of geographical and temporal independence. That is, students will be able to access the modules from any location and at any time convenient to them.
- Increased learner control: Accessing the modules at their own time and at their own convenience gives the students increased control over their learning environment, leading to increased motivation. In addition, the modules leave the student a great amount of choice on how to proceed. They also have the opportunity to repeat a module

or any section of it as often as they need to without experiencing any negative repercussions, such as a lower grade or embarrassment.

As stated above, the modules provide students with immediate corrective feedback. In addition, the modules can be adapted to also provide feedback to the instructor, for example in the form of progress reports and interactive quiz results. Furthermore, students can be given the opportunity to contribute and comment on the modules through suggestions, feedback on problems they encounter, new links and examples, and so on. Future plans also include the development of an Intelligent Tutoring System to support and guide student learning, as such systems have been shown to have a positive effect on student performance [11, 12, 13]. Of course, existing modules will be expanded and new modules will be added on a continuing basis.

Modules for Lower Level Classes

As discussed above, some of the modules are intended as support for lower level classes. So far, the following are available, grouped by content.

Elementary Statistics Content

Four modules in support of *Elementary Statistics* are currently available in an advanced draft version. They cover the subjects of:

- *Histograms*
- *Correlation*
- *Simple Linear Regression*
- *Measures of Central Tendency*

Future plans also include the development of more modules, starting with the topics *Measures of Spread*, *The Central Limit Theorem*, and *t-intervals*.

Number Systems Content

The module on the binary number system is completed in advanced draft version, while the module on the hexadecimal number system is in development. The binary number systems module has the following components:

- *Introduction*: An introductory page.
- *Bits and bytes*: an introduction on how the binary number system is used to represent data.
- *Binary numbers*: includes conversions between binary and decimal numbers, fractional binary numbers, and negative binary numbers.
- *Binary arithmetic*: covers binary addition, subtraction, multiplication and division.

This module can be used in a number of courses, including

- In *Introduction to Computer Science* classes, to introduce students to the binary number system behind the computer.
- In *Programming* classes and *Assembly Language* classes where number systems are often first studied in depth.

- In other classes, including some upper level classes, such as *Digital Logic* and *Systems Programming*, where number systems are pre-requisite knowledge, the module can serve as a review or refresher course on number systems.
- In *Elementary Mathematics* classes the module can be used as an application of number systems to computer engineering. This gives the opportunity for the teacher to introduce the topic of engineering with a practical example.

Modules for Upper Level Classes

As discussed above, other modules are intended as support for upper level classes. So far, the following, available at various levels of completeness, are listed grouped by content.

Introduction to Engineering

This module is intended to introduce the discipline of engineering to non-engineering majors. It is designed to be flexible, and its level of complexity can be varied. Thus it can be used in a variety of classes, including *Introduction to Computer Science* and *Computer Programming* classes, as well as more advanced classes such as *Digital Logic*, *Computer Architecture*, *Topics in Electricity, Magnetism and Circuits, Women and Minorities in Engineering, Mathematics and Science*, and *Calculus*.

This module provides a general overview of what engineering is, and attempts to answer some typical questions such as:

- What is engineering?
- What does an engineer do?
- What different kinds of engineering are there?
- What are some typical courses an aspiring engineer takes?
- What are the future prospects for an engineering major?

Subsequently the module illustrates those concepts with some typical engineering problems. It starts out with two completely worked out problems. Each introduces the student to the problem in an anecdotal fashion, leads the student through a couple of different approaches to solving the problem, and then lays out a complete solution. Then, a third problem is defined, and a solution is given in outline. A fourth problem is simple stated and working out a solution is left as an assignment.

Computer Graphics

The computer graphics module looks at several issues important to the development of computer graphics, such as:

- Digital representation of images
- Image file size
- Image manipulation, such as noise reduction, distortion, blurring, etc.
- Compression methods for text and image data

Again, the contents of this module were designed to be very flexible so they can be used at a variety of levels. The section on the digital representation of images and image file size can be

adapted to *Introduction to Computer Science* classes, *Computer Technology and Applications* classes, and *Introduction to Computer Programming* classes. The compression and image manipulation segments are interesting for advanced classes such as *Matrix Algebra, Data Structures* and *Algorithms.*

Networking and Data Communication

This module, in its initial stages of development, tackles the concepts of packets and cells and the accuracy of message delivery on networks. Its content is appropriate mainly for use in *Networking and Data Communications* classes; although selected sections could be used in *Probability and Statistics* classes.

A Look at the Modules

This section provides more detailed module descriptions with some examples.

An opening page

Each begins with an opening page. The banner on this page situates the module in the whole and links it with the others in the site. It also provides links to contact information, acknowledgements and contributors. A table of contents provides a quick overview of the content and structure of the module. The table of contents is fully linked, and thus provides quick access to each section of the module. An example of an opening screen from the *Introduction to Engineering* module is shown in Figure 1, showing all the features listed above.

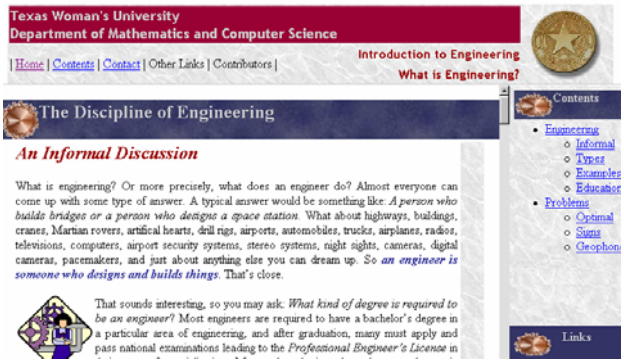

Figure 1: Opening page from the Introduction to Engineering module

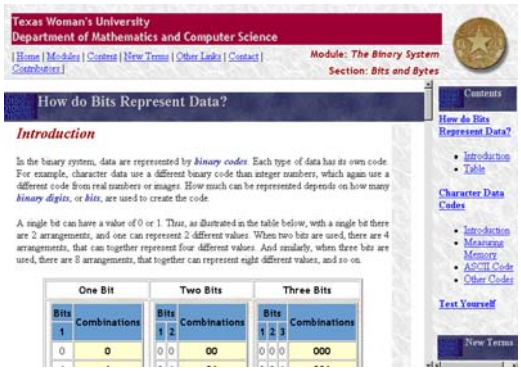

Figure 2: Introductory page from the Binary Number System module

A concise presentation of content material

Each unit includes one or more concise presentations that summarize the material contained in the module. Concepts are explained and defined. Processes and procedures are explained and illustrated with examples. In general, the examples progress from elementary to more complex. The materials presented in each component are divided into small sections, easily managed by students. Many include graphics to illustrate and clarify concepts. Moreover, key concepts are linked to an alphabetized list of terms that are new for the module and/or to a comprehensive glossary of terms. An example screen capture of such a presentation from the Binary Number

Systems module is shown in Figures 2.

Real and realistic examples and data

As much as possible, each component is illustrated with real or realistic examples, and real data are used whenever possible or practical. For examples and student practice problems, the selected examples have small data sets. In the statistics modules many of them are previously published data sets. Where possible, the same example is used consistently through the entire component. An example screen capture of such a sample data from the Scatterplot module is shown in Figure 3.

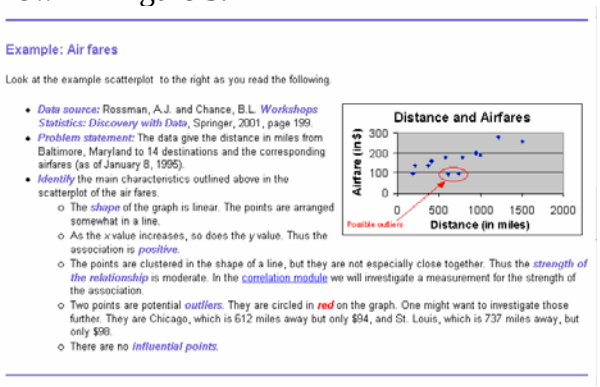

Figure 3: An example with real data from the Scatterplot module.

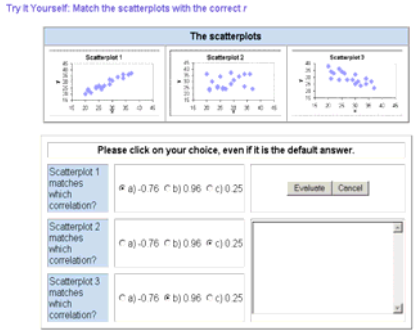

Figure 4: Comprehension testing in the Correlation Module

Testing comprehension of content

All the presentations are interspaced with brief interactive comprehension questions. They allow the students to check their level of understanding of the immediately preceding materials. They receive immediate corrective feedback on their answers. They are usually allowed to repeat the same problem or try another similar one. An example of such a question and answer session from the Correlation module is shown in Figure 4.

Comprehensive testing

Each module also includes a comprehensive *end-of-module* quiz. In both types of test settings, we attempt to keep the test questions varied. In some sections the questions are static, i.e. the questions remain unchanged on subsequent attempts. In other sections, the test problems are completely or partially new, most often controlled by some form of random generation. When the test questions are randomly generate, the students has the choice of repeating the same test or have the program generate a new test. When a test is complete, the student's answers to the test are evaluated, a final score is calculated, and detailed feedback on each question is provided. Finally, a student is given some feedback for continuation. If the student's score on the test was below par, the student is instructed on which sections to review before retrying the test. On the other hand, with a good test score, a student is directed to proceed to the next module. An example from the *Negative Binary Numbers* module is shown in Figure 5.

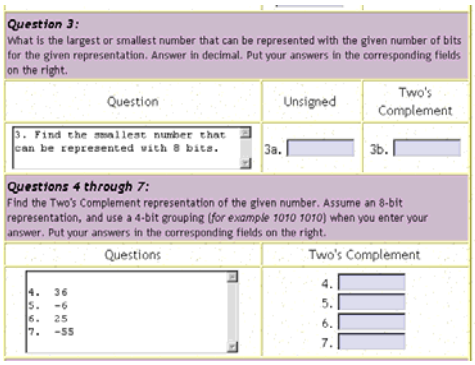

Figure 5: Comprehension testing in the Negative Binary Numbers module

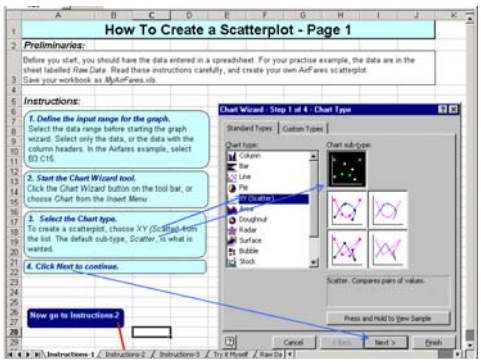

Figure 6: Linking to software (Microsoft Excel) from the Scatterplot module

Links to other software

In the statistics modules, where appropriate, each module also includes instructions and examples on how to perform the statistical calculations using the widely available software tool Microsoft Excel. Each module directly links to an Excel spreadsheet, which contains step-by-step illustrations on how to perform the required calculations. Some of the spreadsheets are supported by macros. Each spreadsheet also contains a completely worked out example, as well as a worksheet that contains just the data, but where the calculations must be completed by the students. An example, showing a Microsoft Excel worksheet sample the Scatterplot module is shown in Figure 6.

Comprehensive problems

A student's overall understanding is also tested through comprehensive problems based on real data. The concept is to present the student with a problem that incorporates knowledge from an entire module, or from more than one module. Some such problems come with complete solutions, as well as with explanatory notes.

Applets

Interactive applets illustrate and/or demonstrate statistical concepts. At present, appropriate pre-existing applets are used. However, previous research indicates there is a limited number of good applets at the appropriate level. In addition, links to such sites may become invalid at any time. Therefore, new applets will be developed as time permits.

Other features

Other features include glossary of terms, interesting facts, historical background information and interesting facts, and frequently asked questions. The glossary of term defines each term and links to the module where a term is first defined. It also references other important locations for a term, and thus acts as an index. The frequently asked questions are intended to help students overcome common problems and errors. In addition, the authors will conduct a thorough survey and evaluation of other materials, applicable to the contents of each module. Interesting sites will be linked from the modules.

Conclusions

Clearly more research and development remains to be done. The preliminary results of this project are encouraging. The preliminary reaction of students to these modules has been positive. The existing information relative to the effectiveness of this form of delivery is still mostly anecdotal. A research project to substantiate those results is currently under way.

As stated above, although the modules provide students with immediate corrective feedback, good feedback to the instructor is not incorporated yet. Part of our efforts in the future will be directed towards the development of an Intelligent Tutoring System[11, 12], most likely Bayesian based[14] to better support and guide student learning. Of course, more modules will be added on a continuing basis.

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Bibliographical Information

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