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Development of Interactive Web-Based Tutorials for Chemical Engineering Undergraduates

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Development of Interactive Web-Based Tutorials for Chemical Engineering

Undergraduates

by

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ABSTRACT

This thesis presents the design, creation, and testing of a web-based tool for generating interactive web-based problem set assignments. In prior research (Stetka, 2001) it was shown that students enjoyed interactive problems. In this research, multiple programming languages were used to provide a web-based, fully interactive, problem solving environment for the students.

Sample problem sets were written by the author and a few chemical engineering students. These web pages were then used as a basis to test the effectiveness of the web-based interactive problem sets for two engineering courses. Initial findings are presented illustrating the student's results along with results of student feedback surveys. Additionally, an analysis of the feedback from the two levels of users, students and instructors are reported and some suggestions for further development are given.

Chapter 1:

Introduction and Objectives

The primary way to learn engineering is through experience. For students, generally this means solving as many problems as possible. In most instances regularly assigned problem sets achieve this objective by incorporating newly learned concepts with fundamental principles. These problem sets require the student to extend the knowledge learned in the classroom and the assigned readings. Unfortunately, many students get stuck and require help to proceed further in solving some of these problems. Help, however, may not always be on-hand as the instructor or teaching assistant may not be available, and electronic mail may not get answered in time for the student to receive the benefit of guidance. Sometimes the students solves the problem incorrectly, but does not realize this unless the problems sets are graded and in a large class the instructor may not have the resources to grade all the problem sets. To address these problems we have created a structure for creating and disseminating web-based engineering problems with built-in help on demand.

It has been shown that as the amount of practice increases, the ability of most students to perform and comprehend more complex problems also increases. This is a form of rehearsal that benefits the student even more when the repetition is not verbatim and builds on previous concepts to progress further (West et al, 1991). Such a concept of

developing sets of problems containing many different questions that guide a student through to a final solution is not new and is known as a tutorial.

The principles behind the problem solving tutorials are:

- Illustrate to the student how to break up problems into smaller pieces.

- Teach systematic approach to engineering problem solving.

- Emphasis on learning as opposed to assessment.

- Provide immediate feedback on the students learning.

- Provide help as needed.

The primary objective of this thesis is to implement, test and evaluate the feasibility and efficiency of web-based problem solving tutorials. Another goal was to develop tools that enable an instructor to generate such web-based problem solving tutorials. The concepts that are employed are simple. Most problems and questions have a common structure and flow. We provide this basic structure in the tools.

Through the recognition of the potential of the internet to deliver an extraordinary amount of content in varieties of different forms, we have also noticed that there is not a particularly easy all in one tool to generate the required code to utilize many of the latest advantages let alone the basics of the web. The creation, preliminary inception, and documentation of this tool were additional objectives of this thesis.

The internet has become a keystone in our culture for living and learning. As this resource continues to grow many new and wonderful technologies are incorporated that can ultimately provide a truly unique experience for the user. This can be easily seen in many fields including but not limited to sales, education, and entertainment. Within all of these categories, various forms of new technology that enable the user to interactively

and graphically work through situations; unfortunately, with the technology comes the disadvantage of proprietary codes and methods that can take days to months to learn proficiently enough to be able to implement.

There are a few course management tools such as Blackboard® and WebCT® that provide an easy interface to create and display information, and a few standalone software titles like Respondus® and WebAssign® that provide the ability to assess students' progress. These commercial products can be invaluable for disseminating information and providing assessments for students in a variety of fashions such as static web pages and questions and answers. Within engineering, solutions to problems require many steps. The solution procedure cannot be easily broken down into the common multiple choice or fill in the blank formats provided from these commercial products. This deficiency has led to the development of proprietary codes that accomplish the task for only one particular subject that is not easily adapted to others. For example, Stetka (2001) has shown the advantage of having students access interactive web-sites with new technologies to understand staged separation principles.

There are a few good tools like CourseBuilder® offered through Macromedia's Dreamweaver® have many of the basic assessment functions available. By utilizing such tools it is possible to work in the median of conforming to a style and making your own from scratch. Based on the work of Stetka (2001) and the fact that most instructors either do not currently know how to program web-pages with proficiency or have the extra time to learn even with the assistance from general web creation tools, we have created a general set of forms and templates that can be easily filled in using only general

computing knowledge to create powerful interactive pages that can be used by students to learn in a new way.

By using the web there are a number of general implications that need to be addressed from the point of view of both the creator (instructor) and the user (student).

The instructor must present information at a level that can be understood by the student. The material should cover the topic in enough depth and so the student will have a complete deep level understanding or the desire to go out and learn more. Additionally, if any questions should arise the instructor needs to be available to assist or clarify the problem. The time required to be able to sufficiently clarify a topic with a student can be very long. This in conjunction with ever growing class sizes presents a great opportunity addressing this problem using interactive web pages. Ideally if web pages were created that could interactively guide a student through a series of small relatively easy steps to solve a larger problem, then it can facilitate the problem solving experience.

The role of the student must compliment the work of the instructor for an efficient transfer of knowledge. This role begins with the understanding that an effort must be applied to learning the subject and topics presented. For students, attending a lecture or reading of text book material is not enough. Having problems broken up into a number of smaller key concepts allows the student to better comprehend complex concepts. By having the subject matter broken down, students can more easily identify their own strengths and weaknesses, and appropriately seek further assistance when necessary.

As mentioned previously, having the content broken down into smaller key concepts allows for better recognition of the learning process. Taking the next step to assist students, the instructor can add links to web-pages that can further assist students.

Typically, students from year to year will need the same general assistance. For the instructor, this means by creating a web-page that already has the answers to the frequently asked questions, more time can be spent on issues that are specific to each student. Likewise for the student, the potential to miss some of the important details from a lecture is minimized.

This thesis is organized as follows: Chapter 2 gives an overview of the current theory of learning and instruction from an engineering point of view. Chapter 3 introduces the programming languages that are used. Chapter 4 discusses the design of the WebPages. Chapter 5 gives some example of the web-based problem solving tutorials. Chapter 6 discusses the results of a preliminary classroom testing of the tools. Finally, the conclusions and recommendations are given in Chapter 7.

Chapter 2:

Instruction and Learning

"Instruction" is defined by Merriam-Webster as "the activities of educating or instructing or teaching; activities that impart knowledge or skill," and "learning" is "the cognitive process of acquiring skill or knowledge." At the most fundamental level, the two are linked, but learning does not require instruction even though the benefits are usually easy to identify (Gagne, 1992). There are a few assumptions that are commonly made to fundamentally describe instruction and learning. First, it is most important to focus on aiding the individual who learning; although it is important to work in groups, the skills necessary to develop must be developed within each person. The intended focus obviously cannot be on a one on one basis all the time, so instruction should be directed at groups of learners with similar abilities and progression levels. Interwoven within, it is important to have goals set, and have students work both immediate and long term goals. The short and long term should not be forced upon the student at one point, but should be subtly hinted towards. At the end of a task, the overall larger picture should be revealed in detail with the explanation that all of the smaller steps have resulted in the much larger objective. Following this approach allows the students to learn a structured method to solving general problems with specific shorter term objectives in the middle (Gagne, 1992).

For instruction to be the most effective, it must be directed and follow a track that was outlined at the beginning, as there is no better method to instruct than from example (Gagne, 1992). This is often considered a systematic approach and results with students that will imitate the methodology and be able to enjoy the satisfaction of completing structured tasks. Systematic instruction can be a formidable task. The required skills to effectively instruct a student need to be taken from the fundamental knowledge of how people think and interact (West, 1991). At the root understanding and knowing how a student will learn there is the concept of internal and external components to learning. Externally the new concepts come to the student and must then be processed with familiar concepts internally.

Traditional, time tested components of learning such as contiguity, repetition and reinforcement have been shown to provide a student with the best retention and comprehension of the presented information. First, contiguity is the simultaneous stimulation of a question with the desired result. This can be difficult to achieve in many situations, but is essentially having the instructor guide the student through a problem posing questions and providing the answer shortly there after to assist in the learning process. This is typically done in a lecture class with the instructor working out a problem on the board.

A second component of learning is the use of repetition. This topic is the center of much debate, as in recent studies, it has been shown that in all situations, the repetition of a particular event is not helpful to students (except note memorization). There are situations that do require repetition, in order to perfect a skill such as learning to speak a new language. The alternative that is proposed to repetition is formulating analogies and

different similarities that will allow the student to better assimilate the knowledge. This leads into the final component of learning which is reinforcement. Reinforcement is most notably the largest of the three components as it can take on many forms such as reading a new concept that relies on a previously learned principle, and thus reinforcing that principle. Another method can be through experimentation where the student is allowed to test different situations and parameters in order to deduce concepts and principles through understanding and generalization. The last method of reinforcement that will be mentioned is the use of homework, where a student is asked to take the fundamentals described in a classroom and textbook and apply them to contexts and situations that the student is familiar with, thus promoting retention through association with prior knowledge (West, 1991).

As new delivery methods become available, a fair expense will need to be invested to have the content correspond to the requirements of the educational goals (Broadbent, 2002). For some instances there are commercially developed products that can make the delivery of the general content easy, but any non-general content will have to be supplemented in some fashion. In a traditional situation, if an instructor is using one particular book, and a pertinent topic to the general subject is missing, it is the instructor's duty to present the details in a comparable level as the text in use. This can be a severe imposition, so it might be best to deliver all of the content using one uniform method.

One of the more highly thought of concepts in instruction is the design of problems to best interact with the student when problem solving skills are needed. Some of the more popular strategies that have been adopted include: inferring transformed

conceptions, classifying an action sequence, choosing the action that steps forward toward the answer, identifying contradictions, breaking the problem into parts, and working backwards from the final solution (Gagne, 1992). The easiest method for problem solving is breaking the larger problem into smaller subsets that can then be more easily addressed by the student. From the studies presented in literature this method is not better or worse than the others, as the only real improvement to the students' ability comes from increasing their knowledge base. In fact studies have shown the approaches taken by experts in a given field are very similar to that of students with the primary difference of having more experience in solving such problems (West, 1991). Experience from solving specific problems does not just apply to the one type. As a new problem is approached, methodology learned from previous experiences is first attempted by the student and analogies are formed throughout. Knowing that such a thought process occurs supports the idea that improvements to the more fundamental approaches are critical to a student's success. These are taught in lower level coursework, but can be applied to more complicated situations involving designs. Within the undergraduate chemical curriculum some of the fundamentals that are critical are thermodynamics; mass, energy and momentum balances; and transport phenomena.

The second implication of a student's learning capabilities is the information should be continually taught in a similar format to eliminate the added complexity of learning a new method and more emphasis can be focused on the content. For the fundamental principles a level of mastery must be had to allow quick recollection and application to new challenges (Gagne, 1992). Consider a somewhat complex problem: a student is asked to determine the transfer function of a control system. First, the

appropriate material balance equations must be developed. Such balances if not mastered previously and easily recalled can cause a significant increase in the time required for a student be able to solve a straight forward problem. This example can be taken back even further to thermodynamic fundamentals if energy balances are in use, and the necessity to understand the concept of energy.

The learning capabilities of a student can also be tied to learning attitude. Although attitude may seem irrelevant, it is very important that the student want to progress. The student first believing that they can do every detail that was once shown to them with no reservation gives them the confidence and knowledge to progress to more complicated situations (Gagne, 1992). Consider as an example in a chemistry laboratory: a student is given a "recipe" to make a compound. One of the steps merely states to mix an acid and some water to achieve a given concentration. Without first knowing the basic calculation to find the quantities required there is no point in continuing. Second, in mixing the two substances it is best and safest to slowly add the acid to the water. This is an oversimplified example, but it illustrates that students need to first know the basic principles, and finally have an attitude that enables them to apply the concepts in a methodically quick fashion.

Problem solving itself is an interesting compilation of many different smaller components or rules that need to be applied. It is a skill that is not formally taught, but is pivotal in being able to process information and present resulting calculations and arguments to support a finding. The key to problem solving is the instructor must generate appropriate problems that enable the student to be able to formulate and generate their own solutions. Attention should be paid to the verb "generate" as it was

used to imply a level of understanding necessary to take a fundamental concept and create an advanced solution. It is not sufficient for problem solving activities to merely have the student recite rules or apply known formulae without first thinking of analogies (Gagne, 1992).

Within any learning model there are nine fundamental instructional events that must occur: gaining attention, informing the learner of the objective, stimulating recall, presenting stimulus, providing learning guidance, eliciting the performance, providing feedback, assessing the performance, and enhancing the retention and transfer (Gagne, 1992). There are a number of different methods for each of these events, and some can even be combined with one another; for example, providing feedback to a student of the correctness of an answer also gives an assessment of the performance of the work.

Chapter 3:

Programming Languages

As more of the world's documents become web pages, web development is becoming increasingly important. In recent years there have been many improvements to enhance the ease of use and functionality available to users. Many of the bells and whistles used now for this purpose come in the form of different programming languages.

Two primary categories of web development languages are client and server side, describing where the actual code is executed. The client side languages, like Hypertext Markup Language (HTML), copy the code from the server system onto the user's local system prior to running. Server side languages, like Perl, simply run the code on the server, where it is also stored. Within the two categories many interesting, useful languages have been developed providing a wonderful opportunity to create a wide array of different methods to deliver content.

3.1 HTML

The most easily recognized programming language today is HTML. This is the backbone of what most people know as the internet; it is a client side language that is universally accepted and used to display web-pages. Today, HTML has some new

variants, for example dynamic HTML and Extensible Markup Language (XML) that are limited on the universal acceptance, so for this project, we have remained with a standardized version to ease accessibility for all involved. HTML is a unique type of computer code that does not require compilation, thus it is easy to create and edit in a standard text editor.

The formatting of HTML is logical, and permits itself to be user friendly and easy to learn, not to mention it is not case-sensitive. HTML is controlled by elements that are referred to as tags. Tags are bracketed commands such as, <html> and </HTML>. Most tags are followed by a string of text to be displayed in a web browser, and a close statement which is the same as the beginning tag but has a forward slash after the first bracket (HTML Complete, 1999).

HTML's hierarchal structure makes it easy to read and edit web pages. Every webpage has all of the content within the <HTML>, tags that let the web-browser know that the following text is formatted HTML. Between the <HTML> tags, are two sections, the header and the body. The header is indicated through the tag <HEADER>; information contained in this section is not directly displayed in a web browser, but rather contains information about the page, such as the title; how a particular browser should handle the web page; file paths for later referencing; etc.

The second section of a webpage, the body, is what is actually displayed when the webpage is opened in a web-browser. To control the formatting of the different items displayed, attributes to tags can be used. For example <BODY> can have the attribute BGCOLOR to specify the background color for the entire webpage. BACKGROUND

can be added to the BODY tag to provide a background image. The result of the simple tag based HTML can be a very powerful configurable tool to deliver information.

HTML was originally intended to deliver content with very little clutter of coding, so it is a simple language that will display information in a format that will take up the smallest portion of the display unless otherwise specified. To handle this issue making information flow more intelligently, there are a number of formatting tags that can be used. Some of the more useful ones include: <P> break up text into paragraphs, <A> add a link to a page, <TABLE> form a table, <IMG> insert an image, <FRAMESET> create frames on the screen to display multiple WebPages simultaneously. For a complete listing of tags and attributes, there are a number of excellent handbooks and support on the web. For the most up to date information, the World Wide Web Consortium should be consulted at http://www.w3.org.

Additional to the many reference books, many companies have products that allow web-pages to be created with ease much like a common word processing program. Most of these development programs have a graphical user interface (GUI) that allows for quick layout and design of pages without having to know all of the intricacies of the different programming languages. These programs usually have a section that allows for the direct editing of the HTML. Of the most widely used products, the companies and products specifically designed to make for the easiest web development include: Composer® in Mozilla®, Dreamweaver® by Macromedia®, Frontpage® by Microsoft®, and Hotdog 32® by Sausage®.

3.2 JavaScript

The second key programming language used within this project is a client-side language called JavaScript. This language allows for a more live interactive experience. A couple of ways JavaScript is used to enhance a web experience is with in-situ calculations and verification of test conditions. JavaScript is written into HTML, and compliments the simple displaying language by adding interactive abilities. A very common misconception is Java and JavaScript are the same. Confusion between languages exists because many of the commands used in JavaScript come from older programming languages like Java or C (Flanagan, 2002).

Client-side JavaScript code is similar to HTML. It is a non-compiled code, which means it can be viewed and edited in a common text editor. This enables a programmer to quickly create and edit code to obtain the desired result. Unlike HTML, JavaScript is case sensitive. Unfortunately, due to the ease of using the two languages interchangeably, simple errors often occur. As an example in HTML the onclick event handler is written by tradition as onClick, whereas in JavaScript it is written as onclick.

Within the scope of this project, JavaScript is used for basic mathematical operations within a web page and minor display changes. JavaScript's basis for mathematical operations is a base-10 integer used in an ordinary fashion. The language can handle numbers from -2^{53} to 2^{53} without the loss of any precision through trailing digits. For most tasks, this provides more than enough flexibility and precision. An additional feature that enables easier use of numbers, especially within engineering is the use of exponential notation. Using numbers in conjunction with common mathematical operators such as +, -, *, /, sin, and cos, most mathematical operations can be completed.

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For example to compute 5*cos(x), use a simple expression like cosine_x = 5*Math.cos(x).

JavaScript, like HTML, has a hierarchy that must be followed to allow a program to function properly. The primary global environment within JavaScript is the window object. Below the window object is the document, which itself is a global object. The primary difference between the two languages is the document object is the displayed webpage, and the window object contains parameters that are not displayed directly, much like the BODY and HEADER in HTML. Because of this difference, it is possible to pass information from the document object to the window object, and have the user not able to view the parameters.

The final important feature of JavaScript for this work that needs to be addressed is the ability of it to interact with a user's actions. This is called being event driven, and within the context of web pages and interactive problem solving means that when a user clicks a button, a script is run to provide a change in the problem allowing for multiple scenarios to be worked out.

3.3 Perl

Having already delved into two client side languages, the third language utilized is Perl, a server side language. Perl is a programming language that takes its functionality back many years, and allows easy communication between the server and client. Unlike the previously described web oriented programming languages, Perl has a greater functionality, as it can easily be used to sort and interlink databases as well as

programs that are kept on the server to web-pages that are viewed via web-browsers everywhere (Wall et al., 2000).

This language was developed to allow for easy use rather than providing extremely small precise programs. Perl was created with many of the best features of previous languages, because of this it is very capable language. Functions of Perl that are useful are scanning text files, extracting data, and generating reports from the collected data. Consider this as a function for maintaining an inventory or any other log that is recorded in a spreadsheet. A second feature of Perl that sets it apart from other programming languages is the fact that it has no file size limit, but rather the hardware is the limit.

In every Perl program, the very first line is one where the location of Perl executable is located on the system. A typical line for a Solaris system will resemble "#!/usr/bin/perl." Following the initial line any number of common operations can be utilized. Print may be the simplest and most versatile of these commands that finds application in large and small programs. With print, all text that is within the quotations will be displayed on the screen, with the exception of commands indicated through the use of a back slash (\) or string character ($). Similarly, whole web-pages can be displayed using the print command.

If Perl could only display some text on a screen it most likely would not have lasted so long and be known as the "Duct tape of the internet." One of the better known abilities of Perl is how it can import, sort, and display or save formatted data. For the first part of importing the data within the scope of this project, data is retrieved from a form on a webpage, using a slightly modified code that can be easily found in handbooks.

After importing, the data needs to be sorted and processed before any meaningful use can be done because it will come into the Perl program in one long string. The general approach to this task is first split the string into variable name and value pairs. After splitting the data, the next operation is to create string values in Perl and organize the data. Basically this will make sure all of the values are in plain text and will be easy to use in the rest of the Perl program. For a detailed description, reference books should be consulted.

The last important function that is necessary to described to allow for a complete understanding of this project is how to run other programs from Perl. This is a simple operation much like the previously described commands. The command to run another system operation is "system", which tells Perl to run the command in the shell Perl is running in itself. The system command requires options to be set, for instance the home directory location, prior to running.

3.4 Matlab

The fourth programming language used in this project is Matlab. Although this is not a real language but rather an extremely powerful program it is widely used in engineering education. It has many built in programs for solving engineering problems. Therefore it is desirable to integrate Matlab with the web to allow problem solving on the web.

Matlab is a flexible interactive environment for performing all mathematical operations. Additional to being an environment to do calculations, Matlab can run script files both from its own environment and the command prompt. As mentioned in the

previous section addressing Perl, such command line operations can be performed through a web interface. The resulting data can then be displayed on a webpage. Matlab is used more like a programming language than a program, as all commands are entered in through a common text interface. The commands can be stored in text files and called upon at anytime to perform specific function. This is one of Matlab's greatest features as there are hundreds of robust solution methods that come standard with every installation. The result is a minimal amount of programming to get to an accurate final number.

Matlab's basic data element is an array, allowing solution to complicated scientific problems, especially those involving matrices and vectors. This fits with the name as Matlab stands for Matrix Laboratory, and was developed into much more as the versions progressed. The very first command entry that requires discussion is the input of numbers and variables and basic mathematical operations. The entry of variables or numbers is as simple as typing it in. Unlike JavaScript described previously there is no need to predefine a variable prior to assigning a value. With variables defined in Matlab, it is possible to perform all mathematical operations using the variables, not the numeric values. Compiling single commands into one lager script file to perform all desired calculations by running only one command is usually done by creating an m-file with the same name as the function defined within the file. M-files are plain text files that can be edited in most editors; however, while using Matlab, it is most convenient to use the built in editor, as it allows for easy debugging.

Chapter 4:

Website Design

For schools to be able to implement a technology based system of learning, it is necessary to first have the infrastructure. The learning opportunities presented must be organized and be continually developed (Broadbent, 2002).

The basic design of any web page is almost as important as the content; consider a web site the same as a book: constants must be organized in order to facilitate the transfer of knowledge or information. On a web page this is even more critical, as everyone absorbs information in their own particular way, and there is the added depth of interaction on the reader's part. The interactive WebPages should be designed in an orderly manner that follows the pedagogy used to teach the subject. Throughout this chapter we will use an example engineering problem taken from heat transfer course to illustrate these ideas.

4.1 Foundation of Web Based Instruction

From the information taught in schools, students are expected to have a foundation to prepare them for their profession. Today the internet has replaced printed media as the primary source of information. It goes without mentioning in detail that the internet is changing education by allowing easy access to all of this information. Since

the students are already immersed in this electronic media, it might be beneficial to provide lessons, and guided course material on the internet. A number of universities already offer online courses, and the courses have shown to be flexible for people on busy schedules. The one drawback many of these courses is the requirement to still submit paper assignments or even just work assignments that are delivered through traditional means.

Working with a new medium in association with a traditional class introduces a concern as to the validity of such methods that can be summarized by asking: "Is this good enough?" Most studies to date seem to indicate that web based delivery is as good as traditional delivery methods. In some situations, the anonymous nature of working online removes inhibitions to experiment with new concepts and ideas. This can provide a much better overall experience to the student, but it has to be monitored and tuned accordingly. Some of the most common methods for monitoring the quality of a course include feedback from students, teachers, and course evaluations. The feedback can be taken and integrated into the coursework. This control scheme provides for a dynamic system, instead of just being a fixed loop. Often such a control network is thought of as an increasing spiral (Kallick and Wilson, 2001). The initial point of the development begins with the creation of the necessary infrastructure. Having created the infrastructure, data must be collected on the different aspects that affect the students including but not limited to the general method of delivery. Fundamental questions that must be asked include: "Does the format inspire and assist in learning or is it a hassle to accomplish a simple task?" The design of the delivery method provide a foundation that will allow better more directed efforts on more relevant topics, or it will not be utilized.

For this endeavor, students are leading the way. For research projects, a thorough search on the internet is considered to be the primary means to find information, while going to the library and reading through printed texts is secondary. It is this effort that further backs the development of online instruction. If a student wants to learn on the internet, why not assist them by providing the information online? The next logical step is to provide only assessments for the students to evaluate their learning. How can this be done? The first answer is to post examinations that provide answers for self-evaluations. The more technology savvy way would be to incorporate the answers into an interactive environment. This enables students to replace the typical paper and pencil with the computer and internet, and gives them the chance to do self assessments. An example of this is the "virtual laboratory" experience. In a virtual lab, students are allowed to design and conduct experiments as part of the learning process. This can be extremely beneficial for many reasons. The first is the significant saving in time for the student and instructor of not having to establish the necessary hardware. This is also seen as a cost and savings issue as it is not necessary to work with any potentially hazardous materials or equipment (Broadbent, 2002).

When looking at such approaches as virtual labs, some may wonder if it is worth the effort. As mentioned previously, online learning technology removes the inhibitions of the students. For example, when discussing chemical laboratories, students can explore various options without the fear of explosions and physical danger. One can simulate explosions, fire, and other events not possible in the real laboratory experiments. This concept can be extended to general engineering problem solving where the students are learning to apply concepts to solve real world application problems.

There are four main methods of learning that need to be incorporated in any structured course. The first type is *informal* learning, where someone may sit down and read a book or a manual (Broadbent, 2002). This has its advantages, but has limitation on how much information is available, where to look for a better explanation. The next level of learning is *self-paced* with some review in the form of questions (Broadbent, 2002). This can be compared to taking a textbook, and reading the text, followed by answering the questions at the end of each chapter. Again, like similar to informal learning this has the disadvantage of not knowing if one answered the questions correctly. Additionally, self-paced learning is a sequentially process and it is hard to break the sequence. Some of the problems with the first two methods are addressed in the third type: *leader-led* learning (Broadbent, 2002). With a leader, the learning is for the most part by the student, but if for some reason the topic goes too far out of the scope, a leader will bring everything back together. Also the leader can direct the person learning in the right direction to the answer by providing extra information. The final method of learning is that of *support tools*. These can include "cheat sheets" or quick reference guides that are very specific to situations (Broadbent, 2002).

By mentioning the four types of learning, there are some common issues associated with each. First, there is a need for extra information that is not always available. Second, although quick guides may provide a solution for a particular problem, the depth necessary to avoid such problems is not always available. Finally, having a leader to guide the learning and answer non-obvious questions is probably the best way, but this requires someone to be present and available.

In this thesis, we discuss the development of a learning system that attempts to address some of the drawbacks of traditional teaching. For example, questions that come up during the course of solving a problem are handled using an online help system. The help feature has been configured to operate two ways. The first operation is to display only one help screen to provide almost the full answer. The other configuration that has been set provides two levels of help: the first time viewing the help page will result in displaying a basic clue and helps get the student started, and the second viewing will provide a more in depth solution method. By having the help feature available, many of the same question that may arises from different students can be answered in a timely fashion.

As described by Broadbent (2002) there are a number of advantages of web-based instruction for the students and instructors, as listed below:
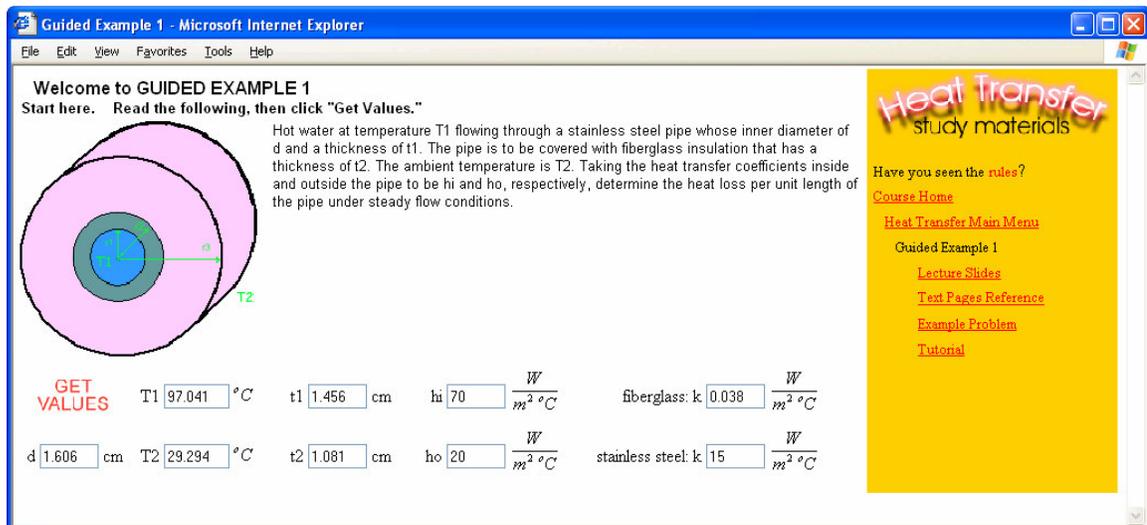
Students:

- Creates interactions that stimulate learning.

- Allows for different types of learners.

- Facilitates self-paced learning.

- Decreased cost of learning.

- Builds self-confidence.

Instructors:

- Convenient access.

- Allows for pre-packaging of lessons.

- Easy record keeping.

- Decreased cost of instructing.

- Provides more one on one time with individuals.

4.2 Heat Transfer Example

A basic heat transfer problem was designed to illustrate the ideas of engineering problem solving concepts using web-based materials. This example considers a fluid moving through a pipe at a different temperature than the surrounding environment, and therefore exchanging heat energy with the surrounding environment.

Figure 1. Problem Statement of Heat Transfer Scenario.

Problem Statement: "Hot water at temperature T1 flowing through a stainless steel pipe whose inner diameter of d and a thickness of t1. The pipe is to be covered with fiberglass insulation that has a thickness of t2. The ambient temperature is T2. Taking the heat transfer coefficients inside and outside the pipe to be hi and ho, respectively, determine the heat loss per unit length of the pipe under steady flow conditions." Additionally, a general diagram of the situations is provided, and a set of values for each

of the problem variables. These values are generated randomly to provide each student with a unique learning experience every time.

Engineering is practical and this is an example of loss from a hot water pipe in a house. There is only one added level of complexity that may not be seen in this situation which is an insulation layer to assist the maintenance of the thermal energy within the pipe. This is a very common situation in most buildings including homes, so the relevance of the problem easily analogues to a scenario one has already encountered or easily imagines (Cengal and Turner, 2001).

Since the cross-section in terms of temperature, the next important numbers are the physical dimensions of the pipe: 1-2 cm inner diameter and a wall thickness from 0.3 to 1.5 cm. The final varying value in this problem is the insulation thickness, which will be 0.5-2 cm. Having the wide range of values for each of the parameters allows each student to work a different numeric problem. Lastly, the two static values are the heat transfer coefficient through stainless steel is 15 W/m^2/^{o}C and for the fiberglass insulation the value is 0.038 W/m^2/^{o}C. Based on the previously stated information a main page can

be created using HTML and JavaScript, as shown in the Figure 1. For the complete problem set go to the URL:

http://www.eng.usf.edu/~cular/interactive/trial/example1frameset.htm.

Performing an engineering analysis of the system described in the problem statement, the first questions that need to be asked are general and help to develop the necessary mathematical expressions. For the very first question, the student is asked to define the individual resistances of the problem, which are: the inside film, pipe wall, insulation, and outer film resistance. Note that the reason for calling the different portion of the system as resistances is two fold. First, the transfer of heat is not perfect and some is lost in the material, and second, because the materials have set losses, they can be modeled as electronic resistors.

The next step is to figure out the engineering assumptions that can be used to keep the system valid, and make our lives as easy as possible.   The first assumption that is made is the system is at steady state because there is no information given in the statement that can direct the problem otherwise. Next, the transfer of heat is only in the radial direction as there is symmetry about the center of the system. Third, thermal conductivities are constant. Primarily these assumption fall into a category of "because there is no information given in the problem statement to infer otherwise." Some of the pertinent information that would not let these assumptions be valid for a final solution includes: no flow rates, no defined heat generation source, and no defined the length of piping. Lastly, the contact interfaces between the different fluids and materials are negligible in terms of the resistance. The justification for this is the coefficients already have such information contained. Second, since the values for the resistance of the pipe

and insulation vary so greatly, the result of adding a tiny specification will make only insignificant changes to this fundamental problem (Cengel and Turner, 2001).

After defining the values and assumptions, the next step is to calculate the individual resistances of the different components. The first resistances encountered are found in terms of the films created from the flowing fluid against the static pipe wall and insulation. Paying close attention to units, the solution can be found by merely taking the reciprocal of heat transfer coefficient times the area exposed. Because the length of pipe has no been given, the calculation is based on one unit of length on pipe.

The second type of resistance found in this problem is the pipe wall and insulation. These resistances are slightly different from the films. For this calculation, the natural logarithm of the outer divided by the inner diameter is divided by twice the product of pi times the heat transfer coefficient of the pipe.

Finally, the total system can be looked at as a whole. To find the total resistance, the individual resistances are simply added together, and the final solution to the problem, the heat loss can be found. This is done by dividing the difference of hot fluid temperature and outer cool fluid temperatures by the total resistance.

Chapter 5:

Description of Software

We have considered the design of a web-based problem solving software from the two points of view: students and instructors. By breaking the description into two categories, it is easy to show how all aspects fit together. A top down perspective is taken for this description of software, as by first seeing what the desired result will resemble, the details of the designing and programming fall into place.

5.1 Students

The primary goal is to develop an interactive system that is capable enough to captivate and motivate students while assisting them in their studies. In learning and developing engineering skills, students solving interactive web-based problems have many features to work with such as: incentive scoring, progressive help, links to related information, and randomization of variables.

Figure 2 below shows the typical screen as seen by a student starting a problem solving session. It has the following features:

- Problem description: A general description of the engineering scenario including a diagram to assist in understanding the problem.

- Random variables: Variables are generated randomly for each session to ensure different numerical solutions.

- Links to relevant information: links to self generated web pages or to any other site may be provided to get the point across.

- Score table: real time scoring of the student's progress is tracked and displayed to motivate the student.

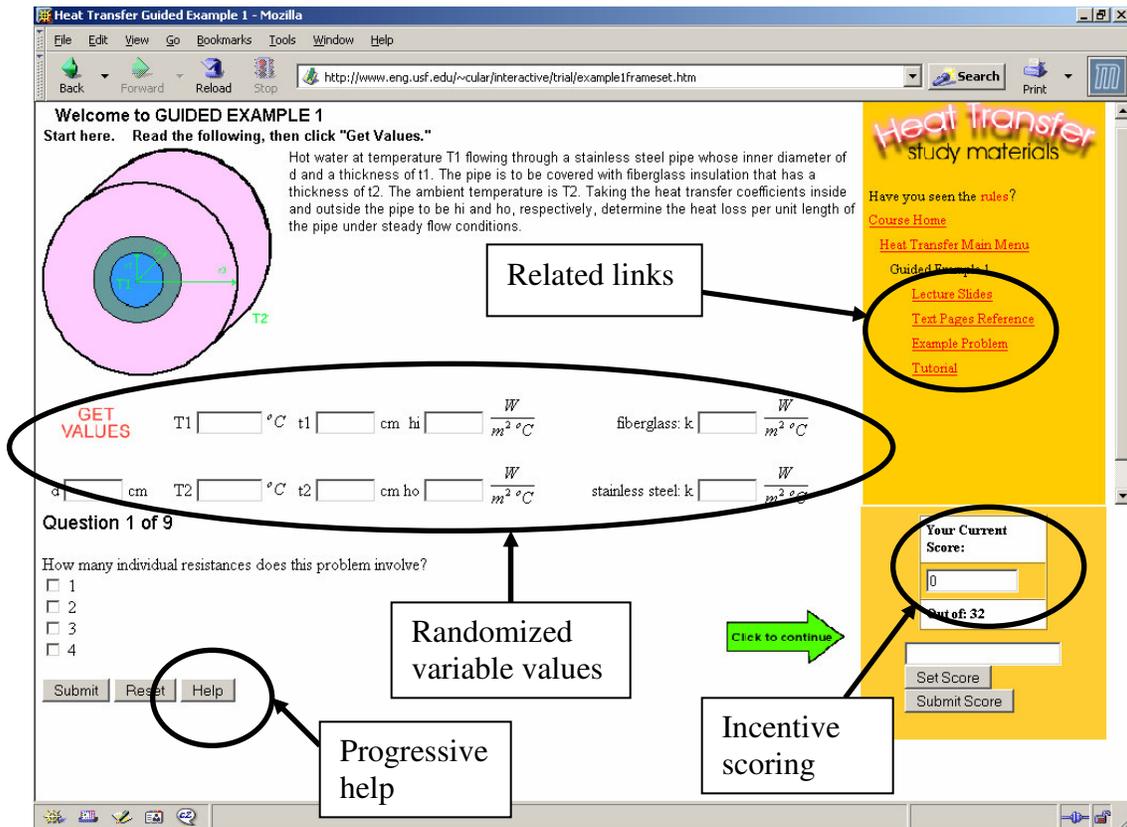- Help button: provides a quick method to obtain relevant problem specific help.

Figure 2. Complete Example of Interactive Web Page.

5.2 Scoring

Previous attempts to study the role of online instruction have shown that students are not motivated to solve problems unless there is some incentive. Sometimes the simplest ideas are the best. In order to support our goal of motivating and assisting undergraduate students, one of the methods used is offering a reward for accomplishing the task at hand (Gagne et al., 1992). A number of different scoring systems were evaluated; one incentive scoring system utilized in this project is based on three tries and a total possible score of four points per question. After each attempt at an answer, a single point is deducted from the total possible. The more interesting portion of the grading is in the help system, which in itself is an interactive feature, and will be discussed later. Should the student take assistance from the help function for a particular question one point is deducted. However, after all attempts are made with no correct answer, the student will receive one point for taking the extra effort for trying. By grading in this fashion students are rewarded for both being able to answer the question individually and for acknowledging the need to find help when appropriate. Through the use of this system, students are motivated to continuing working a problem until they get the correct answer, which promotes learning from trial and error. This type of learning is invaluable and provides for a very thorough understanding of the underlying principles. For the complete scoring system see Table 1.

Table 1. Complete Scoring Scheme.

Guided Example Scoring				
Attempt	Correct without Help	Correct with Help	Incorrect without Help	Incorrect with Help
1	4	3	0	0
2	3	2	0	0
3	2	1	0	1
Total possible 4 points per question				

5.3 Questions

Guidance in problem solving takes on many different forms, with the use of interactive web pages, more can be given by means of directing a solution path. For this reason, questions of problem sets are structured to assist the students by addressing general multiple choice type questions about assumptions and critical general knowledge about the scenario. For example, see Figure 3, the first question of the heat transfer problem, where the student is asked for the total number of resistances. For numerical solutions, instead of giving multiple choice questions, a space is provided as shown in Figure 4, to encourage and allow the student to arrive at their own solution.

Figure 3. First Question in the Heat Transfer Problem Set.

Figure 4. Numerical Solution Question.

5.4 Help Function

Often times in the midst of solving a challenging problem some of the subtle hints well known by experience are hidden to students. This is a common source of concern, and can distract from the desired learning. Should the student be working the same problem in classroom there is the availability of the instructor to help clarify such issues, but for homework or self-paced learning scenarios students are on their own (Broadbent, 2002). When a student becomes stumped by a question from the interactive problem set, a help button is available. The help button provides access to instructor provided information, which can be in the form of an image, text, or hyperlink to another site. The general help file provided for the heat transfer problem described earlier is shown in Figure 5. One of our most recent developments is providing a multi-level help system. For this, a general hint is provided on the first use of the help button, and on subsequent uses, more in depth assistance is provided. The option to use the multiple help levels is for the instructor, at the time of creating a problem set.
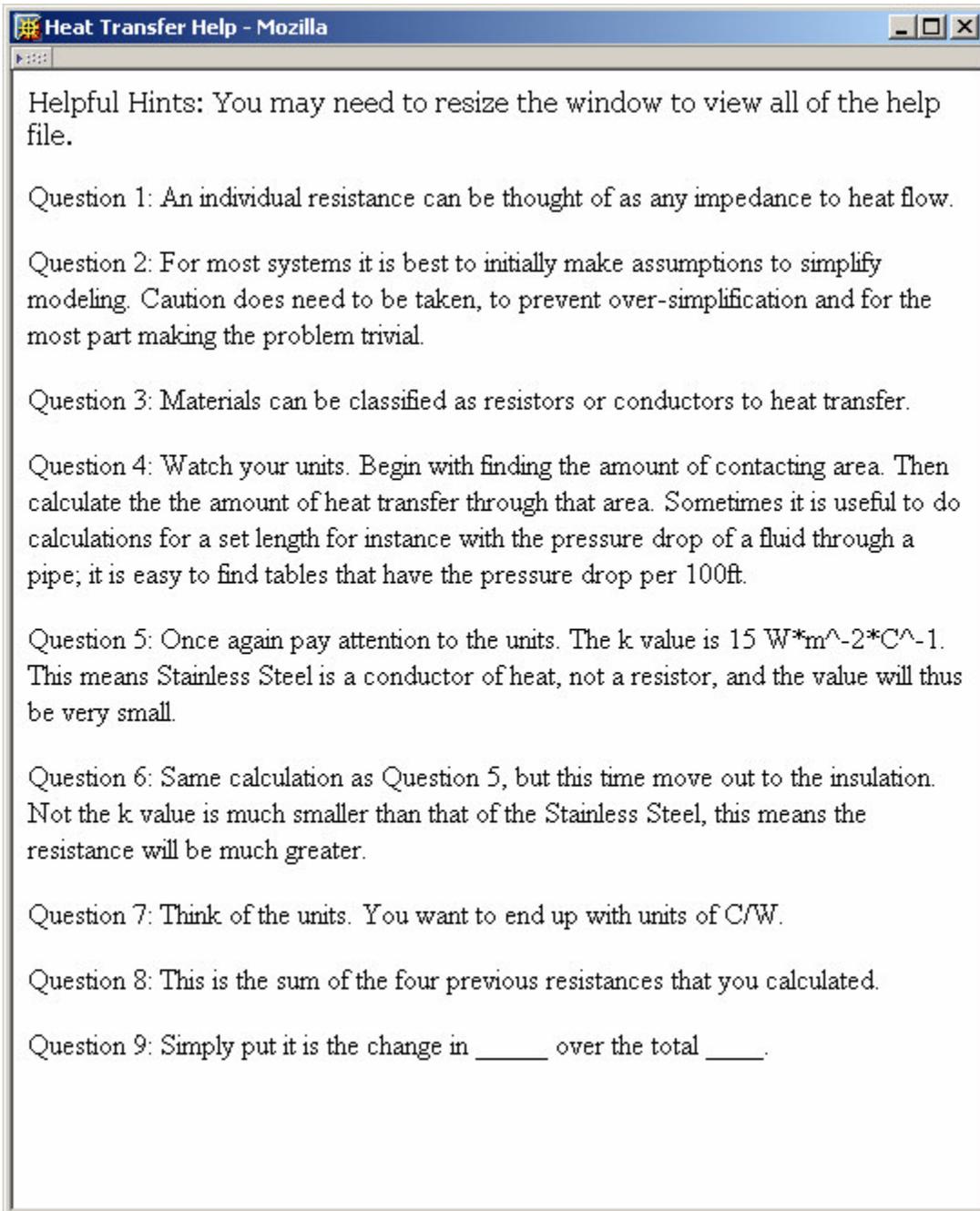
Figure 5. Displayed Complete Help File for Heat Transfer Example.

5.5 Randomized Variables

One significant feature of this tool is the ability to use randomized variables while solving a problem. The ability to use random variables within a set range of numbers is very important; it allows students to work the same question a number of times never using exactly the same set of numbers. But here we are not just providing a set of numbers. When the randomized values are displayed, the system also calculates the entire set of answers, thus allowing checking of answers computed by the student. By allowing students to work out the problem repeatedly, confidence is built (Gagne et al., 1992) for a complete example of a problem solving exercise, go to the URL:

http://www.eng.usf.edu/~cular/interactive/trial/example1frameset.htm.

5.6 Other Features

The most common and useful feature of any website is the ability to link to other pages including web sites that you have not created. With the templates provided, a general location for links is provided. At the time of writing the problem, links can be placed on the web page to allow easy access to a directed site.

5.7 Instructor

On the other side of learning are the features that allow the instructor to do their job, which is to teach. The best way to do this is to spend as much time as possible with every student answering as many questions as possible. For this to work however, it is necessary to have the students prepare and practice. In order to assist the instructor in reducing this burden, web pages can be created that address many of the most common

situations.   A web based solution provides many desirable features.   The only disadvantage here is some of the most desirable features for students and instructors take time to develop and implement. To facilitate the creation of problem solving tutorials we have created a set of simple forms and templates.   It is possible to create a fully functioning website using these templates with a minimal investment of time and effort on the part of the instructor.

We have used many proven tools such as: HTML, JavaScript, Perl, and Matlab to accomplish this task. By using these tools, we have been able to create a robust structure that is simple to use and allows for a maximum flexibility to meet individual instructor's needs. The first part of the tool that an instructor is acquainted with is the general format of the problem sets. As shown in Figure 2, there are separate sections for: the problem statement, randomized variables, links to general help and references, questions, and the score. Each one of these sections has been tested and at this point has been successfully used. Following the general formatting enters the programming of each problem and its associated questions.   The general templates and forms are available at the general development page: http://www.eng.usf.edu/~cular/interactive/development.html   From this page all questions are created by simply filling in the blanks. The problem statement can be created by using a general HTML editor and filling in the provided template as depicted by Figure 6. Once the page has been created, the entire problem set needs to be stored in one location. Following the hierarchy provided with the templates, all data will be stored in one location, where it can then be made fully operationally with the required script files. By limiting the access to the script files, a level of security from reverse engineering is maintained of all problem sets that are available.
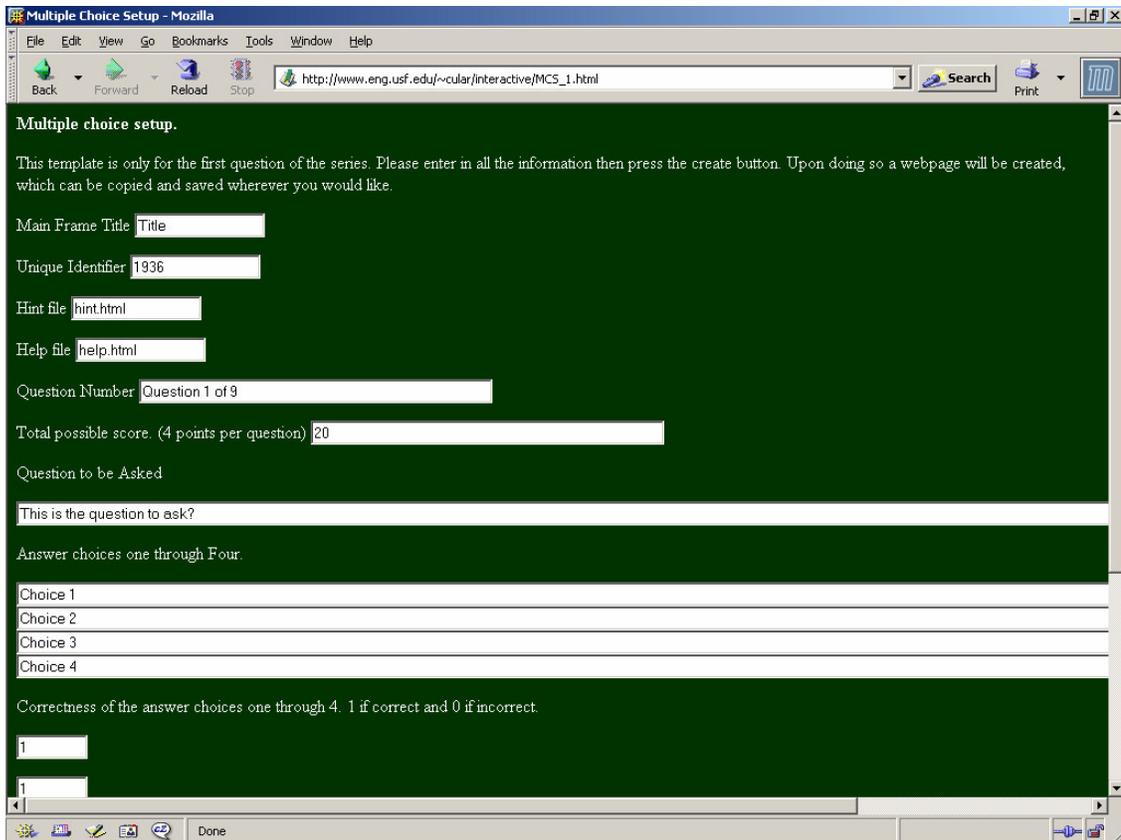
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Figure 6. Fill in the Blank Template for Creating Interactive Web Pages.

Chapter 6:

Testing the Tool

The final component of this work was the evaluation of the interactive web based problem solving that was designed and implemented. Initial testing was done with selected undergraduate students to identify issues with the implementation. Through a spiral loop control scheme as described previously in Chapter 4 these improvements were implemented as the issues were identified. Upon completing the implementation, a preliminary test was conducted to measure the impact on students' learning. This initial evaluation is described in this chapter.

Evaluating data can be done in a number of different ways. For example, in a jelly bean factory the overall output can be measured by the total weight of jelly beans produced, the total number of jelly beans produced, or more specific amounts sorted by color and flavor. Unfortunately when the data involves a persons' response there is a difficult task of weighting each statement, based on the feelings the person had that particular day. Complexity to the data is further added because there is not a clear-cut standard reference; only a small sample size; and a lack of available data for validation (Lewis, 2001). For these reasons and many more, the data presented should only be taken as a first data set and not the unmistakable truth.

After the initial testing/implementation period, the course chosen to asses the work created was Introduction to Automatic Controls, a typical junior/senior chemical engineering course. Four problem sets were created and implemented by Endinzo Iglesias, under the supervision of Dr. Babu Joseph, instructor for the course. The complete evaluation configuration for this class was as follows:

- The 43 student class was divided into two self selected groups at the time of registration of 21 and 22 members.

- During the first month of class all students were given traditional paper assignments. A midterm examination was given and verified that both groups had an equivalent understanding and ability of the subject by mean scores of the test.

- The following two weeks, Group I worked with paper assignments on subject A and web-based assignments on subject B. Group II did the opposite.

- During the subsequent two weeks, the groups switched to the opposite: Group I did the web assignments on subject C and Group II did paper assignments of subject D.

- At the end of the month another midterm examination was given to evaluate the performance of the two groups in each subject.

For the given number of students, the recommended significant level of a response as given by Lewis (2001) is a minimum of 63.9% of the entire class. Due to the larger than normal class size, the evaluation data of the web assignments was more effectively done; however, there is still the uncertainty from not comparing results from

different classes and instructors (Lambert et al., 1996). For this reason, the analysis of the interactive web exercises was based on two perspectives.

First the overall outcome of the course by means of a standard examination from the instructor's point of view. The Introduction to Automatic Controls class of 43 students showed 63% of the students increased their class average while working with web-based problems. The remaining 37% decreased their score. As mentioned previously the significant level of a response within this class size is 63.9%, considering the fraction of a percent is based on a fraction of a student, there is reason to believe the results as being significantly beneficial. Shown in Figure 5 are the scores of the top 25% and bottom 25% of the class. The significance of using web exercises is shown by both the top and bottom 25% of the class increasing ~9% on there examination scores.
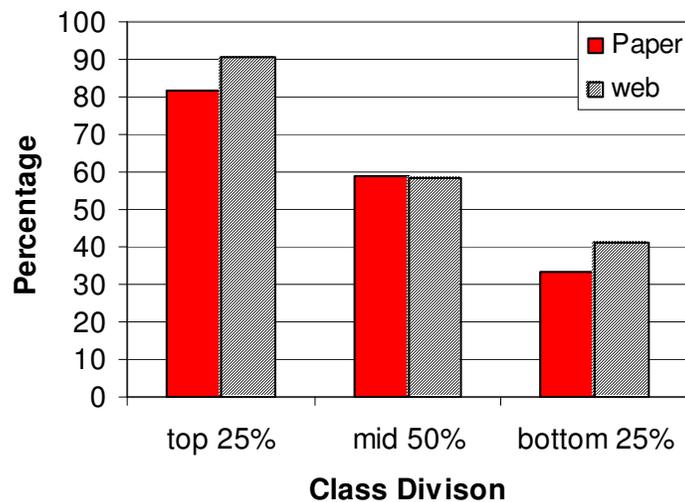
Figure 7. Graphical Representation of Examination Scores After
Paper and Web Exercises.

The second perspective used to evaluate the effectiveness of the interactive web-based problem assignments was the students' input. This portion focused on the

usefulness of features, availability of help, ease of use, and overall impressions in comparison to paper assignments. Represented in Table 2 are questions and averaged numerical responses to a survey conducted at the end of the semester. Again for the given class configuration the statistical evaluation is particularly difficult because there is only one data set to work. Therefore any conclusions are only to represent a possible trend. Once more data is available, a more thorough analysis will be done. In this more advanced analysis, the data collected will be analyzed in with two more dimensions. The first will be a pooling of all data into one set to provide an overall picture to help minimize the effects of students' are having previously taken different courses. The second important variation will be a comparison of data set to data set to compare effectiveness through different classes of students. From this confidence intervals of 95% can be used to mathematically show relevance of web-based instruction.

Table 2. Student Response at End of Evaluation.

Survey of students on Web-based Problem Solving Tutorials Results	Average
30 Students Responded	
5. Strongly Agree 4. Agree 3. Neutral 2. Disagree 1. Strongly Disagree	
I prefer Web-based problems sets over paper based assignments,	3.6
I learned more from paper-based problems sets than web-based assignments:	3.4
The help features of web-based problem sets, allowed me to tackle the problem better	4.0
Web-based assignments were difficult to access	2.1
My performance in the course suffered because of the web-based assignments	2.5
Web-based assignments forced me to review my course material	3.1
I liked the fact that I got immediate feedback on whether I did the problem correctly	4.5
I think I got a fair score in the web-based problem sets	4.1
The web-based problem sets took much longer for me to complete	2.0
The web-based problems sets prepared me better for the assessment quizzes and mid-term tests	2.8
The web-based problem sets motivated me better	3.3
In the future I would prefer to use paper based homework problems	2.7
My performance in the course improved because of web-based problem sets	3.0
I did not like the grading system used in web-based problem sets.	1.7

Chapter 7:

Conclusion

"The important thing to understand is that students learn and understand in many different ways" (Lambert et al., 1996). The evaluation of this project's interactive web-based problem solving tool as taken from the Introduction to Automatic Controls has shown potential advantages of many features. The data shows that using new technology to assist students with problem solving skills can be beneficial. The direct result of this project consists of created forms and templates to allow instructors easier use of web-based tools for problem solving assignments. The added benefit given to the instructor is a fuller experience for the student without exhausting valuable time. Additionally, content once uploaded to the internet does not need to be reproduced with different values from year to year. All components of this project have been tested both by instructors and students. The current data shows encouraging results to pursue this topic further.

Although there is still a learning curve for the instructor in creating problem sets for the web-based assignments; many of the painful details have already been worked out. The one disadvantage to using this tool for more assignments that has been pointed out a number of times from both students and instructors is the added time to create a complete problem set with all of the help files, and links to relevant information. The

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initial time that is required to implement this tool is offset by not having to recreate new problem sets each time a course is taught, having immediate automatic grading for both the student and instructor, and ease of dissemination. So far the novelty of using the web to solve interactive problems has proven to be a motivation in itself that has shown a promising trend to improve the understanding of a subject by students. Basic studies comparing the use of traditional coursework to interactive technology have shown that the learning is comparable. As a final comment on the direction of interactive teaching, there is a need to experiment with different ways of learning and teaching. Ultimately, it is the instructor who decides what and how a student learns in a particular course.

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