The Design, Development, and Assessment
of the Vibrating Beam Experiment
Multimedia Instructional Courseware

by

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1.0 Introduction

Innovative teaching materials and methods are currently being developed by the University of California at Berkeley in collaboration with our partners in SYNTHESIS: An Engineering Education Coalition. SYNTHESIS hopes to revitalize engineering education and improve student learning, which can be enhanced by introducing new information and computer technologies into the classroom. One of SYNTHESIS' major curricular goals is to assist students in 'synthesizing' information — integrating theory with application and integrating the real world with the engineering education.

The ***Vibrating Beam Experiment Instructional Courseware*** (Version 1.0) is one method developed at the University of California at Berkeley to assist the students' integration of seemingly disparate information into a cohesive structure. The *Vibrating Beam Experiment* is one of four in a senior-level, mechanical engineering, Experimentation and Measurement class (ME 107A) at the University of California at Berkeley. The experiment consists of a double vibrating beam apparatus that can be driven in either free or forced vibrational mode. The beams are instrumented with strain gauges, a linear variable differential transformer (LVDT), a voice coil/velocimeter and an accelerometer. The laboratory experiments are designed such that students are required to address open-ended problems by working in teams to integrate theory with actual system behavior. The ***Vibrating Beam Experiment Instructional Courseware*** provides a framework to understand the fundamental principles of the apparatus, theory, and lab procedures related to the experiment.

The courseware functions as an enhanced laboratory manual; it is a multilevel reference tool for the students. Students can use the ***Vibrating Beam Experiment Instructional***

Courseware as a reference source to prepare for the laboratory, to view instrument set-up and calibration videos, and as a post-lab analysis aid for writing laboratory reports

The Theory section provides students with the derivations and mathematical solutions for the physical models that represent the dynamic response of the apparatus in free and forced vibrational modes. It discusses the fundamental vibrational parameters (natural frequency, ringing frequency, and damping ratio) and develops the beam theory that relates local beam displacement to local strain. Students can access supplementary material within this section to help predict the dynamic response of a double guided beam such as the one they will work with in the laboratory.

The Apparatus section provides details regarding the instrumentation on the experimental apparatus, as well as videos and a description of the *Vibrating Beam Experiment* apparatus itself. Fundamental operation and calibration principles related to the instrumentation (strain gauges, linear variable differential transformer (LVDT), voice coil/velocimeter, and accelerometer) are provided in the courseware, along with practical information for use of the devices in the ME 107A laboratory at the University of California at Berkeley.

This report will examine the design process behind the development of the ***Vibrating Beam Experiment Instructional Courseware***. It will also present the results of our user studies to examine how the courseware addresses our pedagogical and design objectives.

1.1 Objectives

The overall goal of this project was to create a computer-based reference tool to assist students in conducting the *Vibrating Beam Experiment*. We developed a set of design and pedagogical objectives to guide our creation of the ***Vibrating Beam Experiment Instructional Courseware***, which are described below.

1.1.1 Pedagogical Objectives

Our governing pedagogical goal was to aid the students' ability to integrate and understand the multidisciplinary material needed to successfully complete the laboratory assignment. To meet this goal we designed the courseware to meet the following three pedagogical objectives. The courseware should:

1. Improve the students' understanding of the *Vibrating Beam Experiment* by providing a centralized source of the disparate information related to the experiment and provide access to a greater depth of material than is normally available to the students.

> In spite of the fact that this experiment has been conducted at the University of California at Berkeley for over ten years, we have not developed a comprehensive, central resource of information related to the apparatus and associated instrumentation. This experiment is particularly complex since the students are given an open-ended task that requires them to understand second-order dynamic response and beam theory as related to double-guided beams. The students work with four unique measurement devices to collect and interpret time-resolved data. The theory and procedures are presented in classroom lectures, but there is no separate laboratory manual. When students conduct the laboratory and have questions, they must rely on their lecture notes, which are not always useful. The courseware provides an enhanced, on-line laboratory manual.

2. Enhance students' physical understanding of the experiment before entering the laboratory by providing visualizations and simulations of apparatus use and laboratory procedures.

> The experiment is conducted over a three week period, yet students often spend the first week familiarizing themselves with the apparatus and associated instrumentation. We wanted to speed up this learning curve by having students view simulations of the apparatus and laboratory procedures before entering the laboratory. In addition, we felt that procedural videos would assist students during the laboratory when the lab instructor was unavailable.

3. Provide guided learning by allowing students to explore information at multiple levels (from fundamental principles to practical tips) without providing a 'cookbook' approach to conducting the experiment.

> In the past, students' desire for information related to the laboratory has varied from wanting basic procedural information to wanting complete theoretical details, including the mathematical solutions to the governing equations. Our objective was to provide the technical content to address these varying information requirements with the courseware. At the same time, we limited the 'cookbook' approach of explicitly stating the 'correct' laboratory and data reduction procedures.

1.1.2 Design Objectives

In order for us to reach our pedagogical goal, the computer-based instructional courseware must be designed for ease of use. To meet this design goal we designed the courseware according to the following three objectives. The courseware should:

1. Provide access to information through the careful design of the user interface and courseware structure.

The courseware was developed using hypertext and hypermedia (for our purposes we will use both terms interchangeably) to provide non-linear access to information. The use of hypertext allows students to choose their own path to information and to choose how much information they view. However, one of the most often cited problems with hypertext is the phenomena of ‘getting lost.’ (Bernstein 1991, Brooks 1993, Stanton and Baber 1994) To address this problem, the user interface can be designed to assist the user in orienting himself to the structure of the courseware. (Nielsen 1990) Another important factor is to assist the user in developing a conceptual map of the structure; this conceptual map allows the user to get an overview of the material. (Dillon, et al. 1990) The presence of map can allow the user to determine his position and how to access information within the courseware. (Stanton, et al. 1992)

2. Provide multiple navigation schemes to address the diversity of information retrieval styles.

“The allure of hypermedia for instruction lies in its ability to actively engage the student user in the acquisition of information, its ability to support multiple instructional uses . . . and its inherent ability to support different learning styles.” (Spoher and Shapiro 1991) Because the courseware can be used to accomplish different tasks (from pre-laboratory assignments to post laboratory data analysis), different navigation methods can improve the ease of information retrieval. For example, simple linear navigation can be useful when the user is attempting to gain a broad overview of the material. On the other hand a search feature or index page can be useful when the user is looking for a specific piece of information.

3. Provide a structure that assists students in seeing connections between the breadth of material in the courseware, while enabling easy access to a greater depth of material in all topics.

In order to meet the wide range of information demands for this experiment, we needed to provide both the breadth and depth of material. However, we did not want to overwhelm the students with an excessive depth of material nor did we want to require students to sift through multiple screens of related, but not centrally important, material in order to get to the most important information.

1.2 Previous Related Work

The Comprehensive Unified Physics Learning Environment (CUPLE) is being developed by a consortium of nationally-recognized leaders to produce a unified, modular framework for the instruction of Physics with software tools. The CUPLE project has three goals: (1) improve current teaching, (2) provide an environment in which innovative approaches can be developed and tested, and (3) provide a basis from which a new learning environment can evolve. (Wilson and Redish 1992) The software in the CUPLE system uses hypertext, computational tools, video, and data acquisition to provide a flexible, modular environment that can be used at any level the instructor desires. CUPLE provides material in conceptual, standard, and sophisticated levels to address the diversity of learning styles. CUPLE goes beyond the inclusion of basic multimedia (text, graphics, animations, video, and audio) by including "powerful problem solving tools for computation, the ability to acquire real data and real phenomena in real time, sophisticated programs for data visualization, and modeling tools." (Wilson and Redish 1992) CUPLE integrates theory and reference materials with activities including modeling, laboratory materials, and tools (data acquisition and analysis).

Whereas the CUPLE project provides a comprehensive learning environment for Physics including basic theory and data acquisition, the ***Vibrating Beam Experiment Instructional Courseware*** is designed to provide students with an enhanced laboratory manual. The courseware assumes a level of sophistication present in junior and senior level mechanical engineering students. The courseware is a reference to refresh students of the related materials from their disciplinary courses (e.g., dynamics, strength of materials, and basic electrical engineering) to perform the *Vibrating Beam Experiment*.

Video, sound, animation, multiple fonts, extensive graphics, color, and multiple layers of information are typical elements of a hypermedia document. However, it is just these elements that have led hypermedia documents to become "design nightmares — ugly screens full of multiple fonts, insignificant boxes, irrelevant noises, and confusing webs of possible interactivity." (Brooks 1993) It is up to us as the designers to "minimize clutter so that the document appears, feels, and ideally, is simple to use." (Brooks 1993)

In an attempt to create better hypermedia documents we investigated various 'best-practices' from the literature. Brooks (1993) sets out "four practical design goals for effective, usable hypermedia design:

1. Simplicity of design elements.

2. Appropriateness of the document to the organizational sponsor and the individual user's needs.
3. Function of the hypermedia document as an aid to information access.
4. Economy of effort, technological constraints, and financial resources necessary to publish hypermedia documents."

Additionally Brooks (1993) suggests the following design tips:

- Keep design elements to a minimum.
- Repeat the placement and format of major document-wide elements.
- Provide the user with multiple means of controlling his or her navigation through the document.
- Provide help explaining or showing how the hypermedia publication functions as soon as the user opens the document, and maintain access to help throughout the user's interaction. Give the user a forecast of how the hypermedia publication interaction will work.

Nielsen (1990) supports these design goals by arguing that "the differences in graphical design are intended to reduce the homogeneity problem in on-line text, which basically is that on-line text always looks the same." By designing an interface with distinctly separate screen regions for different tasks and being consistent in screen layout, color choice, and placement of major elements, we have followed the 'best-practices' set out in the literature.

Nielsen (1990) argues that the process of interface design is an iterative one. The designers constantly refine the design to better serve the user's needs and goals. This iterative design is one method to transition from the engineer's perspective to the user's perspective. Gentner, et al. (1990) argue that "a good engineer's [designer's] model of the system is based on the knowledge of the underlying mechanism, and therefore the interface most natural to the engineer is one that provides direct access to the control points in the mechanism. The user, however, is primarily concerned with the task to be accomplished, and a problem arises if the user's model of the task does not map cleanly onto the system mechanism." It is important that our interface and specifically our navigation methods allow the user to perform his task. The interface should "prevent users from getting lost, allow them to gain an overview of the material, and find specific information if it is present." (Dillon, et al. 1990)

2.0 Design Process

Before discussing the elements of Version 1.0 of the ***Vibrating Beam Experiment Instructional Courseware*** it is informative to understand the design process that was used to develop the courseware. We first present an ideal design process and contrast it with the actual development of the courseware. Then we present the results of our first experience in using the courseware with students; an experience that lead to fundamental changes.

2.1 Ideal Design Process

Drawing from current research and practice in product design and development (Anderson 1993), the ideal design process can be divided into the six phases presented in Table 2.1.

Table 2.1 - Ideal Design Process

	Phase	**Description**
1	Product Definition	Product specifications and resource prioritization
2	Issues	All issues raised and resolved
3	Concept	Optimized, simplified concept
4	Design	Product design thorough to minimize prototyping
5	Ramp-up	Smooth introduction into production
6	Follow-up	Post-mortem to capture the lessons learned

This model emphasizes the majority of work being done at the beginning of a project. In order to shorten 'time to market,' it is important to have a well-defined product in which all of the issues have been raised and resolved early on to 'do-it-right' the first time. Because product development should not be a linear process, a cross-functional team is used to allow the development to proceed in parallel paths by providing the input from the various groups responsible for the design, production, and delivery of the product. The product definition must produce a specification that reflects the 'voice of the customer,' to do so requires the input from many sources (e.g., engineering, manufacturing, marketing, etc.). Additionally the team should look at the required and available skills and resources necessary to produce the final design.

The product definition should be generic, functional, and free of concept choices (to avoid biasing the design). It should be should be frozen (finalized) as soon as possible in order to reduce the 'time to market.' Changes in the definition should be allowed only if the original product definition warrants them, and all schedule and cost ramifications have been considered. The team should identify potential problems and forecast any changes that might affect the product.

When the product is well defined and the team has resolved potential problems, the team should begin developing concepts. Concepts are methods of meeting the product definition. The final concept should be selected upon its ease of design and construction or innovation. The team may reduce the need for prototypes in moving from the final concept through detailed design to the final product by providing the input required to 'do-it-right' the first time. Good designs will ultimately reduce the required prototyping and beta-testing. As the product is pushed into full scale production, continuous improvement should be made to both the process and the product. Finally, a post-mortem analysis should be performed to evaluate the design process and the final design. By learning from each design, the team will be able to develop better products in the future.

2.2 Courseware Design Process

During the development of the ***Vibrating Beam Experiment Instructional Courseware*** the goal of creating an enhanced laboratory manual to assist students in conducting the experiment did not change. However, the way we utilized the hypertext environment to accomplish this goal did change. To focus on our customer, the student, we changed the way the material was presented and how the information was to be used. Instead of settling on one design and then developing it, we developed two major designs through an iterative design process. In both cases, we used student feedback in the form of surveys to refine each design. Table 2.2 shows the evolution and progression of the different versions the courseware during its development.

Table 2.2 - Courseware Development Process

Version	Semester	Courseware Development	Assessment & User-Feedback
Alpha 0	Fall 1993	General content set	Survey
Alpha 1	Spring 1994	Change in focus, new user-interface	
Beta 1	Summer 1994	Refinement of content and user-interface	
Beta 2	Fall 1994	Refinement of content and user-interface	Survey, On-line Audit Trail
Final Beta	Spring 1995	Usability and installation testing	Survey, On-line Audit Trail
Production	Spring 1995	Version 1.0 Release	

Each alpha version shown in Table 2.2 represents a different design based on different product definitions. Generally, design practice suggests the product definition should not be changed during the course of product development. The ideal process should instead identify the reasons for change and act upon them to ‘do-it-right’ the first time. However, our learning curve in hypertext design — our realization of more effective ways to meet our design and pedagogical objectives — required these changes. The original design did not meet our goals of improving understanding and access to information. We did not take advantage of the non-linear capabilities of hypertext to present varying levels on material nor provide suitable navigation schemes to help students access the additional information. When compared to the ideal case of ‘doing-it-right’ the first time, the change in product definition adversely affected the ‘time to market' of our courseware. In order to serve our customers, the students, the faster we can deliver the completed courseware the better.

In addition to the change in product definition, the tools and resources available also changed the direction of development (see Appendix A for the technical resources used to develop the courseware). The release of a new version of the authoring software allowed us to increase the interactivity and improve the user-interface. Also the technological resources required to use the courseware changed. Initially, the courseware was intended to be used in a specific multimedia classroom because of the hardware required to use the Digital Video Interactive (DVI) video format. In the late Spring and Summer of 1994, we made the decision to shift to a software-only video compression method. This change opened the potential to distribute the courseware directly to students via CD-ROM and the Internet.

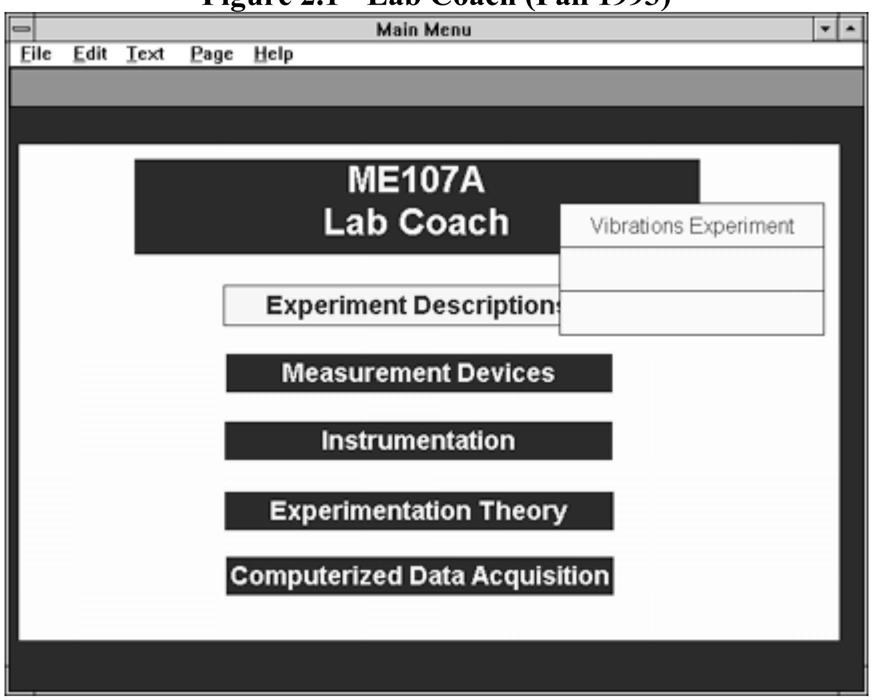
2.3 Original Expectations and Design

Because of the change in the context of use of the courseware, it is important at this stage to examine the original design and expectations, and discuss how results from this Alpha 0 version lead to the final design.

The original design, the *Vibrations Experiment*, that students used in the Fall 1993 was based on a lecture-model. The original, linear, 'page' based tutorial followed the same logical structure used during blackboard lectures. The tutorial was a constantly accessible version of the professor's lecture notes that could be used as a lecture-aid for professors or a study-aid for students. As a study-aid, the tutorial was a conversion from existing lecture notes to a hypertext, computer-based presentation of the material. The addition of a table of contents along with a drop down contents menu were the major improvements with the transition to a computer-based tutorial. There was very little additional depth of material such as extended derivations, videos, simulations, or animations, although the first version did include some additional material concerning the set-up and calibration of the instruments.

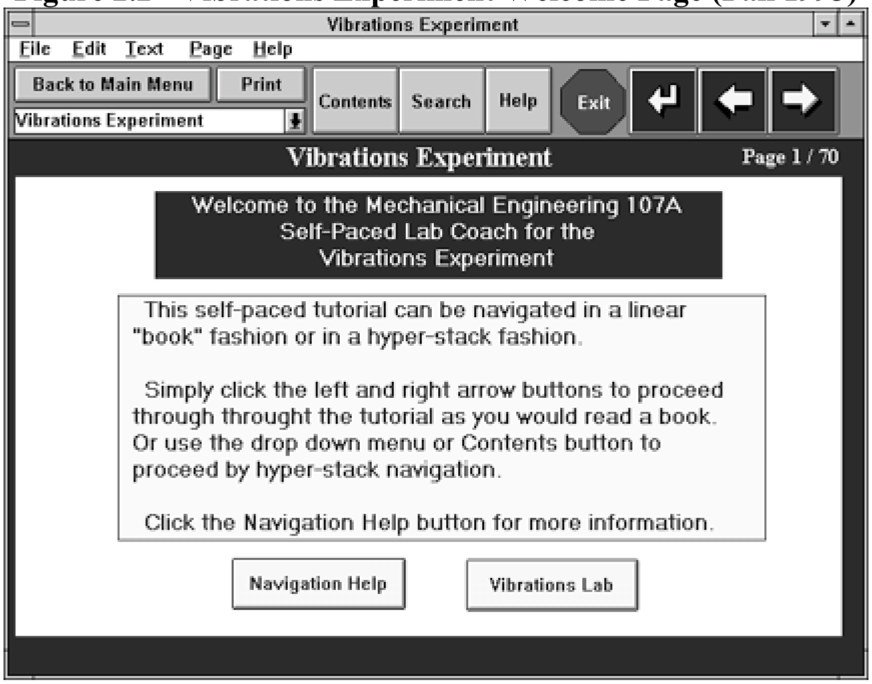
The Fall 1993 version is designed as a series of modules that are accessible through the *Lab Coach*. The *Vibrations Experiment* comprises one module of the *Lab Coach*, which is designed to cover the theory, experiments, and laboratory instrument bench in a typical experimentation and measurement course. By adding or removing information, the *Lab Coach* can be used in any laboratory at any school. Figure 2.1 shows the major topics in the *Lab Coach*.

Figure 2.1 - Lab Coach (Fall 1993)



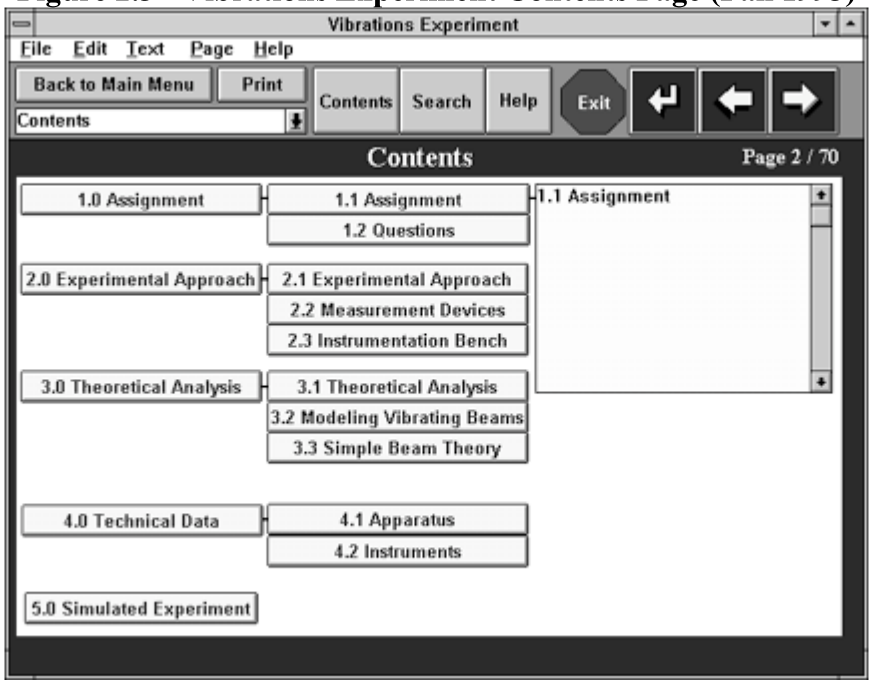
After selecting the *Vibrations Experiment*, the student is presented with the *Welcome* page in Figure 2.2.

Figure 2.2 - Vibrations Experiment Welcome Page (Fall 1993)



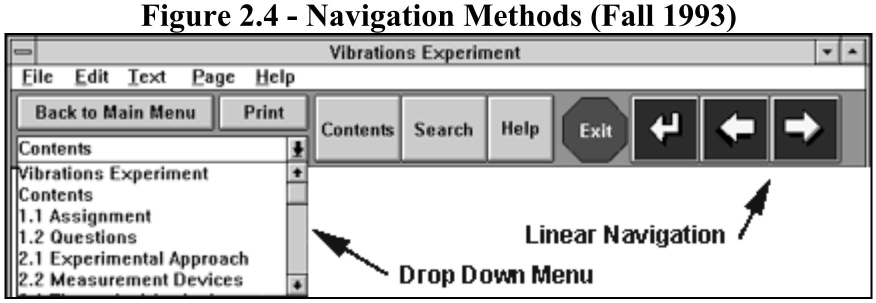
By proceeding to the next page, the student is presented with *Contents* page (see Figure 2.3) that shows the overall of the structure of the information, as well as access to each of the seventy pages of the tutorial.

Figure 2.3 - Vibrations Experiment Contents Page (Fall 1993)



The pages have a well-defined navigation area at the top of each page. The navigation methods (see Figure 2.4) consist of linear navigation (Next page, Previous page, and Back buttons), Search, Contents, drop-down menu with major headings, and a Back to the Main Menu button.

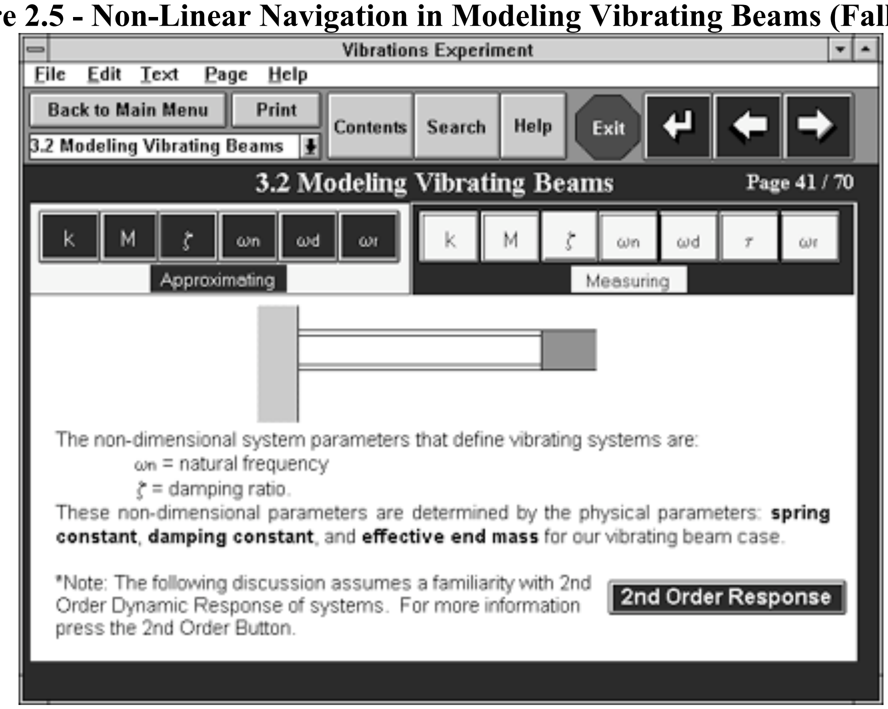
Figure 2.4 - Navigation Methods (Fall 1993)



The Next and Previous page buttons are used to turn the computer 'pages,' just as in a book. One benefit of this interface is its relatively simple and clean design. It should be easy for the user to understand the function of the buttons and the navigation scheme. The content is structured so each page contains one screen of information; there are no scrolling fields and there are very few hidden fields. So, much like the traditional blackboard lecture where the information is presented from one board to the next, the Fall 1993 version progresses from screen to screen.

We did experiment with one navigation method that departs from the blackboard's linear method of navigation. We added a non-linear capability to the Theory section, *3.2 Modeling Vibrating Beams*, with the addition of a button bar (see Figure 2.5). The button bar allows the student to access 'pages' describing the approximation and measurement of each of the model and vibrational parameters listed. Because these buttons appear on all of the pages of this section, the student is able to skip back and forth between measuring and predicting parameters.

Figure 2.5 - Non-Linear Navigation in Modeling Vibrating Beams (Fall 1993)



2.4 Results of Fall 1993 Survey

At the conclusion of the Fall 1993 semester, we conducted a user study in the form of a questionnaire to evaluate the usage and effectiveness of the tutorial using surveys. The survey consisted of Yes/No and Easy/Difficult questions and also asked for written input from the students. The survey, which can be found in Appendix B.1, and the actual results, which can be found in Appendix B.2, lead to fundamental changes in the courseware. The students indicated various weaknesses in the courseware that lead to redesigns of the navigation schemes, inclusion of additional depth of material, and a redesign in the organization of the material.

When asked to comment on the navigation scheme, students understood the function of the buttons (51 of 59) and found the tutorial easy to navigate (45 of 59). Despite this understanding, students still found themselves getting lost (15 of 59). Apparently the structure and location of the information were not clear to students. The students overwhelmingly used the Next and Previous buttons for linear navigation (42 of 59) as their primary means of navigating the courseware. This result is consistent with the lecture-model of the courseware.

The students recognized the lecture material for what it was, but they wanted this “additional source” of information to go beyond the material covered in the traditional lecture. The survey found that students wanted more depth in the tutorial (17 of 59) and wanted “extra description” (12 of 59) such as “more examples” and “derivations of equations.” The students recognized the potential of the medium; hypermedia can permit interactive simulations of the laboratory experience. The students can experience the lab in a “mock experiment” before actually using the real equipment. Students were also interested in information directly related to their lab. For example, students asked for information on "equipment setup," "information on how to calibrate the strain gauges and LVDT," and "videos using lab equipment."

The written comments support a re-examination of the content structure and information retrieval schemes. Students were interested in the "important" material and did not want to be bothered with extraneous material. They wanted to find prioritized information in "bullet" form and in "What's Important sections." The "bullet" approach may be a good method of reviewing material but is not necessarily well suited for an in-depth presentation of the material. They also wanted "quizzes" and "review pages" to help understand the "overall picture" presented in the tutorial.

3.0 Final Design

The major recommendation that can be drawn from the Fall 1993 survey is to improve the structure of the courseware by taking greater advantage of the hypertext environment, while providing multiple methods of navigation and providing additional depth of material. Within the new unified structure, we designed the user interface to support our design goals of improved information access and multiple navigation schemes. We examined and developed alternate methods of information retrieval that could parallel the students' needs. We also organized the courseware to contain additional depth of material, providing information not usually available to students conducting the experiment.

3.1 Structure

The Spring 1995 version of the courseware is still divided into two major areas, the Theory and the Apparatus sections. The courseware now uses graphical maps to provide the conceptual foundation for the courseware rather than relying on the table of contents as in the first version. Graphical maps have been suggested by many to be beneficial to aid users in their formation of a cognitive map. Hypertext is conceived of as an "'electronic space' which is represented in the form of a map and through which users navigate" (Stanton and Baber 1994).

For the ***Vibrating Beam Experiment Instructional Courseware*** the use of maps to lay out both the structure and control navigation is natural. The students perform the experiment in a physical location, the laboratory, where they have access to lab bench instruments (multimeters, oscilloscopes, and function generators) and the apparatus. A photograph of the actual laboratory, the *Lab Room* (see Figure 3.1), seems a natural metaphor to use for both the structure and navigation. "A metaphor provides a way of conceptualising an object or environment and in the information technology domain is frequently discussed as a means for aiding novices' comprehension of a system or application." (Dillon, et al. 1990)

The structure is divided into a five level hierarchy as shown in Table 3.1. See Appendix C.1 for the full hierarchy of the courseware. The *Lab Room* provides the highest level of orientation. The laboratory metaphor is further reinforced with the *Apparatus Map* and *Theory Map* at one level below the *Lab Room*. By using items (the apparatus and a blackboard) that the students are already familiar with, these Maps help to reinforce the structure that we have developed. From the *Apparatus Map* the student can access information on each of the instruments and from the *Theory Map* the student can access information on each of the major theoretical concepts.

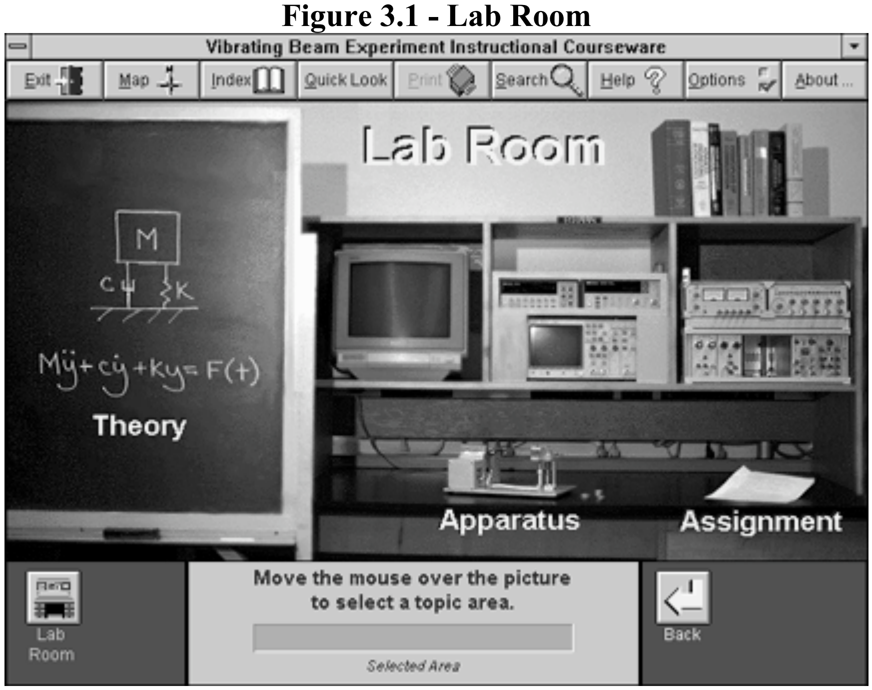
Table 3.1 - Levels in the Hierarchy

	Level	Example
1	*Lab Room*	*Lab Room*
2	Map	*Apparatus Map*
3	Section	*Strain Gauges*
4	Sub-section	*Strain Gauges in the Lab*
5	Page	*Strain Gauge Calibration Video*

3.1.1 The Lab Room

From the *Lab Room* (see Figure 3.1), the user is able to go to the main topics covered in the courseware: the Theory, the Apparatus, and the Assignment. The user can select a topic by clicking on it with the mouse very much in the same way the user can examine the apparatus by picking it up.

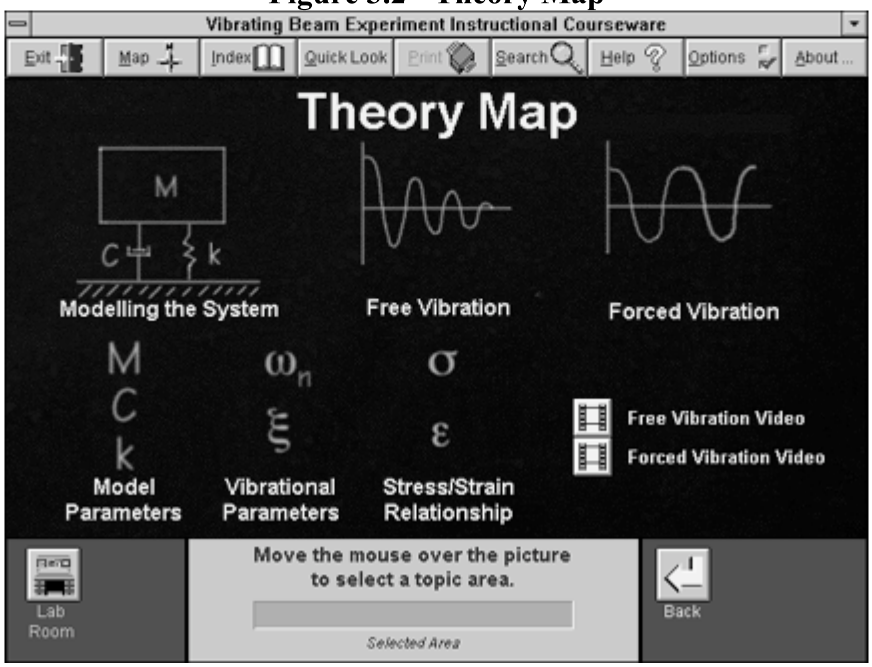
Figure 3.1 - Lab Room



3.1.2 Theory Map

In the courseware, the *Theory Map* (see Figure 3.2) is a 'virtual' professor that presents the theoretical background material. From the *Theory Map*, the user is able to find information on six subjects: Modeling the System, Free Vibration, Forced Vibrations, Model Parameters, System Parameters, and Stress/Strain Relationship. See Appendix C.2 for more information.

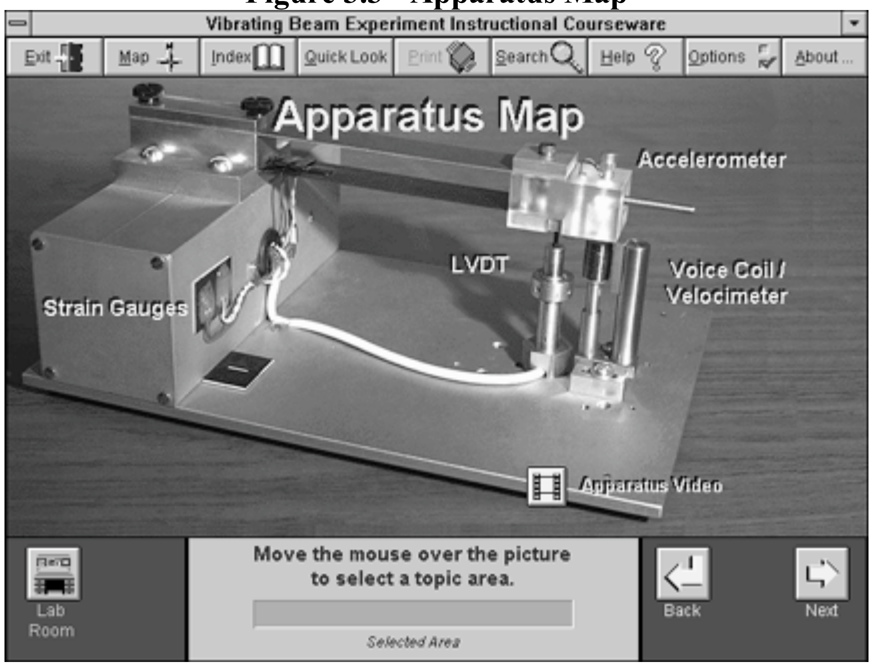
Figure 3.2 - Theory Map



3.1.3 Apparatus Map

Much in the same way that the *Theory Map* allows the students access to the theory, the *Apparatus Map* (see Figure 3.3) lets the students explore both the theory and operation of the measurement instruments attached to the Apparatus. The *Apparatus Map* is divided into four sections: Strain Gauges, LVDT, Voice Coil/Velocimeter, and Accelerometer. Each section is further divided into Sub-sections. See Appendix C.3 for more information.

Figure 3.3 - Apparatus Map



3.1.4 Assignment

The Assignment contains a copy of the assignment the courseware is designed around and can be updated by the instructor.

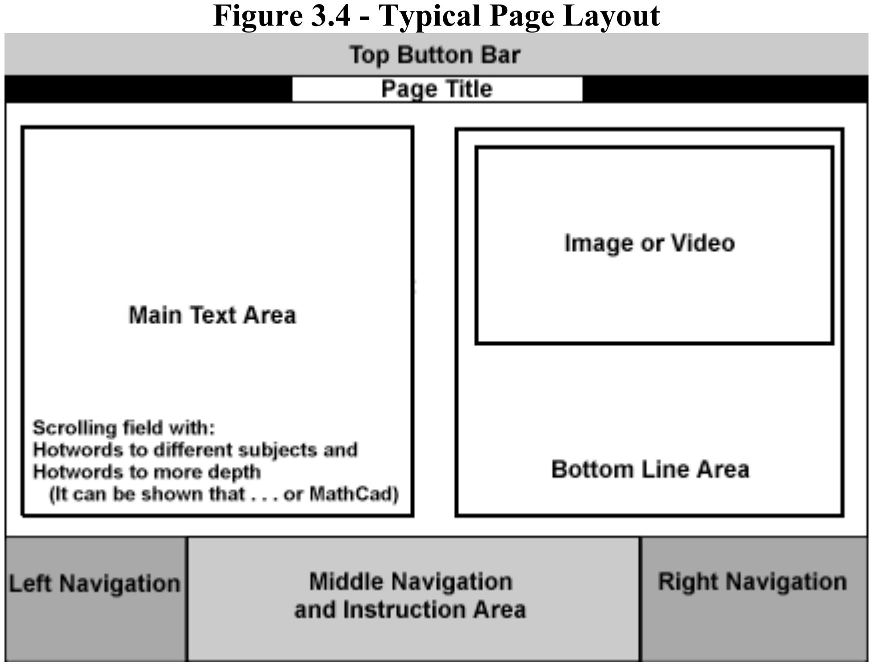
3.2 Content

The basic content (breadth) in the Spring 1995 version is nearly identical to the Fall 1993 version. The content is rearranged and combined in a slightly different way to improve the cohesiveness and facilitate understanding by the users. The technical content of the courseware is presented in greater detail in Appendix C. The new version includes additional information that is presented in a greater depth than is required to successfully complete the experiment.

3.2.1 Screen Layout

The screen is designed to facilitate the presentation of the breadth material while allowing easy access to the additional layers of information. A typical page is shown in Figure 3.4. We redesigned our screen layout from the Fall 1993 version. Instead of presenting material one screen at a time, we chose to divide the screen into two fields. The left field is a scrolling field that provides the basic content — text, equations, and links to additional material. The right field contains either images, videos, or a textual summary of the 'bottom line' of the text in the right field. At the top and bottom of each page are the navigation areas. Additional depth is provided through pop-up windows that overlay the main screen.

Figure 3.4 - Typical Page Layout



3.2.2 Main Text

The Main Text is the primary method of presentation in the courseware; it conveys the information required for a basic understanding of the theory and operation of the instruments and apparatus. The Main Text may contain Hotwords to other pages or to more detailed derivations through the *It can be shown that* . . . windows.

3.2.3 Bottom Line

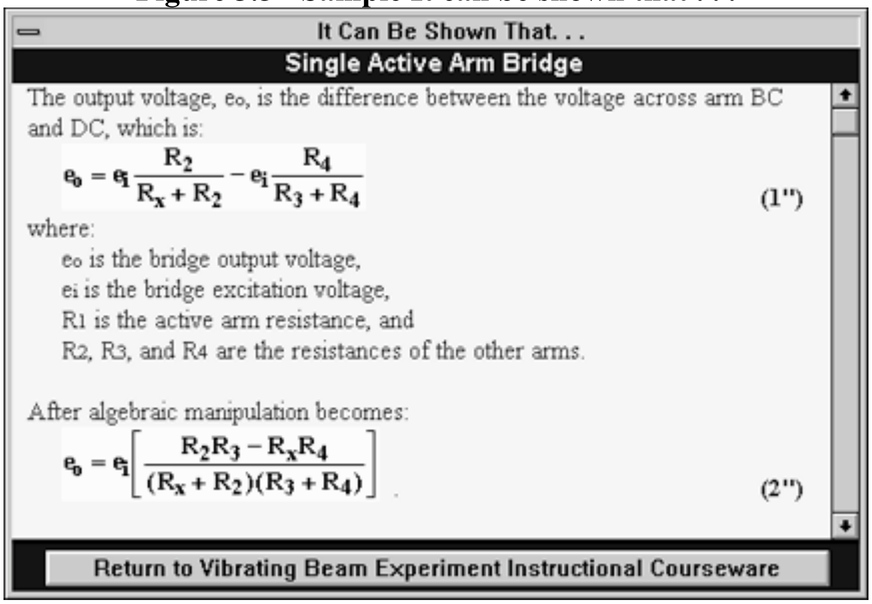
The *Bottom Line* is a compilation of the 'most important' information in the Main Text and is presented at the right of the screen.

3.2.4 It can be shown that . . . Windows

The *It can be shown that* . . . information contains in-depth derivations of equations and are shown in pop-up windows that are linked via Hotwords in the Main Text. The *It can be shown that* . . . windows contain the initial equations and assumptions necessary to derive the equations in the Main Text. The user is able to follow the derivation of the equation from start to finish. Because the user is required to actively select the hotword, he is able to decide for himself whether or not to view this "additional information."

Figure 3.5 shows an example of the information displayed when the user chooses an *It can be shown that . . .* Hotword on the *Bridges* page.

Figure 3.5 - Sample It can be shown that . . .



3.2.5 MathCad Documents

MathCad is a commercial product that describes itself as an "interactive math scratchpad"; it allows the user to input equations and performs the mathematical analysis. We have developed MathCad documents to allow the student to examine the effects of different vibrational parameters on apparatus behavior (see Appendix C.5 for a list of topics covered). Students are able to vary the parameters in the document to predict the vibrational behavior of the actual apparatus.

3.2.6 Depth of Material

The non-linear nature of hypertext also permits the presentation of material at varying levels of depth. The final design allows the user to choose his own path through the information and the amount of information he views. The varying levels of depth of material provide in-depth derivations for some and provide quick summaries to others.

There are five levels of material in the courseware. The Main Text and *Bottom Line* are the primary sources of information that provide both the basic understanding and a simple summary of the material. The *It can be shown that* . . . windows and the MathCad documents provide additional information that is available to the user if he chooses to view it. The *It can be shown that* . . . windows show in-depth derivations of the equations summarized in the Main Text. The MathCad documents allow the user to plot the theoretical response of apparatus behavior for varying vibrational parameters. Finally, the *Quick Look* (see Section 3.3) presents the material with a different organization that is geared towards quickly providing information to a user in the laboratory.

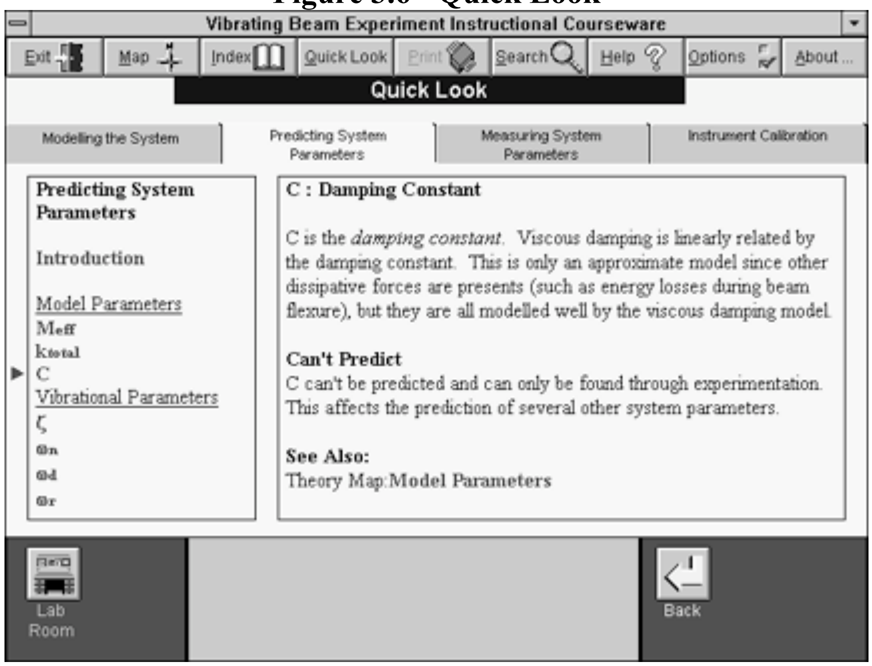
The depth of material is also designed to support the same users needs at different times. The Main Text, *It can be shown that* . . ., and MathCad documents are useful for a first, in-depth usage of the courseware. These sections are designed to provide the breadth and depth of information contained in the courseware. The *Quick Look* and *Bottom Line* are useful when the student revisits the courseware to review information.

3.3 Quick Look

While the *Apparatus Map* and *Theory Map* are designed to provide the user with a breadth of information, the *Quick Look* (see Figure 3.6) is specifically geared towards addressing specific tasks the user finds in the laboratory. The *Quick Look* is a different method of structuring the information as well as an alternative method of navigating the information. It is designed for students who are already familiar with the material; it is not meant as a stand-alone source of information.

The *Quick Look* contains the definitions, equations, and laboratory procedures for each of the major tasks that need to be completed during the experiment. The *Quick Look* is structured so that each tab contains a major task, which include: Modeling the System, Predicting System Parameters, Measuring System Parameters, and Instrument Calibration. See Appendix C.5 for a full content listing. While the *Quick Look* does not contain any new information, it is linked via Hotwords to the full development of the subject as presented in the main body of the courseware.

Figure 3.6 - Quick Look



By presenting the information by task (such as predicting the damping coefficient) we address the user comments from Fall 1993 that asked for the "important material" in "bullet" form that is specifically geared towards improving their performance in the experiment. While we do not use the *Quick Look* to provide a 'cookbook' approach to the user, it specifically integrates the disparate information to assist the student at performing the experiment more efficiently.

3.4 Navigation Tools

The navigation tools should allow the user to access the information contained within the structure described above. Navigation "has been highlighted as one of the major design issues in hypertext. Users get lost, users find it difficult to gain an overview of the information, users have difficulty finding specific information, and users ramble through the information in an unstructured way." (Stanton, et al. 1992) As described by Stanton, et al. (1992), navigation is more than just "where you are, where you want to be, how to get there, and how to overcome obstacles." We have developed six methods of navigation, the *Lab Room* and Maps, Bottom Navigation, *Index Page*, *Map Page*, Search, and Hotwords.

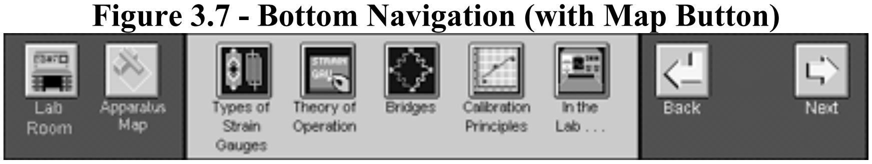
3.4.1 The Lab Room and Maps

The *Lab Room*, *Apparatus Map*, and *Theory Map* are more than just a structural representation of the hierarchy; they are an integral part of the navigation scheme. (Stanton and Baber 1994) The *Lab Room* and Maps combined, function as a table of contents allowing the user access to the two highest levels of the hierarchical structure (see Table 3.1). The student is able to select a topic (Map) from the *Lab Room* and is then taken to the corresponding Map. From that Map, the user can select a Section for further examination.

3.4.2 Bottom Navigation

In most cases the user changes navigation schemes once he leaves the *Lab Room* and Maps; the user typically uses one of the Bottom Navigation schemes (see Figure 3.7) when he enters a Section.

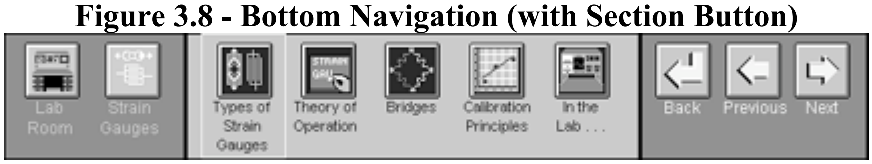
Figure 3.7 - Bottom Navigation (with Map Button)



As its name implies, the Bottom Navigation is present on every page of the courseware at the bottom of the screen. The Bottom Navigation consists of three separate sections: Left Navigation, Middle Navigation, and Right Navigation boxes (see Figure 3.4).

The Left Navigation box contains three types of buttons, of which two are visible at any given point in time. The first button, which is always present, is the *Lab Room* button; this button allows the user to go to the *Lab Room* (top level of the hierarchy) at any point in time. Because of design limitations, the second button is either a Map Button or a Section Button. The student can navigate up one level in the hierarchy with this second button. This difference can be seen between Figures 3.7 and 3.8. Figure 3.7 shows a Map button (*Apparatus Map*) and Figure 3.8 shows a Section button (*Strain Gauges*).

Figure 3.8 - Bottom Navigation (with Section Button)



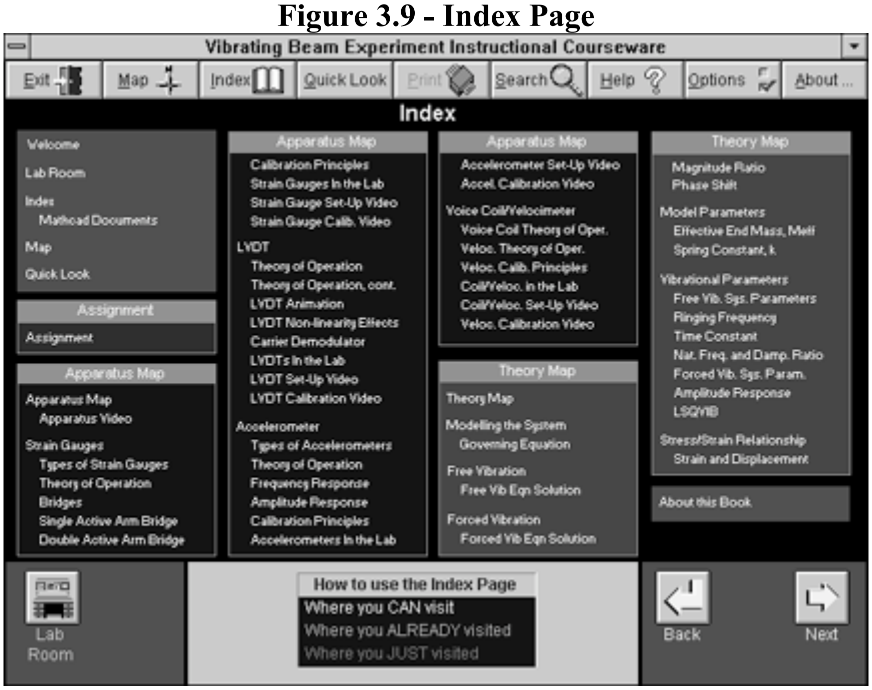
The Middle Navigation box contains buttons allowing the student to navigate among the Sub-sections if any exist (not all Sections have Sub-sections). The student can see the structure of the content each Section. Additionally, a box is used to highlight the current Sub-section allowing the student to see his position in the courseware. In Figure 3.8 the box is highlighting the *Types of Strain Gauges* Sub-section.

The Right Navigation box contains linear navigation buttons. It has a Next page, Previous page, and Back buttons; these buttons form the standard navigation buttons in most hypertext systems. The user can navigate through the information in a linear fashion making the courseware essentially an 'electronic book.' To motivate the student to navigate and explore the information in the courseware, the student is not allowed to turn 'pages' of the courseware from front to end. The student cannot use the Next or Previous buttons to transition from one Map or Section to another. He must either go up the hierarchy, to the *Index Page*, to the *Map Page*, or to the *Quick Look* to navigate further.

3.4.3 Index Page

The *Index Page* quickly turns into the navigation method of choice for most students because it allows access to every page in the main body of the courseware (see Figure 3.9).

Figure 3.9 - Index Page

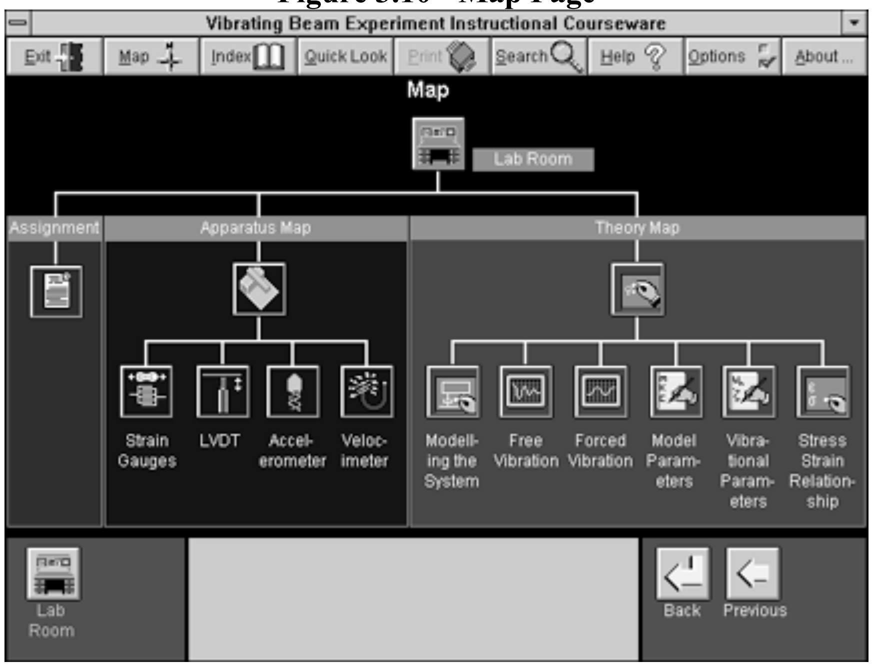


It is designed for use after the student has become familiar with the courseware. The *Index Page* is divided by Map and Section and it has tabbed entries to show the overall hierarchy. One especially useful feature is that the courseware programming keeps track of the pages visited in the current session. The student is able to see what pages he has seen already, the pages he has not seen yet, and the page that he was just on.

3.4.4 Map Page

The Map page (see Figure 3.10), added for the Spring 1995 semester, is a different visualization of the hierarchical structure of the courseware. It allows access to the *Lab Room*, Maps, and Sections. It is meant to serve as an aid to those students that want to see the underlying structure.

Figure 3.10 - Map Page



3.4.5 Search

User feedback from the Fall 1993 version indicated that a number of students (10 of 59) used the search feature. A simple text search feature is retained in the final design. The search feature allows the student to find specific words if the information is held within a visible text field on the page.

3.4.6 Hotwords

Hotwords are contained in the Main Text and allow the user to follow a thread of information from one page to the next. There are two types of Hotwords used in the courseware. The first is a simple link between related information on different pages.

The second forms part of the additional depth of material in the courseware. The *It can be shown that . . .* Hotwords provide additional information on the derivation of the equations presented in the Main Text.

4.0 Analysis of Courseware Usage

We collected information in the form of surveys and on-line usage logs to evaluate navigation patterns and student perception about the material presented in the courseware. We will examine the usage in terms of our pedagogical objectives: improving student understanding by providing a centralized source of information, providing guided learning opportunities instead of a 'cookbook' approach, and providing visualizations of apparatus use and laboratory procedure. We will also examine the usage in terms of our design objectives: improving information access, providing multiple means of navigation, and providing varying levels of material to appeal to different users.

4.1 Data Collection Methods

In order to collect data to analyze the navigation patterns and evaluate the depth of material we considered the following methods of data collection: evaluation by 'experts,' user survey, user interviews, protocol analysis, and navigation usage logs. Loo and Chung (1991) examined numerous previous studies aimed at evaluating and analyzing navigation patterns in hypertext documents and concluded "that the survey method and the audit trail capturing methods are most widely employed in the study of navigation in hypermedia systems." The results from our usage surveys and navigation usage logs are used as the two data sources for our evaluation of the ***Vibrating Beam Experiment Instructional Courseware***.

4.1.1 Survey

We designed our survey to collect a wide range of information including: navigation methods, content quality and accessibility, lab preparation, motivation, and overall effectiveness. The survey uses a 1 (low) to 5 (high) scale with 1 being Not at All, 3 being Sometimes/Somewhat, and 5 being Quite a Bit/Very. The survey was redesigned from the Fall 1993 version to the Fall 1994 version. The new survey design also includes a section that is customized to include questions about the pre-laboratory preparatory exercises (homework questions) and the laboratory assignment. The Spring 1995 survey also included an additional section on student motivation. The Fall 1994 and Spring 1995 surveys and actual results can be found in Appendices D and E respectively.

4.1.2 Navigation Audit Trail

We have implemented navigation audit trails to track the 'individualized' nature of each student's exploration through the courseware. A navigation audit trail is a usage log that tracks the progress of the student through courseware. We will use the navigation audit trails at a high level to examine the overall usage patterns, as well as how users take advantage of the varying levels of depth of material.

The Fall 1994 and Spring 1995 versions of the ***Vibrating Beam Experiment Instructional Courseware*** are programmed to write navigation audit trail logs for each student. The navigation audit trails capture information on what pages the student uses and how the student leaves the page; by leaving the page we mean going to a different page or going into more depth (MathCad documents or *It can be shown that . . .*). Each entry comprises one line of the usage log. The usage logs provide us with information on the overall use duration, the duration per user, duration per page, types and number of pages visited, and navigation tool usage. Table 4.1 shows a sample tabulated Navigation Audit Trail.

Table 4.1 - Sample Tabulated Navigation Audit Trail

Page Name	Date	Enter Time	Leave Time	Duration (min.)	Button Used to Leave the Page
Welcome 00 0	11/3/94	11:39:44	11:40:06	0.37	Index
Index 00 0	11/3/94	11:40:06	11:40:15	0.15	Home
Lab Room 00 0	11/3/94	11:40:17	11:40:26	0.15	Theory
Theory Map 00 2	11/3/94	11:40:28	11:40:44	0.27	Determining System Parameters
Determining Sys. Parameters 25 2	11/3/94	11:40:44	11:41:16	0.53	Free Sys. Parameters 25
Free Vib. Sys. Parameters 25a 2	11/3/94	11:41:18	11:48:29	7.18	Forced Sys. Parameters 25
Forced Vib. Sys. Param. 25b 2	11/3/94	11:48:30	12:00:02	11.53	Exit

We compiled usage logs for each uniquely identifiable user (based on name and student identification number). For Fall 1994 we compiled 81 separate logs (over 10,400 total entries) and for Spring 1995 we compiled 39 logs (3,500 total entries). Appendices F and G contain the results of the Fall 1994 and Spring 1995 usage logs respectively.

It is difficult to accurately measure usage because it is possible for the student to stop interacting with the courseware without exiting the courseware. Because of the volume of entries — almost 14,000 total entries — we chose to only examine usage times greater than 10 minutes for inconsistencies. For each of these times, we included all entries that showed continuous usage and used two criteria to determine which entries to excluded from analysis:

1. when the student accesses a MathCad document and does not continue to interact with the courseware itself as shown by continued usage log entries and
2. when the duration is long and the user does not continue to interact with the courseware as shown by continued usage log entries.

4.2 Overall Usage

The overall usage of the ***Vibration Beam Experiment Instructional Courseware*** for the Fall 1994 and Spring 1995 semesters is encouraging. Table 4.2 shows the overall duration and access use for each semester as collected from the navigation audit trails.

Table 4.2 is divided into overall usage per semester and is then further divided by before and after the pre-laboratory assignment was due.

Table 4.2 - Overall Usage of the Courseware

	Fall 1994			Spring 1995		
	Overall	**Before 11/10/94**	**After 11/11/94**	**Overall**	**Before 3/3/95**	**After 3/4/95**
Total Users	81			39		
Total Use Duration (minutes)	10620.92	8970.73	1650.18	3545.48	1418.63	2126.85
Total Use Duration (hours)	177.02	149.51	27.50	59.09	23.64	35.45
Average Use Duration per Access (minutes)	40.69	44.41	27.97	43.24	41.72	44.31
Average Use Duration per Person (minutes)	131.12	110.75	20.37	90.91	36.38	54.53
Accesses	261	202	59	82	34	48
Average Number of Access per Person	3.22	2.49	0.73	2.10	0.87	1.23

The navigation audit trails show that there were 81 users in Fall 1994 and 39 users in Spring 1995. The navigation audit trails also show a major difference in the way each semester used the courseware. Additionally the data show that the Fall 1994 user spent significantly more time using the courseware than those in Spring 1995 (131 versus 91 minutes).

The overall usage patterns are dependent upon how the instructor made use of the courseware. The courseware contains significant content to allow the instructor flexibility in using the courseware as supplemental material for the experiment. In Fall 1994, the pre-laboratory assignment contained many theory-oriented questions that were directly addressed by the courseware. Because of the assignment's focus, the Fall 1994 users spent 49% of their time in the *Theory Map* and Sections and only 28% of their time in the *Apparatus Map* and Sections. In contrast, the Spring 1995 users spent 58% of their time in the *Apparatus Map* and only 25% of their time in the *Theory Map* because the pre-laboratory assignment was more laboratory oriented. Additionally, Spring 1995 users were asked if they planned to use the courseware after the homework was due to help write up their lab. The high rating of 3.77 combined with the audit trails that show 59% of the access after the homework demonstrate that the students were using the courseware to help them with their laboratory report.

4.3 Pedagogical Objectives

As can be seen in Section 4.2, the courseware received a fair amount of usage in both the Fall 1994 and Spring 1995 semesters. We used the results of the surveys combined with the navigation audit trails to examine how the courseware addresses our pedagogical goals. See Appendices D, E, F, and G for the full results of the survey and navigation audit trails.

Our main goal is to improve the users' understanding of the material by providing them with a centralized source of information that includes material in greater depth than was available in the past, and by encouraging them to explore the information to learn on their own. The surveys revealed that the users rated the overall effectiveness of the courseware as greater than average (3.66 and 3.69). Additionally, the students indicated that the courseware contributed to their understanding of the lab (3.69 and 3.15) as well as the homework (3.89 and 3.15). The ratings for these items are not significantly different, however we believe that the higher numerical ratings in the Fall 1994 are due to the increased usage of the courseware.

We wanted to encourage the user to explore the information and to draw conclusions on their own by providing them access to the information necessary to gain an understanding of the theory and operation of the apparatus. The results from the survey for both Fall 1994 and Spring 1995 are discouraging. In Fall 1994, the students were asked to rate the depth of material about the spring constant (2.87) and free vibration (3.10), topics they had to understand to complete the homework assignment. In Spring 1995, the students were asked to rate the depth of material about performing the calibration of strain gauges (2.46) and relating strain at the surface of the beam and the tip displacement (2.31), both were topics on their homework assignment. The low response in Fall 1994 and Spring 1995 show that the students were not satisfied with the information presented in the courseware, although we specifically provided sufficient information to answer the questions. The results from the Spring 1995 survey show that the users used the courseware because they wanted a better score on the homework (4.15) and on the Lab Report (3.77). One conclusion that can be drawn from these results is that the users were looking for an explicit presentation of the material that directly addressed the assigned questions. Alternately, we may not have presented the information clearly enough.

The courseware is intended to provide information not usually available in typical laboratory instruction. The usage of this additional material shows that the users were, by far, more interested in the practical tips and information contained within the *Apparatus Map* than they were with the additional tools to help them understand the theory such as the *It can be shown that . . .* windows and MathCad documents. Fall 1994 users spent 5% and Spring 1995 spent 27% of their time in the *In the Lab* sections, which contained instrument set-up and calibration information and videos. In contrast the users spent only 0.37% of their time in Fall 1994 and 0.05% in Spring 1995 in the *It can be shown that . . .* windows. The users spent 23% and 0.43% of their time in the MathCad documents. The extremely high usage of the MathCad documents in Fall 1994 is due to an assignment that required MathCad usage to answer the questions.

The *Quick Look* section was designed to integrate the information into a concise form that was particularly applicable to tasks performed in the laboratory itself. We expected high usage of the *Quick Look* section because it should improve performance in the laboratory. Despite this explicit presentation of material, users spent only 5% of their time in Fall 1994 and less than 7% of their time in Spring 1995.

4.4 Design Objectives

We attempted to increase the accessibility of information by providing multiple methods of navigation. Although we sought to reduce the linearity by introducing the *Index Page*, *Lab Room* and Maps, and *Map Page*, the majority of usage, as shown in the audit trails and surveys, is still linear. The results from the Fall 1994 and Spring 1995 surveys are shown in Figures 4.1 and 4.2 respectively.

Figure 4.1 - Navigation Frequency by Type (Fall 1994 Survey)

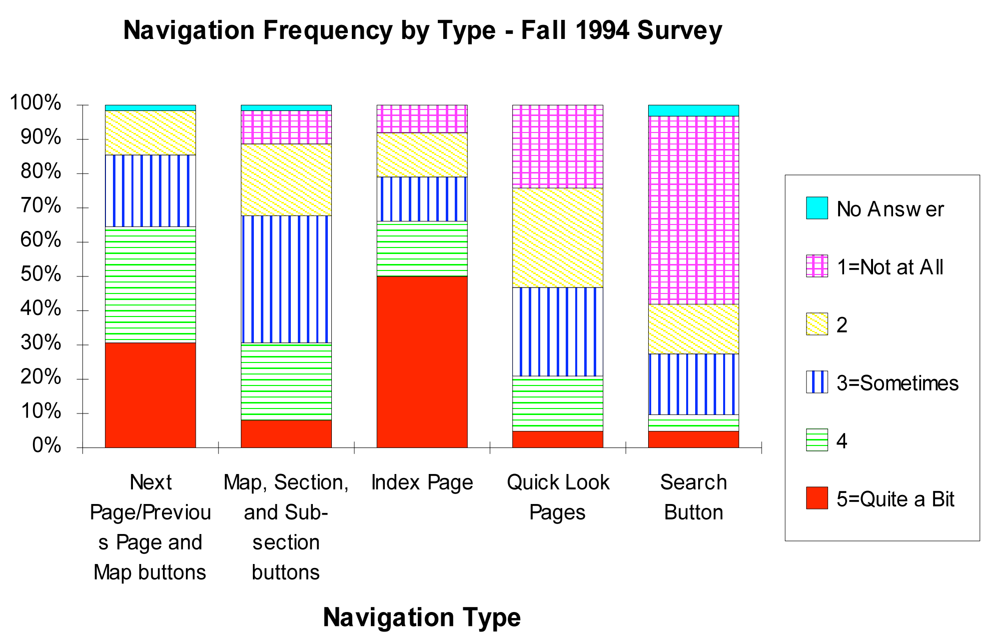
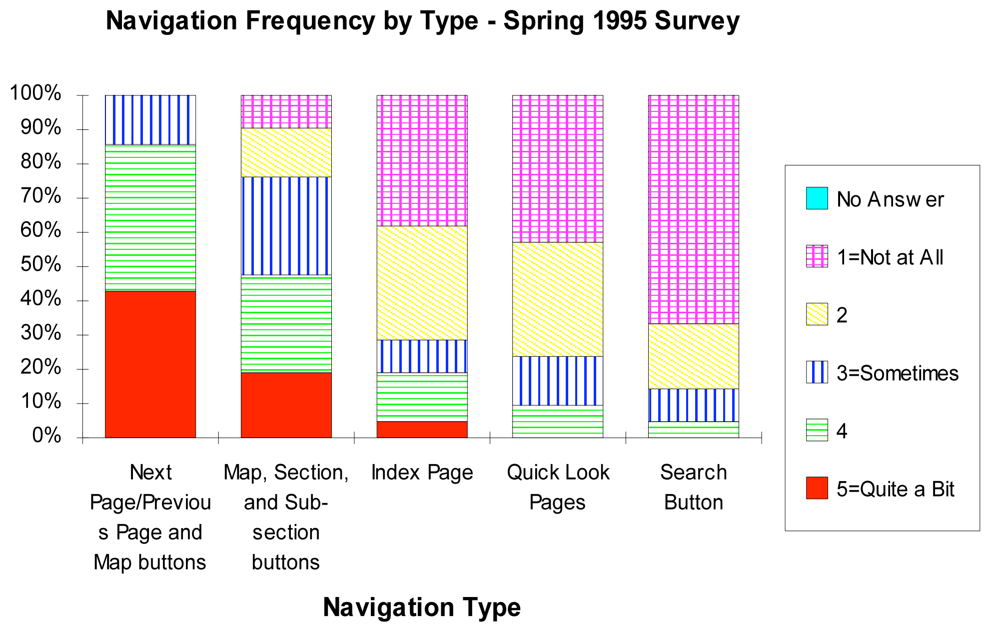


Figure 4.2 - Navigation Frequency by Type (Spring 1995 Survey)



The users were asked to rate the frequency that they used each form of navigation from not at all to quite a bit. By looking at user ratings of 4 and 5, the usage of the linear navigation — Next, Previous, and Back buttons — scored a 64% and 85% for frequency of navigation. The users were also asked to rate which method of navigation they preferred most (see Table 4.3)

Table 4.3 - Preferred Navigation Method

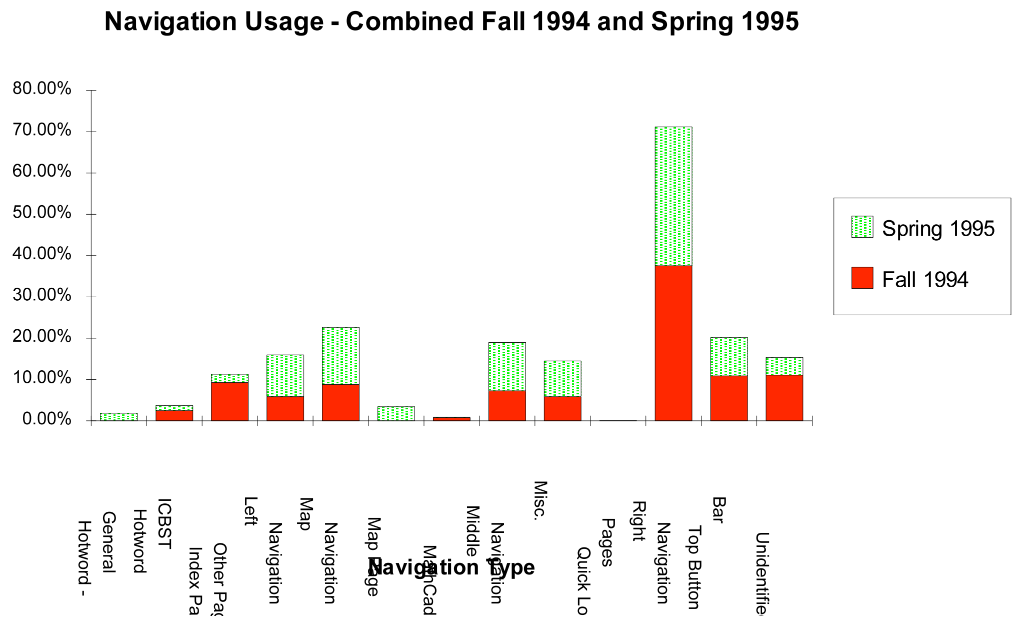
Which method of navigation did you prefer most?	Fall 1994	Spring 1995
(a) Next Page/Previous Page and Map buttons	12.90%	33.33%
(b) Map, Section, and Sub-section buttons	4.84%	38.10%
(c) Index Page	62.90%	14.29%
(d) Quick Look Pages	6.45%	4.76%
(e) Search Button	9.68%	9.52%
No Preference	3.23%	0.00%

In particular for Fall 1994, despite the fact that the students said they used the linear navigation with a high frequency, they overwhelmingly preferred the Index Page (63%)

to the linear navigation (13%). The Spring 1995 students' preferences were split between the linear navigation (33%) and the Map, Section, and Sub-section buttons (38%).

The actual navigation as indicated by the navigation audit trails for Fall 1994 and Spring 1995 (see Figure 4.3) confirms that linear navigation (right navigation in Figure 4.3) is the dominant form of navigation in both semesters.

Figure 4.3 - Navigation Usage (Fall 1994 and Spring 1995)



One explanation for the discrepancy between the preferred navigation and the actual navigation is that the *Index Page* and Map, Section, and Sub-section buttons take the user to starting points for further exploration, from there they use linear navigation to find the exact information that they want. Additionally, the Fall 1994 users may have been biased towards the *Index Page* because they were introduced to the courseware with a 15 minute information session that specifically suggested that the students use the *Index Page*.

The one most surprising piece of information from the navigation audit trails was the usage of the middle navigation (Sub-section) buttons; the Fall 1994 usage was 7% and Spring 1995 usage 8%. We did not expect to see high usage from these buttons since, as developers, we see the middle navigation buttons as mainly way-markers for the user.

This is a case where the developer's perception differs from the user's perception as described in Gentner and Grudin (1990).

With the exception of the *Index Page*, students only used the non-linear navigation schemes that were an integral part of the structure (e.g., navigation areas integrated with Maps or the Bottom Navigation). The usage of General Hotwords, *It can be shown that . . .* Hotwords, MathCad links, the *Map Page*, and the *Quick Look* hotwords comprises less than 5% of the total overall usage. While we expected higher usage from some of these alternate forms of navigation, the results are somewhat encouraging. By using what we consider to be the 'main' forms of navigation — the Maps, Bottom Navigation, and the *Index Page* — the users appear to have a good concept map of the structure and how to navigate the courseware to find the information that they need. The one disappointing result is the students did not take advantage of the additional depth of material and links (e.g., MathCad documents) that we provided (as shown above in Section 4.3).

5.0 Summary and Conclusions

5.1 Suggested Improvements

The development of the ***Vibrating Beam Experiment Instructional Courseware*** is an ongoing process. With version 1.0 we concentrated on the technical content in the development process. We feel that the structure and content that we have developed do increase the students' understanding of the experiment. Nonetheless we can envision two areas for further development to greatly improve the students' understanding of the material. An experiment planning section could be added that would include tips and techniques for designing the experiment and planning data collection. Additionally, we could include “reflective questions” and “quizzes” to help students gauge their understanding of the material, as well as provide us with a quantifiable measurement of performance.

In addition to the experiment planning section, we suggest adding a ‘How to Use the Courseware’ section. The orientation session given in Fall 1994 definitely influenced the navigation usage (high *Index Page* usage). To improve performance and understanding a short video with descriptive text orienting the student to both the structure and navigation schemes may be beneficial to the novice user.

Additionally we see fine tuning the user interface by continuously monitoring navigation usage and enhancing the navigation schemes. For example, before we started taking data, it was our intention to remove the Middle Navigation (Sub-section buttons) because as developers we did not see the student using those buttons. However, after viewing the navigation audit trails, we would keep the scheme but modify it slightly to reduce the screen space taken up by the buttons. There are numerous examples of navigation schemes that serve our two purposes of allowing the user to see where they are located in the hierarchy and navigate to the different levels in it.

While we use videos in the courseware to demonstrate set-up and calibration procedures, we do not fully utilize animation and simulation tools. The MathCad documents we use to allow the user to visualize the dynamic response of the apparatus are static, only displaying the end result of calculations. The extension of this simulation will be to provide an interactive, dynamic modeling of the system using a program such as Working Model. By allowing the user to change the vibrational parameters on the fly, we would allow them to use a “mock experiment” before they enter the laboratory.

One of the most rewarding anecdotal comments that we have received from the students is whether multimedia courseware has been developed for the other experiments in this class (ME 107A). Despite the long courseware development time, additional modules for the other experiments could be developed using the ***Vibrating Beam Experiment Instructional Courseware*** as a template.

5.2 Summary

The ***Vibrating Beam Experiment Instructional Courseware*** (Version 1.0) provides a centralized source of information. Through the multiple levels of material (from the Main Text and *Bottom Line* to the *It can be shown that* . . . windows and the MathCad documents), we provide additional information that has not traditionally been available for this experiment (e.g., full derivations and supplementary reference material). Additionally Version 1.0 provides informational videos of the apparatus and procedural videos of the set-up and calibration of the instrumentation. While this version does not provide interactive, dynamic simulations, it does provide static examples (MathCad documents).

To access this information, the courseware has a consistent screen layout that provides distinctive areas for content and navigation. Additionally, the ***Vibrating Beam Experiment Instructional Courseware*** has numerous navigation schemes that range from simple linear navigation to graphical maps. Students can find information via the *Index Page* or through the task-oriented *Quick Look*. Much of the navigation is an integral part of the structure; it allows access to the breadth of material while reducing the obtrusiveness of the depth of material.

As designers we feel that we met our individual pedagogical and design objectives, but we must ask if we met our overall goals. We have developed a computer-based, enhanced laboratory manual that provides the students with information required to complete the experiment. Despite the existence of the additional theory material, students were not motivated to use this material outside the presence of specific laboratory preparation questions. On the other hand, students did use the additional material that provides practical tips on performing the experiment, such as the *In the Lab* sections.

Students were able to access material within the *Lab Room* structure and multiple 'main' navigation schemes (Maps, Bottom Navigation, and the *Index Page*). The addition of the *Lab Room* navigation metaphor appeared to improve the students' understanding of the structure. Despite the fact that the students were able to access information, they were not satisfied with the level of material. The students appear to prefer an explicit presentation of information that specifically addresses their laboratory preparation questions and experiment.

In summary, the courseware addresses the need for a comprehensive reference source to explain the theory and the apparatus of the Vibrating Beam Experiment. We focused on the technical content and information structure with Version 1.0 of the ***Vibrating Beam Experiment Instructional Courseware***. The design of the courseware allows it to be used in numerous ways depending on the instructor's prerogative. The existence of this courseware allows the instructor to spend more time with open-ended problem solving since the courseware provides the basic reference material. The existing courseware, supplemented with additional experiment planning and reflective quizzes, used as part of a comprehensive educational experience, can only have a positive impact.

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Wilson, J. and Redish, E. (1992). Comprehensive Unified Physics Learning Environment: Part I. Background and System Operation. *Computers in Physics Education 6(2)*, (pp. 202-309).

Appendix A - Technical Specifications

Vibrating Beam Experiment Instructional Courseware is authored using Asymetrix Toolbook Version 3.0. The courseware contains Video for Windows and Quicktime for Windows movies. The courseware is available on CD-ROM and via World Wide Web.

The minimum configuration to use the courseware is:

Microsoft Windows 3.1
Video for Windows 1.1 or later
Quicktime for Windows 2.0 or later
80386-33 MHz processor
Hard drive with 5 MB of free space
8 MB of physical RAM
VGA Graphics Adapter (256 Colors at 640x480)
Windows compatible Mouse
Double speed CD-ROM drive

The suggested configuration to use the courseware is:

Microsoft Windows 3.1
Video for Windows 1.1 or later
Quicktime for Windows 2.0 or later
80486-33MHz processor
12 MB of physical RAM (16 MB Highly recommended)
Graphics Accelerator (32,000 or 64,000 colors at 640x480)
Windows compatible Mouse
Double speed CD-ROM drive

(The entire courseware may be used from a hard drive, but a full install currently requires 180+ MB.)

For more information or to obtain a copy of the courseware, please contact:

SYNTHESIS Coalition
Engineering Systems Research Center
University of California
3115 Etcheverry Hall
Berkeley, CA 94720-1750

Appendix B - Fall 1993 Survey

B.1 Survey

Mechanical Engineering 107A
Computer-Based Instruction Survey
Fall 1993

NAME (OPTIONAL): ____

General:

1. How many years of Computer Experience do you have?

2. Is the majority of your computer experience on Macintoshes or on IBM PC's?

3. If you are a Macintosh user, was it easy for you to use the IBM and Toolbook?

4. Did you understand the function of the buttons and how to navigate the book the first time you used the courseware?

5. Did you use the Help buttons?

6. What would you have liked to have seen the Help screens?

Lectures:

1. Which did you prefer, lectures using the blackboard or lecture material presented with the computer?

2. Was the pace of the computer-based lectures too fast?

3. Was the quality of the graphics sufficient?

4. Was too much information presented in each screen?

5. The lecture courseware presented more material in one and a half hours than could have been covered on the blackboard. Did you feel overwhelmed?

6. Did the lecture courseware cover the material in sufficient depth?

7. What about the physical arrangement of the lecture halls:

Was the room too dark?

Was viewing the screen uncomfortable?

Was the screen readable?

Should the text and graphics be larger?

8. Did you access the lecture courseware on your own? Did you find it useful?

9. What did you especially like about the lecture courseware?

10. What did you dislike about the lecture courseware?

11. What would you suggest to improve the lecture courseware?

Vibrations Lab Tutorial:

1. Was the courseware easy or difficult to navigate?

2. Did you find yourself becoming lost?

2. If it was difficult to navigate or you got lost, please suggest an alternate navigation scheme.

3. Concerning navigation, which did you find yourself using more, the Contents page, drop down menu, or the Previous and Next Page buttons?

4. Which of the buttons types did you like more, the gray buttons or the blue, gold, red and white buttons (e.g., Previous Page, Next Page, and Exit)?

5. Did you use the Search button?

6. Given the lab assignment, was the material presented sufficient?

8. Did you like the order in which the material was presented?

9. How would you improve the presentation of the material?

10. Would you have preferred to have more description in the lab courseware (e.g., a complete derivation of simple beam theory)?

11. Were the scanned photos effective?

12. How could multimedia be used effectively?

13. Would voice-overs of the text have helped?

14. Would you have liked music-based audio included throughout the lab courseware?

14. What would you suggest to improve the courseware?

Conclusion:

1. Any other comments?

2. Any overall suggestions?

B.2 Survey Results

Mechanical Engineering 107A
Computer-Based Instruction Survey
Compilation Results
Fall 1993

General:

1. How many years of Computer Experience do you have? (59)

0 < 1 yr.	1	6 - 8 yr.	15
1 - 2 yr.	6	9 - 10 yr.	10
3 - 5 yr.	22	>10 yr.	5

2. Is the majority of your computer experience on Macintoshes or IBM PC's? (53)

IBM	32	Both	8
Mac	12		

3. If you are a Macintosh user, was it easy for you to use the IBM and Toolbook? (23)

Easy to use 23

4. Did you understand the function of the buttons and how to navigate the book the first time you used the courseware? (59)

Yes	51	Not Used	1
No	4	N/A	3

- Navigation buttons get kind of confusing at times, too many of them
- Some buttons not clear
- Long distance jumps were a little tricky. I could get to the beginning of each sub-section but not to a specific page that was at the beginning of a sub-section

5. Did you use the Help buttons? (59)

Yes	20	N/A	5
No	34		

6. What would you have liked to have seen in the Help screens?

N/A	46

- I'd like to see some of the help screens actually work
- Could put more of text in help screens
- Most of help unavailable
- Slightly more detailed explanations of relationships between measurement systems and quantities they measure
- More detailed explanations or a list of related topics
- An explanations of the various navigation buttons (answered no to #5)
- Hints
- Answers to my questions
- Liked to have seen actual help, often the help was incomplete or non-existent

Lectures:

1. Which did you prefer, lectures using the blackboard or lecture material presented with the computer? (59)

Blackboard	32	No Pref.	5
Computer	21	N/A	1

- Blackboard--only important material is put on the board, not everything, we don't have to select important material from computer lecture
- Hard copy of the notes as on the computer would be very smart thing to have, it could be in reader form and would save an incredible amount of time in class
- Easier to follow lectures on blackboard because the pace of material presented on the computer might sometimes be too fast
- Computer based more organized
- Prefer blackboard but still have information on computer so can go in and verify notes
- Computer moves too quickly and covers extraneous material
- Hard to take notes in the dark
- Sometimes an information overload

2. Was the pace of the computer-based lectures too fast? (59)

Yes	32	Sometimes	12	N/A	1
No	13	Too Slow	1		

- It was hard for you to know how long it would take us to write down the important information and it was hard to find the important information (4)

- Couldn't take notes and listen to lecture (4)
- Pass out lecture notes
- Copying prevented from learning
- Computer lectures require more than one screen, so last 2 screens can be seen at once, or references can be made to another screen without flipping back and forth between screens
- Easier to follow blackboard lectures
- It was either just right or too slow, most students copied down too much

3. Was the quality of graphs sufficient? (59)

Yes	51	N/A	2
No	6		

- Extremely important to avoid putting misleading information in the schematic diagram

4. Was too much information presented in each screen? (59)

Yes	25	Sometimes	7
No	25	N/A	2

- Thin the important points should be on each screen and the other background not covered in lecture detailed through use of buttons, excess information makes note-taking difficult
- It wasn't organized in a clear fashion
- Had to write all of the stuff down
- Highlight important information
- Wording so carefully thought out that a student wants to copy it verbatim
- Pick out most important information wasn't that hard
- Put multiple pieces of information on 1 screen only when they need to be seen at once
- It seems when the professor had to stand and wait for more than one minute there was too much to write down on that page
- Screens are like pages in a textbook, which is meant to be carefully read and slowly digested
- copy of notes instead of frantically copying down screen
- If slowed down not too much information
- Just have essential on screen since the Professor read most of the text anyway

5. The lecture courseware presented more material in one and a half hours than could have been covered on the blackboard. Did you feel overwhelmed? (59)

Yes	26	Sometimes	8

No	25

- Underwhelmed would be a better word (2)
- Pass out lecture notes
- Did not comprehend nearly as well
- Seemed like more information than usual, not enough to be overwhelmed, it was enough to keep me awake
- Computer's major advantage--more time to explain relevance and importance of information, lose the advantage when students copy too much and not enough time spent listening
- It was no the pace but the note-taking that is the limiting factor, strongly recommend any method to speed up the pace
- I was clueless when I started the lab because I couldn't figure out the procedure

6. Did the lecture courseware cover the material in sufficient depth? (59)

Yes	44	Sometimes	3
No	5	N/A	7

- Sometimes too much depth
- Sometimes governing lab themes not sufficiently covered at all
- Couldn't listen to the professor
- That is up to you isn't it? Did the courseware cover material as you had wanted it to?
- Yes but not possible to access material in allotted time
- Felt kept the talk to rigid and did not allow for discussion

7. What about the physical arrangement of the lecture halls:

Was the room too dark? (58)

Yes	12
No	46

Was the viewing screen uncomfortable? (59)

Yes	24
No	35

Was the screen readable? (59)

Yes	40
No	14
Sometimes	5

Should the text and graphics be larger? (59)

Yes	15
No	44

8. Did you access the lecture courseware on your own? Did you find it useful? (59)

Yes	42	Yes	30
No	13	No	4
N/A	4	N/A	8

9. What did you especially like about the lecture courseware?

N/A 13

- Come back to things and review them at any time & Go back and look up at own pace (11)
- Liked nothing (3)
- It could make the course more efficient, but too much time wasted waiting for people to take notes
- Graphics (7)
- Help section
- Through
- Like it in general
- Liked organization of it, tree arrangement of material was very effective (6)
- Liked information present, idea is great, but I would like the lecture on the blackboard, I Guess it is a nice way to study for finals
- Ability to go right to material wanted to look at by using contents
- Legible (5)
- Clarity (4)
- Like a book
- Amount of information
- Color (2)

10. What did you dislike about the lecture courseware?

N/A 12

- Interface is slow and clunky
- Nothing
- Too much text
- Pace too fast (2)
- Too much electronics

- Too much reading
- Don't have sense of following the lecture step by step like that you get with a blackboard
- Too much information (7)
- Most of the buttons didn't work (2)
- Errors
- Vibrations symbols different from the text
- Seemed inflexible, major production to switch to the blackboard
- Too detailed
- Slow progress
- The fact that I had to go through it myself
- Uncomfortable
- Equation problems (3)
- Everything except legibility
- Blocks of text
- Pages and pages, like a book
- Hard to find specific topics when wanted to
- Sometimes material not loaded such as concepts needed for homework
- Everything except color, graphics, and diagrams
- Too wordy--when using the blackboard, Professors are forced to outline, condensing and prioritizing, this should be done in the courseware since we can't read and copy as fast as the professor speaks anyway, the should <u>not</u> be more detail in the courseware than the professor wants to read and cover
- Disliked navigation buttons, thought they were confusing
- Interface
- Going to 2111 an inconvenience
- Nothing

11. What would you suggest to improve the lecture courseware?

N/A 19

- Have it supplement the lecture instead of being it, the lectures could come from the courseware, but we wouldn't look at it in class
- Hard copy of notes (7)
- Less text and more illustration
- Shorten and focus on main points
- Okay the way it is
- Remove most of the extra material, highlight main points, I can read a book to get the details
- Slow down lecture
- Larger text screen
- Make complete (2)
- Develop it fully before using it in class
- More time to copy the screen before discussing it

- Better optics, full use of computer capabilities--audio, CD-ROM
- Clean it up from time to time to keep up on current class developments
- Writing was good
- Examples
- Leave it out of class and use it as a workshop
- Will be better when multimedia possibilities are realized
- Less, only have what you feel is necessary
- All or nothing on courseware
- No improvements
- Keep up to date (2)
- More screens or forget it
- Have space for key equations or phrase in reader
- Get rid of Windows, run OS/2 or use WABI on top of AIX
- Basic layout is good, need to refine details
- Limit it to bullet format and graphs

General Comments

- It seemed like a waste of my time to come to school and sit in front of a computer with no multimedia interaction in order to copy down 7-8 equations that could have been handed out in lecture
- I did not view the courseware on my own, nor did I use the tutorials. Again the material is not that complex for it to be worth the time it would take to make the trip and fumble around to figure out how to use it. The idea of courseware, etc. is good. At Berkeley though, we are expected to learn at a faster pace than the courseware assumes. If it is really took that long to understand, we would all drown in the amount of material we were expected to learn
- Professor reluctant to expand on subjects using the blackboard
- Thanks for the time and efforts
- Course was great overall

Tutorial:

1. Was the courseware easy or difficult to navigate? (59)

Easy	45	N/A	8
Difficult	6		

2. Did you find yourself becoming lost? (59)

Yes	12	Sometimes	3
No	36	N/A	8

3. If it was difficult to navigate or you got lost, please suggest an alternate navigation scheme.

See General Comments below.

4. Concerning navigation, which did you find yourself using more, the Contents page, drop down menu, or the Previous and Next Page buttons? (59)

Contents	4	P/N Page	42
Drop down	2	N/A	11

5. Which of the button types did you like more, the gray buttons or the blue, gold, red and white buttons (e.g., Previous Page, Next Page, and Exit)? (59)

Gray	7	No Pref.	8
Colored	17	N/A	27

6. Did you use the Search button? (59)

Yes	10	N/A	10
No	39		

7. Given the lab assignment, was the material presented in sufficient depth? (59)

Yes	28	N/A	14
No	17		

8. Did you like the order in which the material was presented? (59)

OK	37	N/A	16
No	6		

9. How would you improve the presentation of the material?

See General Comments below.

10. Would you have preferred to have more description in the lab courseware (e.g., a complete derivation of simple beam theory)? (59)

Yes	12	N/A	12
No	29		

11. Were the scanned photos effective? (59)

Yes	26	N/A	11
No	22		

12. How could multimedia be used effectively?

See General Comments below.

13. Would voice-overs of the text have helped? (59)

Yes	10	Maybe	7
No	25	N/A	17

14. Would you have liked music-based audio included throughout the lab courseware? (59)

Yes	19	N/A	7
No	33		

15. What would you suggest to improve the courseware?

See General Comments below.

General Comments

- More information on how to calibrate the strain gage and LVDT
- Place extra description in courseware
- Videos using lab equipment
- Terminals in lab for reference (2)
- Hard copy (4)
- More equipment setup
- Let students access from home PC's (3)
- Complete
- Does not help write good reports or perform good experiments
- Scale in photographs

- Courseware may not have been worth the effort
- More examples
- Optional user selectable music
- Use it <u>only</u> as a tutorial
- Dot use as a substitute
- More access to multimedia
- More facilities
- Interactive
- Animation (2)
- Integrate it better into the class or don't use it
- Need a better role for courseware
- Derivations of equations
- Make screen readable in lecture
- Multimedia <u>not</u> effective in lecture
- Use bullets or something so we don't have to write down every bit of extraneous description
- Found it hard to fit time in schedule to use it, but it was nearly required, if it is so important, spread section with shorter lectures would be helpful
- Go through mock experiment
- Quizzes, review pages, "What's important" screens
- Goto page
- Overall picture
- Search for equations
- Limit number of topics in drop down menu, index it in alphabetical order

Appendix C - Courseware Content

C.1 - Hierarchy

0. Lab Room
    1. Apparatus Map
        1.11 Strain Gauges
            1.11a Types of Strain Gauges
            1.11b Bridges
            1.11c Theory of Operation
            1.11d Calibration Principles
            1.11e Strain Gauges in the Lab
        1.12 Linear Variable Differential Transformer (LVDT)
            1.12a Theory of Operation
            1.12b LVDTs in the Lab
        1.13 Voice Coil/Velocimeter
            1.13a Theory of Operation
            1.13b Calibration Principles
            1.13c Voice Coil/Velocimeter in the Lab
        1.14 Accelerometer
            1.14a Types of Accelerometers
            1.14b Theory of Operation
            1.14c Calibration Principles
            1.14d Accelerometers in the Lab
    2. Theory Map
        2.21 Modeling the System
        2.22 Free Vibration
        2.23 Forced Vibration
        2.24 Model Parameters
        2.25 Vibrational Parameters
            2.25a Free Vibration System Parameters
            2.25b Forced Vibration System Parameters
        2.26 Stress/Strain Relationship
    3. Assignment

C.2 - Theory Map Sections and Sub-sections

Section	Description
Modeling the System	Introduces the theoretical model of the actual system. Derives the second order differential equation that we use as the theoretical model that governs the system.
Free Vibration	Provides the solution to second order differential equation for conditions of free vibration (and underdamping). Also shows a video that demonstrates free vibration in the actual apparatus.
Forced Vibration	Provides the solution to the second order differential equation when a forcing function that is applied to the system. Also shows a video that demonstrates forced vibration with the application of a sinusoidal forcing function.
Model Parameters	Provides theoretical basis for estimating and measuring the model parameters: Mass, Spring Constant, and Damping Constant.
Vibrational Parameters	Provides theoretical basis for estimating and measuring vibrational parameters: Natural Frequency and Damping Ratio. Those parameters that can uniquely define the vibration of the beam either in free or forced vibrational modes.
Stress/Strain Relationship	Provides theoretical relationship that allows the students to infer displacement from measurements of stress.

C.3 - Apparatus Map Sections and Sub-sections

Section	Sub-section	Description
Strain Gauges	Types of Strain Gauges	Provides brief introduction to strain gauges including different types.
	Theory of Operation	Focuses on resistance strain gauges.
	Bridges	Describes the wheatstone bridge as it applies to making measurements using strain gauges.
	Calibration Principles	Describes principles by which students can use theory to infer a displacement from a measured strain.
	In the Lab	Describes method for setting up and calibrating the strain gauge system in the lab
Linear Variable Differential Transformer (LVDT)	Theory of Operation	Provides brief description of the theory of operation of LVDTs. Used to measure displacement.
	In the Lab	Provides method for setting up and calibrating the LVDT in the lab.
Voice Coil/Velocimeter	Theory of Operation	Provides a brief introduction to the combined measurement device and drive mechanism. The Velocimeter/Voice Coil can be used to either drive the apparatus in forced vibrational mode (Voice Coil) or it can be used to measure velocity (Velocimeter).
	Calibration Principles	Describes principles by which students can use theory to infer velocity from measurements.
	In the Lab	Provides method for setting up and calibrating the Velocimeter.
Accelerometer	Types of Accelerometers	Provides brief introduction and covers types of primary and secondary transducers.
	Theory of Operation	Covers frequency and amplitude response to time-varying signals.
	Calibration Principles	Describes principles by which students can use theory to infer accelerations from measurements.
	In the Lab	Provides method for setting up and calibrating the Accelerometer in the lab.

C.4 - Quick Look Topics

Tab	Subjects
Modeling the System	Governing Equation
	Free Vibration
	Forced Vibration
Predicting System Parameters	Introduction
	M_{eff} (Effective end mass)
	k_{total} (Spring Constant)
	C (Damping Constant)
	ζ (Damping Ratio)
	ω_n (Natural Frequency)
	ω_d (Damped Natural, or Ringing, Frequency)
	ω_r (Resonant Frequency)
Measuring System Parameters	M_{eff} (Effective end mass)
	k_{total} (Spring Constant)
	C (Damping Constant)
	ζ (Damping Ratio)
	ω_n (Natural Frequency)
	ω_d (Damped Natural, or Ringing, Frequency)
	ω_r (Resonant Frequency)

C.5 - Mathcad Documents

MathCad Document	Description
Accelerometer Simulator	Examines the analytic relationship between displacement, velocity and acceleration for forced vibration
Accelerometer Calibration Procedure	Explains the theory behind the calibration of the accelerometer.
Velocimeter Simulator	Examines the analytic relationship between displacement and velocity for free vibration.
Velocimeter Calibration Procedure	Explains the theory behind the calibration of the velocimeter.
Free Vibration Simulation	Takes input of SYSTEM parameters and shows the free response of the system
Forced Vibration Simulation	Takes input of SYSTEM parameters and shows the forced response of the system
Magnitude Ratio	Shows the effects of varying damping ratio on magnitude ratio.
Free Vibration from k, Meff, C	Takes input of MODEL parameters and shows the free response of the system
Forced Vibration from k, Meff, C	Takes input of MODEL parameters and shows the forced response of the system
Free Response	Takes input of MEASURED values and shows the free response of the system allowing the user to compare experimental results with theoretical values.
Forced Response	Takes input of MEASURED values and shows the forced response of the system allowing the user to compare experimental results with theoretical values.

Appendix D - Fall 1994 Survey

D.1 Survey

Part of your Homework #5 is to fill out this questionnaire.

Please Circle Your Lab Group

Lab Group MON. TUE. WED. THU.

Navigation

	Not at All		Somewhat		Very
1. Overall, rate how easy it was to navigate through the courseware?	1	2	3	4	5
2. Rate how intuitive you felt the navigation scheme was.	1	2	3	4	5

	Not at All		Sometime		Most of the Time
3. Rate the frequency with which you used each navigation scheme.					
(a) Next Page/Previous Page and Map buttons	1	2	3	4	5
(b) Map, Section, and Sub-section buttons	1	2	3	4	5
(c) Index Page	1	2	3	4	5
(d) Quick Look Pages	1	2	3	4	5
(e) Search Button	1	2	3	4	5

4. Which method of navigation did you prefer most?	a	b	c	d	e

5. Why did you prefer this method of navigation?

6. How would you improve the navigation scheme?

Overall Effectiveness of the Courseware

	Not at All		Somewhat		Very
1. Rate the Overall Effectiveness of the courseware.	1	2	3	4	5

	Not at All		Somewhat		Quite a Bit
2. Rate how much the courseware contributed to your understanding the lab as a whole.	1	2	3	4	5
3. Rate how much the courseware contributed to your understanding your lab preparation (Homework #5) assignment.	1	2	3	4	5

	Not at All		Somewhat		Very
4. Rate the GENERAL usefulness of these sections:					
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	1	2	3	4	5
Apparatus description and background information	1	2	3	4	5
Apparatus calibration and set-up information	1	2	3	4	5
Assignment and Experiment Planning	1	2	3	4	5
5. Rate the usefulness of each section in LAB PREPARATION (Homework #5):					
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	1	2	3	4	5
Apparatus description and background information	1	2	3	4	5
Apparatus calibration and set-up information	1	2	3	4	5
Assignment and Experiment Planning	1	2	3	4	5
6. Rate the usefulness of each section in the LAB:					
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	1	2	3	4	5
Apparatus description and background information	1	2	3	4	5
Apparatus calibration and set-up information	1	2	3	4	5
Assignment and Experiment Planning	1	2	3	4	5
7. Rate the usefulness of each section in post-LAB ANALYSIS and DATA REDUCTION:					
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	1	2	3	4	5
Apparatus description and background information	1	2	3	4	5
Apparatus calibration and set-up information	1	2	3	4	5
Assignment and Experiment Planning	1	2	3	4	5

	Strongly Disagree				Strongly Agree
8. The courseware helped me:					
Understand lecture better	1	2	3	4	5
Finish the homework faster	1	2	3	4	5
Understand the lab better	1	2	3	4	5
Analyze the lab data better	1	2	3	4	5
Write a better lab report	1	2	3	4	5

Content Quality and Accessibility

	Not Enough		Just Right		Too Much
1. Rate the overall depth of material. Was there sufficient content?	1	2	3	4	5

	Not at All		Sometime		Most of the Time
2. Rate how often you found yourself looking at the "It can be shown that . . . " sections	1	2	3	4	5

	Not at All		Somewhat		Very
3. Rate how useful you found the Mathcad links.	1	2	3	4	5

	Not at All		Somewhat		Quite a Bit
4. Rate how much the Mathcad links improved your understanding of the material.	1	2	3	4	5

Concerning the LAB PREPARATION (Homework #5) . . .

	Not at All		Somewhat		Very
5. Rate how easy it was to find the information on the spring constant. (Homework Question 7)	1	2	3	4	5
6. Rate how easy it was to find the Theory and Mathcad links for the Free Vibration. (Homework Question 9)	1	2	3	4	5

	Not Enough		Just Right		Too Much
7. Rate the depth of material about the spring constant. (Homework Question 7)	1	2	3	4	5
8. Rate the depth of material about Free Vibration. (Homework Question 9)	1	2	3	4	5

	Not at All		Somewhat		Very
9. Rate the similarity between the Forced Vibration Theory and Modelling the Accelerometer.	1	2	3	4	5

General Comments

1. Overall how would you improve the courseware?

2. What information would you have liked to have seen in the courseware?

3. What information do you think is unnecessary in the courseware?

Thank you for filling out this questionnaire. The results will be used to improve the courseware for future generations of ME students at Berkeley.

D.2 Survey Results

Navigation

	Average	Standard Deviation	Confidence 95%
1. Overall, rate how easy it was to navigate through the courseware?	3.66	0.90	0.23
2. Rate how intuitive you felt the navigation scheme was.	3.34	0.97	0.25

3. Rate the frequency with which you used each navigation scheme:	Not at All		Some-time		Most of the Time	No Ans-wer
(a) Next Page/Previous Page and Map buttons	0	8	13	19	21	1
(b) Map, Section, and Sub-section buttons	6	13	23	14	5	1
(c) Index Page	5	8	8	10	31	0
(d) Quick Look Pages	15	18	16	3	10	0
(e) Search Button	34	9	11	3	3	2

4. Which method of navigation did you prefer most?	
(a) Next Page/Previous Page and Map buttons	8
(b) Map, Section, and Sub-section buttons	3
(c) Index Page	39
(d) Quick Look Pages	4
(e) Search Button	6
No Preference	2

Overall Effectiveness of the Courseware

	Average	Standard Deviation	Confidence 95%
1. Rate the Overall Effectiveness of the courseware.	3.66	0.81	0.21
2. Rate how much the courseware contributed to your understanding the lab as a whole.	3.69	0.86	0.22
3. Rate how much the courseware contributed to your understanding your lab preparation (Homework #5) assignment.	3.89	0.96	0.24
4. Rate the GENERAL usefulness of these sections:			
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	3.53	1.10	0.28
Apparatus description and background information	3.23	1.12	0.29
Apparatus calibration and set-up information	3.31	1.22	0.31
Assignment and Experiment Planning	2.95	1.18	0.30
5. Rate the LAB PREPARATION usefulness of these sections:			
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	3.65	1.15	0.29
Apparatus description and background information	3.10	1.18	0.30

Apparatus calibration and set-up information	3.26	1.30	0.33
Assignment and Experiment Planning	3.05	1.36	0.35
6. Rate the LAB usefulness of these sections:			
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	3.29	1.16	0.30
Apparatus description and background information	3.29	1.15	0.29
Apparatus calibration and set-up information	3.48	1.29	0.33
Assignment and Experiment Planning	2.98	1.29	0.33
7. Rate the POST-LAB usefulness of these sections:			
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	2.60	1.82	0.46
Apparatus description and background information	2.19	1.59	0.40
Apparatus calibration and set-up information	2.37	1.74	0.44
Assignment and Experiment Planning	2.08	1.62	0.41
8. The courseware helped me:			
Understand lecture better	3.27	0.94	0.24
Finish the homework faster	3.81	1.17	0.30
Understand the lab better	3.76	0.97	0.25
Analyze the lab data better	2.76	1.68	0.43
Write a better lab report	2.35	1.66	0.42

Content Quality and Accessibility

1. Rate the overall depth of material. Was there sufficient content?	3.13	0.97	0.25
2. Rate how often you found yourself looking at the "It can be shown that . . . " sections	3.13	1.12	0.29
3. Rate how useful you found the Mathcad links.	4.06	1.07	0.27
4. Rate how much the Mathcad links improved your understanding of the material.	3.81	1.16	0.29
5. Rate how easy it was to find the information on the spring constant. (Homework Question 7)	3.56	1.11	0.28
6. Rate how easy it was to find the Theory and Mathcad links for the Free Vibration. (Homework Question 9)	3.66	1.14	0.29
7. Rate the depth of material about the spring constant. (Homework Question 7)	2.87	0.95	0.24
8. Rate the depth of material about Free Vibration. (Homework Question 9)	3.10	1.00	0.25
9. Rate the similarity between the Forced Vibration Theory and Modelling the Accelerometer.	2.87	1.35	0.34

Appendix E - Spring 1995 Survey

E.1 Survey

Please Circle Your Lab Group

Lab Group	MON.	WED.	THU.		
How many years of computer experience do you have?	1-2	3-5	6-8	9-10	>10
What type of computer do you use most often?	Mac	PC	Mac and PC		

Navigation

	Not at All		Somewhat		Very
1. Overall, rate how easy it was to navigate through the courseware?	1	2	3	4	5
2. Rate how intuitive you felt the navigation scheme was.	1	2	3	4	5

	Not at All		Sometime		Most of the Time
3. Rate the frequency with which you used each navigation scheme.					
(a) Next Page/Previous Page and Map buttons	1	2	3	4	5
(b) Map, Section, and Sub-section buttons	1	2	3	4	5
(c) Index Page	1	2	3	4	5
(d) Quick Look Pages	1	2	3	4	5
(e) Search Button	1	2	3	4	5

4. Which method of navigation did you prefer most?	a	b	c	d	e

5. Why did you prefer this method of navigation?

6. How would you improve the navigation scheme?

Overall Effectiveness of the Courseware

	Not at All		Somewhat		Very
1. Rate the Overall Effectiveness of the courseware.	1	2	3	4	5

	Not at All		Somewhat		Quite a Bit
2. Rate how much the courseware contributed to your understanding the lab as a whole.	1	2	3	4	5
3. Rate how much the courseware contributed to your understanding your lab preparation (Homework #5) assignment.	1	2	3	4	5

	Not at All		Somewhat		Very
4. Rate the GENERAL usefulness of these sections:					
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	1	2	3	4	5
Apparatus description and background information	1	2	3	4	5
Apparatus calibration and set-up information	1	2	3	4	5
Assignment and Experiment Planning	1	2	3	4	5
5. Rate the usefulness of each section in LAB PREPARATION (Homework #5):					
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	1	2	3	4	5
Apparatus description and background information	1	2	3	4	5
Apparatus calibration and set-up information	1	2	3	4	5
Assignment and Experiment Planning	1	2	3	4	5
6. Rate the usefulness of each section in the LAB:					
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	1	2	3	4	5
Apparatus description and background information	1	2	3	4	5
Apparatus calibration and set-up information	1	2	3	4	5
Assignment and Experiment Planning	1	2	3	4	5
7. Rate the usefulness of each section in post-LAB ANALYSIS and DATA REDUCTION:					
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	1	2	3	4	5
Apparatus description and background information	1	2	3	4	5
Apparatus calibration and set-up information	1	2	3	4	5
Assignment and Experiment Planning	1	2	3	4	5

	Strongly Disagree				Strongly Agree
8. The courseware helped me:					
Understand lecture better	1	2	3	4	5
Finish the homework faster	1	2	3	4	5
Understand the lab better	1	2	3	4	5
Analyze the lab data better	1	2	3	4	5
Write a better lab report	1	2	3	4	5

Content Quality and Accessibility

	Not Enough		Just Right		Too Much
1. Rate the overall depth of material. Was there sufficient content?	1	2	3	4	5

	Not at All		Sometime		Most of the Time
2. Rate how often you found yourself looking at the "It can be shown that . . . " sections	1	2	3	4	5

	Not at All		Somewhat		Very
3. Rate how useful you found the Mathcad links.	1	2	3	4	5

	Not at All		Somewhat		Quite a Bit
4. Rate how much the Mathcad links improved your understanding of the material.	1	2	3	4	5

Concerning the LAB PREPARATION (Homework #5) . . .

	Not at All		Somewhat		Very
5. Rate how easy it was to find the information on the spring constant. (Homework Question 7)	1	2	3	4	5
6. Rate how easy it was to find the Theory and Mathcad links for the Free Vibration. (Homework Question 9)	1	2	3	4	5

	Not Enough		Just Right		Too Much
7. Rate the depth of material about the spring constant. (Homework Question 7)	1	2	3	4	5
8. Rate the depth of material about Free Vibration. (Homework Question 9)	1	2	3	4	5

Motivation

	Not at All		Somewhat		Quite a Bit
1. Rate how much you used the coureware.	1	2	3	4	5
2. I plan to use the courseware after the Homework is due to help wirte-up my Lab.	1	2	3	4	5

	Strongly Disagree				Strongly Agree
3. I used the courseware because:					
I wanted a better score on the Homework.	1	2	3	4	5
I wanted to get a better score on my Lab Report	1	2	3	4	5
I wanted to understand the Homework better.	1	2	3	4	5
I wanted to understand the Material better.	1	2	3	4	5

General Comments

1. Overall how would you improve the courseware?

2. What information would you have liked to have seen in the courseware?

3. What information do you think is unnecessary in the courseware?

Thank you for filling out this questionnaire. The results will be used to improve the courseware for future generations of ME students at Berkeley.

E.2 Survey Results

Navigation	Average	Standard Deviation	Confidence 95%
1. Overall, rate how easy it was to navigate through the courseware?	4.08	0.76	0.33
2. Rate how intuitive you felt the navigation scheme was.	3.77	0.60	0.26

3. Rate the frequency with which you used each navigation scheme:	Not at All		Some-time		Most of the Time	No An-swer
(a) Next Page/Previous Page and Map buttons	0	0	3	9	9	0
(b) Map, Section, and Sub-section buttons	2	3	6	6	4	0
(c) Index Page	8	7	2	3	1	0
(d) Quick Look Pages	9	7	3	2	0	0
(e) Search Button	14	4	2	1	0	0

4. Which method of navigation did you prefer most?	
(a) Next Page/Previous Page and Map buttons	7
(b) Map, Section, and Sub-section buttons	8
(c) Index Page	3
(d) Quick Look Pages	1
(e) Search Button	2
No Preference	0

Overall Effectiveness of the Courseware	Average	Standard Deviation	Confidence 95%
1. Rate the Overall Effectiveness of the courseware.	3.69	0.63	0.28
2. Rate how much the courseware contributed to your understanding the lab as a whole.	3.15	1.14	0.50
3. Rate how much the courseware contributed to your understanding your lab preparation (Homework #5) assignment.	3.15	1.41	0.61
4. Rate the GENERAL usefulness of these sections:			
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	3.15	1.14	0.50
Apparatus description and background information	3.31	1.11	0.48
Apparatus calibration and set-up information	3.38	1.33	0.58
Assignment and Experiment Planning	2.46	1.39	0.61
5. Rate the LAB PREPARATION usefulness of these sections:			
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	3.38	0.77	0.34
Apparatus description and background information	3.54	0.66	0.29
Apparatus calibration and set-up information	3.38	0.96	0.42
Assignment and Experiment Planning	3.00	1.22	0.53

6. Rate the LAB usefulness of these sections:			
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	3.08	0.49	0.22
Apparatus description and background information	3.31	0.75	0.33
Apparatus calibration and set-up information	3.77	0.73	0.32
Assignment and Experiment Planning	2.85	1.21	0.53
7. Rate the POST-LAB usefulness of these sections:			
Theory (Spring-Mass-Dashpot, Beam Theory, etc.)	2.62	1.66	0.72
Apparatus description and background information	2.31	1.55	0.68
Apparatus calibration and set-up information	2.31	1.55	0.68
Assignment and Experiment Planning	1.92	1.44	0.63
8. The courseware helped me:			
Understand lecture better	3.38	0.87	0.38
Finish the homework faster	3.23	0.93	0.40
Understand the lab better	3.69	0.85	0.37
Analyze the lab data better	3.23	1.24	0.54
Write a better lab report	2.77	1.36	0.60

Content Quality and Accessibility

1. Rate the overall depth of material. Was there sufficient content?	2.92	0.64	0.28
2. Rate how often you found yourself looking at the "It can be shown that . . . " sections	3.00	0.82	0.36
3. Rate how useful you found the Mathcad links.	2.54	1.56	0.68
4. Rate how much the Mathcad links improved your understanding of the material.	2.31	1.32	0.57
5. Rate how easy it was to find information about performing the calibration of the strain gauges.	3.54	0.88	0.38
6. Rate how easy it was to find information realting the strain at the surface of the beam to the tip displacement.	3.54	0.88	0.38
7. Rate the depth of material about performing the calibration of the strain gauges.	2.46	0.78	0.34
8. Rate the depth of material about relating the strain at the surface of the beam and the tip displacement.	2.31	0.85	0.37

Motivation

1. Rate how much you used the courseware.	3.46	0.78	0.34
2. I plan to use the courseware after the Homework is due to help write-up my Lab.	3.77	1.09	0.48
3. I used the courseware because:			
I wanted a better score on the homework.	4.15	1.46	0.64
I wanted to get a better score on my Lab Report	3.77	1.64	0.72
I wanted to understand the Homework better.	3.92	1.55	0.68
I wanted to understand the Material better.	4.31	1.03	0.45

Appendix F - Fall 1994 Navigation Audit Trail

F.1 Overall Usage

	Overall	Before 11/10/94	After 11/11/94
Total Use Duration (minutes)	10620.92	8970.73	1650.18
Total Use Duration (hours)	177.02	149.51	27.50
Average Use Duration per Access (minutes)	40.69	44.41	27.97
Average Use Duration per Person (minutes)	131.12	110.75	20.37
Accesses	261	202	59
Average Number of Access per Person	3.22	2.49	0.73

Total Number of Accesses	10544
Number Excluded Accesses	84
Number Included Accesses	10460
% Excluded Accesses	0.80%
% Included Accesses	99.20%

F.2 Usage by Area

	Duration (minutes)	Accesses	Duration %	Accesses %
Welcome	236.85	503	2.23%	4.81%
Lab Room	319.27	613	3.01%	5.86%
Index	616.75	1102	5.81%	10.54%
Quick Look	550.07	345	5.18%	3.30%
Map Page	0.00	0	0.00%	0.00%
It Can Be Shown That . . .	38.77	492	0.37%	4.70%
About this Book	14.83	31	0.14%	0.30%
Apparatus Map and Sub-Sections	2968.77	2901	27.95%	27.73%
Theory Map and Sub-Sections	5161.70	3541	48.60%	33.85%
Assignment and Sub-Sections	486.78	617	4.58%	5.90%
Misc.	227.13	315	2.14%	3.01%
	10620.92	10460	100.00%	100.00%

Note: This Data Includes All Accesses

F.3 Usage by Map and Section

Map #	Section #	Description	Duration	Accesses	Time per Access
0	0	Misc.	224.60	288	4.06
0	0	Welcome	236.85	503	0.47
0	0	Lab Room	319.27	613	0.52
0	0	Index	616.75	1102	0.56
0	0	Quick Look	550.07	345	5.03
0	0	Read Only Pop-up (ICBST)	38.77	492	0.08
0	0	About this Book	14.83	31	0.48
1	1	Apparatus Map	205.75	461	1.97
1	11	Strain Gauge	499.47	722	8.57
1	12	LVDT	287.07	513	5.25
1	13	Accelerometer	968.30	681	14.61
1	14	Velocimeter	1008.18	524	19.03
2	0	Theory Map	87.80	433	0.20
2	21	Modelling the System	738.33	390	5.64
2	22	Free Vibration	1301.27	372	5.42
2	23	Forced Vibration	915.58	280	9.83
2	24	Beam Theory	427.93	731	3.47
2	25	Determining Sys. Parameters	1690.78	1335	18.36
3	0	Assignment	98.42	112	0.88
3	31	Experiment Planning	388.37	505	4.64
4	0	Quiz Index	2.53	27	0.42
			10620.92	10460	

F.4 Button Used to Leave Page

Navigation Type	Quantity	Percentage	Description
Hotword - General	0	0.00%	Hotword - Section page contents, derivations references
Hotword ICBST	265	2.51%	Hotword - It Can Be Shown That
Index Page to Other Pages	976	9.26%	Index Page to Other Pages
Left Navigation	619	5.87%	Lab Room, Map and Section buttons
Map Navigation	928	8.80%	Lab Room to Map, Map to Section
Map Page	0	0.00%	Map Page to Lab Room, Maps, and Sections
MathCad Link	86	0.82%	To MathCad
Middle Navigation	767	7.27%	Sub-section buttons
Misc.	625	5.93%	MathCad, Quiz, To Video page, Welcome Page to Lab Room, Options
Quick Look to Pages	0	0.00%	Quick Look to Other Pages
Right Navigation	3962	37.58%	Next, Previous, and Back buttons
Top Button Bar	1148	10.89%	About, Exit, History, Search, Index, Quick Look
Unidentified	1168	11.08%	Nothing Saved by Toolbook (many may be Hotwords)
	10544	100.00%	

Appendix G - Spring 1995 Navigation Audit Trail

G.1 Overall Usage

	Overall	Before 3/3/95	After 3/4/95
Total Use Duration (minutes)	3545.48	1418.63	2126.85
Total Use Duration (hours)	59.09	23.64	35.45
Average Use Duration per Access (minutes)	43.24	41.72	44.31
Average Use Duration per Person (minutes)	90.91	36.38	54.53
Accesses	82	34	48
Average Number of Access per Person	2.10	0.87	1.23

G.2 Usage by Area

	Duration (minutes)	Accesses	Duration %	Accesses %
Welcome	38.71	159	1.09%	4.53%
Lab Room	152.26	323	4.29%	9.20%
Index	42.87	112	1.21%	3.19%
Quick Look	237.52	25	6.70%	0.71%
Map Page	28.76	142	0.81%	4.05%
It Can Be Shown That . . .	1.12	6	0.03%	0.17%
About this Book	1.74	61	0.05%	1.74%
Apparatus Map and Sub-Sections	7.44	17	0.21%	0.48%
Theory Map and Sub-Sections	2059.68	1787	58.09%	50.93%
Assignment and Sub-Sections	891.11	809	25.13%	23.06%
Misc.	62.9	54	1.77%	1.54%
	21.37	14	0.60%	0.40%
	3545.48	3509	100.00%	100.00%

Note: This Data Includes All Accesses

G.3 Usage by Map and Section

Map #	Section #	Description	Duration	Accesses	Time per Access
0	0	Misc.	21.37	14	1.53
0	0	Welcome	38.71	159	0.24
0	0	Lab Room	152.26	323	0.47
0	0	Index	42.87	112	0.38
0	0	Quick Look	237.52	25	9.50
0	0	Map 00 0	28.76	142	0.20
0	0	Mathcad Documents 00 0	1.12	6	0.19
0	0	Read Only Pop-up (ICBST)	1.74	61	0.03
0	0	About this Book	7.44	17	0.44
1	1	Apparatus Map	51.45	217	0.93
1	11	Strain Gauge	739.84	577	13.29
1	12	LVDT	317.37	335	8.01
1	13	Accelerometer	632.81	370	15.99
1	14	Velocimeter	318.21	288	8.47
2	0	Theory Map	29.63	166	0.18
2	21	Modelling the System	102.27	81	2.76
2	22	Free Vibration	148.63	87	4.31
2	23	Forced Vibration	120.3	94	6.54
2	24	Beam Theory	116.09	108	3.55
2	25	Determining Sys. Parameters	198.45	180	7.27
2	26	Stress/Strain Relationship 26 2	175.74	93	4.13
3	0	Assignment	62.9	54	1.16
			3545.48	3509	

G.4 Button Used to Leave Page

Navigation Type	Quantity	Percentage	Description
Hotword - General	65	0.46%	Hotword - Section page contents, derivations references
Hotword ICBST	41	2.17%	Hotword - It Can Be Shown That
Index Page to Other Pages	72	7.45%	Index Page to Other Pages
Left Navigation	357	6.93%	Lab Room, Map and Section buttons
Map Navigation	489	10.07%	Lab Room to Map, Map to Section
Map Page	121	0.86%	Map Page to Lab Room, Maps, and Sections
MathCad Link	4	0.64%	To MathCad
Middle Navigation	413	8.38%	Sub-section buttons
Misc.	303	6.59%	MathCad, Quiz, To Video page, Welcome Page to Lab Room, Options
Quick Look to Pages	2	0.01%	Quick Look to Other Pages
Right Navigation	1187	36.58%	Next, Previous, and Back buttons
Top Button Bar	327	10.48%	About, Exit, History, Search, Index, Quick Look
Unidentified	151	9.37%	Nothing Saved by Toolbook (many may be Hotwords)
	3532	100.00%	

G.2 Usage by Area

	Duration (minutes)	Accesses	Duration %	Accesses %
Welcome	38.71	159	1.09%	4.53%
Lab Room	152.26	323	4.29%	9.20%
Index	42.87	112	1.21%	3.19%
Quick Look	237.52	25	6.70%	0.71%
Map Page	28.76	142	0.81%	4.05%
It Can Be Shown That . . .	1.12	6	0.03%	0.17%
About this Book	1.74	61	0.05%	1.74%
Apparatus Map and Sub-Sections	7.44	17	0.21%	0.48%
Theory Map and Sub-Sections	2059.68	1787	58.09%	50.93%
Assignment and Sub-Sections	891.11	809	25.13%	23.06%
Misc.	62.9	54	1.77%	1.54%
	21.37	14	0.60%	0.40%
	3545.48	3509	100.00%	100.00%

Note: This Data Includes All Accesses

G.3 Usage by Map and Section

Map #	Section #	Description	Duration	Accesses	Time per Access
0	0	Misc.	21.37	14	1.53
0	0	Welcome	38.71	159	0.24
0	0	Lab Room	152.26	323	0.47
0	0	Index	42.87	112	0.38
0	0	Quick Look	237.52	25	9.50
0	0	Map 00 0	28.76	142	0.20
0	0	Mathcad Documents 00 0	1.12	6	0.19
0	0	Read Only Pop-up (ICBST)	1.74	61	0.03
0	0	About this Book	7.44	17	0.44
1	1	Apparatus Map	51.45	217	0.93
1	11	Strain Gauge	739.84	577	13.29
1	12	LVDT	317.37	335	8.01
1	13	Accelerometer	632.81	370	15.99
1	14	Velocimeter	318.21	288	8.47
2	0	Theory Map	29.63	166	0.18
2	21	Modelling the System	102.27	81	2.76
2	22	Free Vibration	148.63	87	4.31
2	23	Forced Vibration	120.3	94	6.54
2	24	Beam Theory	116.09	108	3.55
2	25	Determining Sys. Parameters	198.45	180	7.27
2	26	Stress/Strain Relationship 26 2	175.74	93	4.13
3	0	Assignment	62.9	54	1.16
			3545.48	3509	

G.4 Button Used to Leave Page

Navigation Type	Quantity	Percentage	Description
Hotword - General	65	0.46%	Hotword - Section page contents, derivations references
Hotword ICBST	41	2.17%	Hotword - It Can Be Shown That
Index Page to Other Pages	72	7.45%	Index Page to Other Pages
Left Navigation	357	6.93%	Lab Room, Map and Section buttons
Map Navigation	489	10.07%	Lab Room to Map, Map to Section
Map Page	121	0.86%	Map Page to Lab Room, Maps, and Sections
MathCad Link	4	0.64%	To MathCad
Middle Navigation	413	8.38%	Sub-section buttons
Misc.	303	6.59%	MathCad, Quiz, To Video page, Welcome Page to Lab Room, Options
Quick Look to Pages	2	0.01%	Quick Look to Other Pages
Right Navigation	1187	36.58%	Next, Previous, and Back buttons
Top Button Bar	327	10.48%	About, Exit, History, Search, Index, Quick Look
Unidentified	151	9.37%	Nothing Saved by Toolbook (many may be Hotwords)
	3532	100.00%	

Appendix H - Fall 1994 and Spring 1995 Survey Results Compared

This Appendix presents the averages, standard deviations, and confidence values for the survey results for Fall 1994 and Spring 1995. It also examines the averages to see if the difference in values between Fall 1994 and Spring 1995 are significantly different.

The values are significantly different if the Average+Confidence(Error) and the Average-Confidence(Error) ranges for Fall 1994 and Spring 1995 do not overlap. This is done with a 95% confidence level (= standard deviation /(2 * Number of values)). In the far right hand column a code of No means that the results are not significantly different and a code of CC means that the results cannot be compared (because of the way the questions are worded).

Please reference Appendices D and E for wording for the questions listed here.

	Fall 1994					Spring 1995					
	Average	Standard Deviation	Confid.	Ave+Err	Ave-Err	Average	Standard Deviation	Confid.	Ave+Err	Ave-Err	Different ?
Q1	3.66	0.90	0.23	3.89	3.43	4.08	0.76	0.33	4.41	3.75	No
Q2	3.34	0.97	0.25	3.59	3.09	3.77	0.60	0.26	4.03	3.51	No
Q3a	-	-	-	-	-	-	-	-	-	-	CC
Q3b	-	-	-	-	-	-	-	-	-	-	CC
Q3c	-	-	-	-	-	-	-	-	-	-	CC
Q3d	-	-	-	-	-	-	-	-	-	-	CC
Q3e	-	-	-	-	-	-	-	-	-	-	CC
Q4	-	-	-	-	-	-	-	-	-	-	CC
Q1	3.66	0.81	0.21	3.87	3.46	3.69	0.63	0.28	3.97	3.42	No
Q2	3.69	0.86	0.22	3.91	3.47	3.15	1.14	0.50	3.65	2.65	No
Q3	3.89	0.96	0.24	4.13	3.64	3.15	1.41	0.61	3.77	2.54	No
Q4a	3.53	1.10	0.28	3.81	3.25	3.15	1.14	0.50	3.65	2.65	No
Q4b	3.23	1.12	0.29	3.51	2.94	3.31	1.11	0.48	3.79	2.82	No
Q4c	3.31	1.22	0.31	3.62	3.00	3.38	1.33	0.58	3.96	2.81	No
Q4d	2.95	1.18	0.30	3.25	2.65	2.46	1.39	0.61	3.07	1.85	No
Q5a	3.65	1.15	0.29	3.94	3.35	3.38	0.77	0.34	3.72	3.05	No
Q5b	3.10	1.18	0.30	3.40	2.80	3.54	0.66	0.29	3.83	3.25	No
Q5c	3.26	1.30	0.33	3.59	2.93	3.38	0.96	0.42	3.80	2.97	No
Q5d	3.05	1.36	0.35	3.39	2.70	3.00	1.22	0.53	3.53	2.47	No
Q6a	3.29	1.16	0.30	3.59	2.99	3.08	0.49	0.22	3.29	2.86	No
Q6b	3.29	1.15	0.29	3.58	3.00	3.31	0.75	0.33	3.64	2.98	No
Q6c	3.48	1.29	0.33	3.81	3.16	3.77	0.73	0.32	4.09	3.45	No
Q6d	2.98	1.29	0.33	3.31	2.66	2.85	1.21	0.53	3.38	2.32	No
Q7a	2.60	1.82	0.46	3.06	2.13	2.62	1.66	0.72	3.34	1.89	No
Q7b	2.19	1.59	0.40	2.60	1.79	2.31	1.55	0.68	2.98	1.63	No
Q7c	2.37	1.74	0.44	2.81	1.93	2.31	1.55	0.68	2.98	1.63	No
Q7d	2.08	1.62	0.41	2.49	1.67	1.92	1.44	0.63	2.55	1.29	No
Q8a	3.27	0.94	0.24	3.51	3.03	3.38	0.87	0.38	3.76	3.01	No

Q8b	3.81	1.17	0.30	4.10	3.51	3.23	0.93	0.40	3.64	2.83	No
Q8c	3.76	0.97	0.25	4.00	3.51	3.69	0.85	0.37	4.07	3.32	No
Q8d	2.76	1.68	0.43	3.18	2.33	3.23	1.24	0.54	3.77	2.69	No
Q8e	2.35	1.66	0.42	2.78	1.93	2.77	1.36	0.60	3.36	2.17	No
Q1a	3.13	0.97	0.25	3.37	2.88	2.92	0.64	0.28	3.20	2.64	No
Q2	3.13	1.12	0.29	3.41	2.84	3.00	0.82	0.36	3.36	2.64	No
Q3	4.06	1.07	0.27	4.34	3.79	2.54	1.56	0.68	3.22	1.86	Yes
Q4	3.81	1.16	0.29	4.10	3.51	2.31	1.32	0.57	2.88	1.73	Yes
Q5	3.56	1.11	0.28	3.85	3.28	3.54	0.88	0.38	3.92	3.16	CC
Q6	3.66	1.14	0.29	3.95	3.37	3.54	0.88	0.38	3.92	3.16	CC
Q7	2.87	0.95	0.24	3.11	2.63	2.46	0.78	0.34	2.80	2.12	CC
Q8	3.10	1.00	0.25	3.35	2.84	2.31	0.85	0.37	2.68	1.93	CC
Q9	2.87	1.35	0.34	3.21	2.53	-	-	-	-	-	CC
Q1	-	-	-	-	-	3.46	0.78	0.34	3.80	3.12	CC
Q2	-	-	-	-	-	3.77	1.09	0.48	4.25	3.29	CC
Q3a	-	-	-	-	-	4.15	1.46	0.64	4.79	3.52	CC
Q3b	-	-	-	-	-	3.77	1.64	0.72	4.49	3.05	CC
Q3c	-	-	-	-	-	3.92	1.55	0.68	4.60	3.25	CC
Q3d	-	-	-	-	-	4.31	1.03	0.45	4.76	3.86	CC