THE DEVELOPMENT OF THE "STRUCTURAL CONCEPTS LEARNING MODULE (SCLM)"

by

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B.A.Sc., Civil Engineering, The University of British Columbia, 2001

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF APPLIED SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

Department of Civil Engineering

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

March 2003

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ABSTRACT

When drafting their teaching curriculum for structural courses, instructors of civil engineering and architectural courses rely heavily on learning tools as an extra curricular component or accompaniment. These instructors desire tools that are interactive and supported by a computer-based environment. However, despite the large selection of learning tools in the market, there are only a few fulfill these requirements. The “Structural Concepts Learning Module” (SCLM) was created with regard to several critical aspects which must be considered when building a web-based interactive learning tool. The SCLM designer assembled key positive features from existing structural learning tools and developed methodologies to create an educational environment that is able to enhance structural understanding through self-learning as well as sharpen students’ autonomy and sense of responsibility in their own learning process. The SCLM was based on three principal elements. Firstly, an educational theory, known as Constructivism, was chosen to be the SCLM development scaffold. The second principal element is comprised of three distinct aspects of learning: interactive, visual, and computer-based learning. Each of these aspects possesses distinct learning objectives that, when connected with the other two, contribute to the module construction. The last principal element is the module content which consists of the fundamental concepts that are taught in structural classes, such as “Engineering Mechanics”, “Structural Behaviour”, “Structural Systems”. When designing SCLM’s visual appearance, specific criteria were established in regard to the selection of colours, fonts, and graphics. Two software programs, RoboHelp and Macromedia Flash, were chosen as the main tools to construct the module interface as well as the interactive components. The interface is divided into a certain number of frames and each frame contains elements that assist module users. The interactive teaching components include animation clips, interactive charts, and interactive illustrations, while the interactive practicing components include true or false, multiple choice, fill in the blank, hot object, drag and drop, and hot spot. At present, there was no actual testing done to evaluate SCLM’s effectiveness and the module can only run in computers with Windows 95m or more up-to-date versions installed. Nonetheless, there are no limitations for further improving this module.
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ACKNOWLEDGEMENT

I would like to thank my thesis supervisor, Professor S.F. Stiemer, for directing me towards this interesting study. His invaluable guidance and encouragement made this project possible.

I would also like to thank Professor S. Taylor, from the School of Architecture, for giving me great assistance during the development this project.

In addition, I would like to acknowledge my friends, Sunita Wiebe and Joyce Tung, for providing great support by evaluating my work. I am very grateful to my family for making my studies and education possible.
Chapter 1 Introduction

1.0 INTRODUCTION

1.1 Background

In the schools of structural engineering and architecture, instructors put great effort into seeking appropriate learning tools that will improve the quality of their teaching as well as the quality of their students' education. They are often interested in tools that contain interactive characteristics and are supported by a computer-based environment. These learning tools can be obtained through various methods. For example, some structural textbooks provide corresponding software and encourage instructors to use the software academically, while some instructors receive recommendations from their colleagues on the kinds of teaching-learning tools available. According to Struchiner (1996), the right kind of interactive learning tools allows users to control their choice of information and working rhythm, while promoting different learning styles and preferences. Additionally, research demonstrates that interactive multimedia technology helps students retain more knowledge and learn about 30 to 50% faster than on average (Stiemer, 1996). However, despite the large selection of learning tools, there are only few which perform the functions that users want (Zoghi, 2000). Many instructors who teach structural courses are frustrated when using unsuitable teaching software which, ironically, claims to be interactive and easy to use. In fact, many existing tools for structural learning lack well-explained and guided context, instructive content, and/or practice opportunities for students.

1.2 Purpose and Methodology

This thesis examines the building of a web-based interactive learning unit, named “Structural Concepts Learning Module” (SCLM), for both structural and architectural students. In order to accomplish this objective, the designer of this module needed to achieve the following goals:
Chapter 1 Introduction

- Gather positive attributes about existing teaching-learning tools and develop methodologies that can accommodate these positive features.
- Build a learning environment that can assist in and encourage self-learning.
- Employ RoboHelp and Macromedia Flash to create a user-friendly interface as well as interactive components.
- Test different visual design criteria and determine whether or not they suit the educational purpose of structural engineering courses.
- Design practical activities and supplementary interactive exercises to provide students with frequent opportunities to test their understandings.

1.3 Theoretical Framework

Constructivism is a well-known educational theory that serves as the backbone of the SCLM. This educational theory was chosen to be the scaffold for the development of the SCLM because it best suits the goals of engineering education. Constructivism’s influence on the SCLM can be felt in three areas: curriculum, instruction, and assessment. The SCLM was also structured with three distinct aspects of learning in mind: interactive learning, visual learning, and computer-based learning. Interactive learning allows users to select learning material and customize working patterns in accordance with the possibilities offered by the SCLM. Visual learning utilizes graphical elements to strengthen the meaning of a principle, replace a lengthy paragraph, and eliminate wordiness. Computer-based learning promotes the use of technologies to provide support to visual and interactive learning, as well as the use of the Internet to support an informative route between students and educators. Each learning aspect not only has its own distinctive theories, but also relies on the other two aspects during the module development.
1.4 Overview

This thesis presents a detailed discussion of the SCLM development. There is a total of six chapters and chapter 2 to 5 are organized as follows.

Chapter 2, *Literature Review on Computer-Based Learning Tools*, investigates the positive and negative attributes of seven learning units that were designed to provide didactic support in structural engineering education. The module designer amalgamated the positive features of these learning units and implemented them into the SCLM. The examined tools are divided into three main categories:

- Structural modeling simulators:
  - Dr. Software – Dr. Beam and Dr. Frame;
  - West Point Bridge Designer.

- Learning tools packaged with textbooks:
  - “Mathcad Student CD” for *Mechanics of Materials* (Bedford and Liechti, 2002)

- Web-based learning tools:
  - Study site for *Engineering Mechanics* (Bedford and Fowler, 2002)
  - “Teaching concepts utilizing active learning computer environments”
    (Shepherdson, 2001)
  - “Architectonics” (Luebkmam, 2001)

Chapter 3, *Planning*, explains the three SCLM principal elements: module philosophy, module learning aids, and module content. Constructivism is the module philosophy, while interactive learning, visual learning, and computer-based learning are the module learning aids. The module content includes the fundamental concepts that structural engineering and architectural students are required to learn. The SCLM covers four main structural concepts:
Chapter 1 Introduction


Chapter 4, Visual Elements, describes the visual design criteria for the SCLM development. Colours, fonts, and graphics were carefully selected, according to guidelines drawn from research done on website design, to perform specific function or accommodate different requirements. The general module page layout consists of five separate frames named “Top”, “Bottom Left”, “Centre”, “Centre Right”, and “Bottom Right”. Each frame contains buttons, tabs, a dropped down list, and/or navigating tools for operating the module. This chapter also discusses the page layout of a photo gallery used in the module.

Chapter 5, Interactive Element Design, discusses the software programs, including RoboHelp and Macromedia Flash, that were chosen as the main construction tools for the SCLM and the technological concerns in the module development. Additionally, this chapter describes explicitly the presentations of all the interactive teaching and practicing components in the SCLM. The interactive teaching components can be categorized into three kinds: animation clips, interactive charts, and interactive illustrations. On the other hand, there are six types of interactive practice components: true or false, multiple choice, fill in the blank, hot object, drag and drop, hot spot.

SCLM is an end product of this research. Engineering and architectural students, as well as other people who are interested in this research work, are welcome to download it from http://sigi.civil.ubc.ca/mabel http/SCLM/SCLM.chm.
2.0 LITERATURE REVIEW ON COMPUTER-BASED LEARNING TOOLS

Various attempts have been made to deal with the need for teaching structural concepts and behaviour to engineering and architectural students. In recent years, many computer-based educational tools launched the market and claim that they are able to help students and instructors to learn and teach structural understanding. This chapter conducts a detailed investigation into the current teaching-learning tools available in structural education; both pros and cons are included. The tools are divided into three main categories: 1) structural modeling simulators, 2) learning tools packaged with textbooks, and 3) web-based learning tools.

Section 2.1, Structural Modeling Simulators, investigates educational applications which have the ability to provide a hands-on experience for designing structures such as a beam, frame, and truss in a computer-based environment. However, they are unable to provide beneficial guidance for users as they are building structural model with these tools. Simulators discussed include Dr Software and West Point Bridge Designer.

Section 2.2, Learning Tools Packaged with Textbooks, examines two learning tools packaged with textbooks. “Mathcad Student CD” for Mechanics of Materials (Bedford and Liechti, 2002) contains 15 pre-selected computational examples for students to study, but the content in the CD-ROM is fixed and cannot be updated. “Working Model 2D” for Engineering Mechanics (Bedford and Fowler, 2002) offers practice opportunities to model many structural systems, but the price of the textbook along with the software is high and may cost more than a student can afford.

Section 2.3, Web-Based Learning Tools, evaluates three websites that support structural learning. Study site for Engineering Mechanics (Bedford and Fowler, 2002) provides a well-facilitated online platform for educational purpose, but it misuses technologies to teach in the traditional fashion. “Teaching concepts utilizing active learning computer environments” (Shepherdson, 2001) is a Ph.D. research project that proposes the approach to build an
interactive computer-aided learning module. However, there are flaws about the visual and content design in the module. “Architectonics” (Luebkeman, 2001) is a website covering most of the basic structural concepts that a senior architectural student should learn. The structural analysis applications available in this website are written in java script, which may cause some technical limitations in the applications.

2.1 Structural Modeling Simulators

This section talks about structural modeling simulators, two examples are studied: Dr. Software and West Point Bridge Designer.

2.1.1 Dr. Software- Dr. Beam and Dr. Frame

- Relevant Link: http://www.drbeam.com/
- Company/Vendor: Dr. Software
- Description: Beam and frame analysis software
- Platforms: Windows and Mac operating systems
- Target users: Junior civil engineering and senior architectural students

“Dr. Beam” and “Dr. Frame” are real-time structural modeling simulators that allow direct manipulation of beam bending behaviour, model truss, and frame structures. “Dr. Beam” and “Dr. Frame” are of interest to instructors and students who want to explore the engineering and architectural principles of beams and frames. These programs allow users to construct structural systems with different support conditions, load settings, and material properties, and to assess the structure’s behaviour under the designated condition. The results include simplistic representations of structure deflection, bending moment diagrams, and shear force diagrams. These diagrams are updated instantly so users can clearly see the effects of the changes on the structure.
There are some imperfections in the software. One major problem is that while the software provides an on-line help system for the simulation, it does not direct users with step-by-step instructions. Instead, the help system provides information for users to search for when they encounter problems. The users may thus experience the sense of being thrown into deep water and learning how to swim themselves. Science Man, a web site devoted to assessing and evaluating software, conducts an assessment on Dr. Beam and says: “Dr. Beam” has a great set of pages for on-line help... but Dr. Beam is kind of hard to get the hang of; I'd like to see the help system integrated with the program. The biggest problem is learning to use all of the tools;” (Science Man, 2002) As shown in Figure 2.1, there is a large selection of modeling devices available for constructing a beam or frame; however, without proper instruction, users may need hours to self-learn ways of using these tools.

Figure 2.1: Screen shot of Dr. Software toolbar.
Chapter 2 Literature Review on Computer-Based Learning Tools

- Screen shots:

Figure 2.2: Screen shot of Dr. Software: Dr. Beam
2.1.2 West Point Bridge Designer

- Relevant Link: http://bridgecontest.usma.edu/index.htm
- Company/Vendor: United States Military Academy at West Point
- Description: Bridge stability analysis software
- Platforms: Windows
Chapter 2 Literature Review on Computer-Based Learning Tools

- Target users: Junior civil engineering students

The West Point Bridge Designer is a computer-aided design (CAD) software package developed to introduce students to bridge construction through the design of a steel highway bridge. The software provides a computerized civil engineering design experience that demonstrates how practicing engineers design a truss bridge. Each year, the United States Military Academy at West Point holds a bridge design contest and encourages students from different institutes to participate. Given a realistic set of design specifications, including the location of the proposed bridge, material used, budget restrictions, etc., contestants use the software to construct a bridge, test it for structural adequacy, and optimize it to minimize cost. The analysis includes a 3-D animation of the load test, which shows a truck drives across the bridge, and detailed structural results including the maximum internal force, tensile strength, compressive strength, actual computed displacement, and the cost of every member in the bridge model. As loads are applied on the structural members, they change color according to their internal forces: blue and red for tension and compression respectively. Plus, color intensity based on the relationship of the magnitude of each member's force-to-strength ratio is included. The 3-D animation indicates how the load is transferred and how heavily each member is loaded. If the truss members are strong enough to withstand the loads, the truck crosses the bridge successfully. But if any member is inadequate, that member fails at the appropriate point during the animation, and the entire structure collapses into the river (Ressler, 2000).

This software provides an enjoyable experience for designing truss bridges in a computer-based environment. However, it is unable to provide helpful guidance for students as they undergo the building experience. Despite being given structural criteria, the students have to start constructing a truss bridge from scratch. They may not know whether or not the bridge can withstand the given load condition until a load test is generated and indicates which part of the truss fails. Users, especially beginners, may feel lost when building a truss bridge, particularly because they have to choose the structural members themselves. The software neither gives clues to users to help them make a structurally sound choice, nor encourages reflective conceptual thought by highlighting key observations (Shepherdson, 2001).
"trial and error" method is basically the technique of building a truss bridge in the West Point Bridge Designer software, but this method is not acceptable in real engineering practice.

Like "Dr. Beam" and "Dr. Frame", "West Point Bridge Designer" is also a simulation. The flaw is that these programs do not ensure effective learner engagement by providing strategic guidance and informative feedback specific to the student and his or her actions. Furthermore, these examples do not explicitly encourage conceptual observations to strengthen structural knowledge. Although the software tries to model a real world structural situation, it still lacks stimulating connections to practical design experiences.

Njoo and de Jong (1992), and Goodyear (1990) conducted research on computer-based learning studies that support such complaints. These simulators are useful for experienced students to model their structural systems, but unsuitable for beginning students who are learning fundamental structural concepts because these simulators do not provide an in-depth structural knowledge overview. Shepherdson (2001) has conducted a research recently on various structural software, including Dr. Software and West Point Bridge Design, and discovered the following: "These examples do not explicitly encourage conceptual observations to better build the intuition of the expert," thus, they should act as supplements or extra practices to regular classroom material.
Chapter 2 Literature Review on Computer-Based Learning Tools

- Screen shot:

Figure 2.4: Screen shot of West Point Bridge Designer.

2.2 Learning Tools Packaged with Textbooks

This section talks about the learning tools which packaged with structural textbooks, two examples are studied: Mathcad Student CD for Mechanics of Materials and Working Model Software (WM2D) for Engineering Mechanics.
2.2.1 Mathcad Student CD for Mechanics of Materials

- Relevant Link: http://cwx.prenhall.com/bookbind/pubbooks/bedford/
- Company/Vendor: Bedford, Liechti, and MathSoft
- Description: Mathcad worksheets on a CD
- Platforms: Windows and Mac operating systems
- Target users: Junior civil engineering students

The CD-ROM included with the textbook, Mechanics of Materials, includes 15 build-in Mathcad\(^1\) worksheets on pre-selected examples and problems on mechanics of common structural materials. Users are able to change the magnitude of the material properties, dimensions, and design parameters of the pre-designed structural systems, and then observe how the results are altered. However, because this courseware is distributed on a CD-ROM, there is a limited amount of examples and information for students to explore; additionally, the illustration is static, content is fixed, and the CD-ROM cannot be updated. According to Buchal (1996), courseware like this is rooted to the old model of learning and is frequently criticized as being no more than a "talking textbook". Like a textbook, the number of chapters, case studies, examples, and exercises in the CD-ROM is fixed and cannot be expanded. The amount of interaction and exploration is limited to carefully linear and prescribed paths. It lacks the flexible characteristic of a web-based learning environment which allows multimedia supports and constant update. Although those Mathcad worksheets are able to generate accurate structural results, they do not tell users much about the associate structural situation which the users are modeling. The existence of such learning tool is not important because it does not help students to understand basic structural concepts.

\(^1\) "Mathcad", which is a popular engineering software which allows students to compute complex mathematical problems precisely and conveniently.
Chapter 2 Literature Review on Computer-Based Learning Tools

- Screen shot:

![Worksheet 12: Example 9.1](image)

This example is concerned with the calculation of beam deflection. Appropriate boundary conditions are applied such that the solution conforms to certain values at specific locations along the beam. This example can be used to solve a number of problems in Section 9.1. These include Problems 9-1.1, 9-1.2, 9-1.3, 9-1.4, 9-1.9, 9-1.10, 9-1.11, 9-1.12, and 9-1.13.

**Statement**

The beam in the figure below consists of material where the modulus of elasticity is $E$, the moment of inertia of its cross section is $I$, and the length is $L$. What is the deflection at the right end of the beam?

![Figure 2.5: Screen shot of Mathcad Student CD.](image)

2.2.2 Working Model Software (WM2D) for *Engineering Mechanics*

- Relevant Link: [http://www.workingmodel.com/](http://www.workingmodel.com/)
- Companies/Vendors: Bedford, Fowler, and MSC.Software
- Description: Structural modeling examples demonstrated in WM2D
- Platforms: Windows, and Mac operating systems with a CD Rom Drive
Target users: Junior civil engineering students

The textbook is packaged with WM2D in a CD which contains pre-set simulations of textbook examples. The CD offers students extra practice and opportunities to explore engineering mechanics. Simulations are powered by the Working Model Engine and are created with similar illustrations from the text. The software is able to model and analyze various pre-designed structural situations conveniently. For example, the user is able to alter the configuration of the system by switching a dial to increase the load acting on a location of the structural system. The software generates an analysis as well as a movie clip that shows the structural behaviour of the system (Bedford and Fowler, 2002). See Figure 2.6 for an illustration of WM2D.

WM2D is well-designed software that enables students to conduct structural analysis for static and dynamic systems; however, this software is quite expensive. Depending on the version of the product, the price ranges from $350US to $1500US (Working Model, 2002). Textbooks with similar supplementing software are usually high-priced and sometimes cost more than a student can afford. Only students who can afford the price of the textbook have the opportunity to benefit by using this software.
2.3 Web-Based Learning Tools

This section talks about previously developed web-based learning tools, three examples are studied: a study site for *Engineering Mechanics*, a learning module developed by a Ph.D. student, and Architectonics.
2.3.1 Study Site for Engineering Mechanics

- Relevant Link: http://cwx.prenhall.com/bookbind/pubbooks/bedford2/
- Company/Vendor: Bedford and Fowler
- Description: Study site
- Platforms: Web browsers such as Internet Explorer and Netscape
- Target users: Junior civil engineering students

This web site is restricted to the student who receives the access code provided by the textbook or by his or her instructor. The web site contains 500 engineering mechanics problems, with the corresponding solutions, for instructors to choose from and provides a variety of online practices based on the content of the textbook. Additionally, the web site provides a grading system for instructors to record student performance in an online grade book for class credit. The instructor selects a set of questions and establishes the rules that govern the assignment. This online assignment offers immediate scoring and can be configured to provide personal feedback to the students about their achievement. In addition, the site contains an unprotected public section with multiple choice and true/false questions. These practices can be used as self-study sessions as the user logs onto the web site anonymously (Bedford and Fowler, 2002).

Computers and information technology offer many tools necessary to supporting student-centered learning. A web site provides a well-facilitated online platform for instructors to teach and for students to learn. However, some technologies are used to buttress the traditional educational model, which is a teaching-centered environment that promotes passive information absorption. The study site offered by Bedford and Fowler is an undesirable example of using technology to teach in the old way: an instructor assigns practice problems to students as homework or quizzes; students complete and submit their work to the online grading system; the system automatically grades and records the students' performance, then sends feedback to the students when necessary. Throughout the process, technology helps the instructor to complete most of the academic chores, such as grading assignments and recording the students' performance. However, the benefit offered by the
web site to the students is minimal. As Figure 2.7 shows, the online exercise has the same presentation as a regular structural textbook. The only difference is that there is a text box for the students to enter and submit their answers to the grading system. The students are expected to complete questions on their own, and there is no guidance and interaction throughout the learning process.

- Screen shot:

![Screen shot of study site.](image)

Figure 2. 7: Screen shot of study site.
Chapter 2 Literature Review on Computer-Based Learning Tools

2.3.2 “Teaching Concepts Utilizing Active Learning Computer Environments”

- Relevant Links: http://moment.mit.edu/thesisemma/module/module.htm
- Company/Vendor: Emma Shepherdson
- Description: Interactive learning module for basic structural concepts
- Platforms: Web browsers such as Internet Explorer and Netscape, and Shockwave plugin
- Target users: Junior civil engineering students and senior architectural students

This is a Ph.D. research project done by Shepherdson with the department of Civil Engineering at the Massachusetts Institute of Technology. According to the author, elementary engineering education generally overstresses the role of structural analysis while downplaying the teaching conceptual and qualitative material. Her thesis proposes a solution to encourage conceptual understanding through interactive computer-aided learning tools. The thesis comes with a multimedia learning module utilizing simulating components and interactive exercises. The module covers the concept of structural stability and is divided into two main sections: 1) Stability of Structural Elements and 2) Stability of Structural Systems. Shepherdson conducted an in-depth study during the creation of this module and tested the effectiveness of the prototype of the module. The evaluation process involved a range of students from various engineering and architectural schools, and the author received positive feedback as well as negative criticism.

The result of the experiment shows partial success in the student’s learning progress. First, the interactive exercises engage students’ attention during the self-learning process. Second, the students display a high level of persistence when learning, which suggests that the module has the ability to successfully assist and attract students. However, negative criticism from students indicates that problems exist in the module. In the evaluations, many participants complained about the complexity of the material presented in the latter part of the module. According to Shepherdson, the participants showed an enthusiastic learning attitude during the first section but not during the second. Most of them encountered difficulty understanding the concept of the Stability of Structural Systems and complained...
that the second section appeared to be too advanced for them. Furthermore, a few of them were discouraged, and hence, lost concentration and interest in continuing the self-learning process. The author admits that she downplayed the level of complexity of the latter section and did not consider the audiences' structural knowledge background when designing the content. These complaints indicate that the interactive guidance and instructions in the module are sometimes misleading. Such criticism was not what Shepherdson had expected when developing this learning module, and from these negative responses, she learnt that it is important to understand the knowledge level and the learning needs of the students. Beside its content, the physical look of the module requires serious attention. For example, some students complained that the font sizes are too small and that the text is longwinded and unclear. Another shortcoming of the module is that it does not have a printable version for the user. Students may want to have a hard copy of the module for studying purposes or personal reference, but the dark interface makes the screen hard to print. Thus, the module certainly has plenty of room for improvement.
2.3.3 Architectonics

- Relevant Link: http://darkwing.uoregon.edu/~struct/index.html
- Company/Vendor: Chris Luebkeman
- Description: JAVA applets tools for learning the architectonics of architecture
- Platforms: Web browsers such as Internet Explorer and Netscape
- Target users: Senior architectural students

"Architectonics", according to Luebkeman, means the science of architecture and it is the name of a web site for architectural students who are interested in exploring structural concepts. This web site covers most of the basic structural concepts that a senior
architectural student should learn. The site contains lectures, examples of problems, case studies, structural typologies, essays, links, animations, movies, and structural analysis tools; each element supports the other through the linking environment of the Internet. It is one of the few architectural web sites that provide both online lectures and multimedia learning elements. The structural analysis tools are written in java script, and there are currently four developments: 1) evenly distributed loads on a simply supported beam, 2) reaction forces of a 3-hinged frame, 3) axial load on a column, and 4) pencil tower loads.

Java script is a popular programming language for software development, but there are some technical limitations in a program that is written with this programming language. For example, the interface performs differently when the applet is sitting in a different browser. If the applet is not sitting at the designated platform, the performance of the applet can experience severe “slow downs” or display undesirable results. Such deficiencies strongly discourage users from using the program and keep users away from continuing to explore its features. Computers for web surfing usually have primitive technological quality, and not everyone has the same equipment and capabilities that the program developer has; thus, it is important to ensure that the software developed can be adapted to most computer platforms.

- Screen shots:

Figure 2. 9: Screen shot of Architectonics: reaction forces of a 3-hinged frame.
2.4 Summary

One of the objectives of SCLM development is to complement already existing teaching techniques, take advantage on previous developed contents, and amalgamate positive attributes to form an interactive learning tool. Both the positive and negative attributes of existing programs can be summarized as follows:

- Proper instructions are needed to guide the user, especially the beginner, along the self-learning process.
- Informative and personal feedback specific to the user on his or her actions is part of the interactive learning process.
- A CD-ROM acting as a platform for a learning tool is not flexible and does not allow updates.
- Linear navigation in a prescribed path is not desirable for a self-exploring learning environment.
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- Expensive learning tools are limited to certain group of students only.
- Computers and information technology help promote student-centered learning rather than teacher-centered methodologies.
- Interactive learning activities engage students’ attention during the self-learning process, and have been proven to successfully assists students.
- Careful consideration on the content, sequence, and visual appearance is required when designing a learning module.
- A software support that is adaptable to most computer platforms is preferable.
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The goal of the SCLM is to enhance structural understanding through self-learning as well as sharpen students' autonomy and sense of responsibility in their own learning process. In order to accomplish these goals, the SCLM was based on three principal elements: module philosophy, module learning aids, and module content.

Firstly, Constructivism, which serves as the backbone of this development, was chosen to be the SCLM module philosophy because it best suits engineering education. The impact of Constructivism on the module can be felt in these three areas: curriculum, instruction, and assessment. Secondly, the module learning aids in the SCLM draws from research done on the following aspects of learning: interactive learning, visual learning, and computer-based learning. Each discipline has its own theoretical background and, at the same time, connects with the other two aspects in the module development. Thirdly, the SCLM structural content can be divided into four main concepts: "Engineering Mechanics and Materials", "Statics and Mechanics of Materials", "Structural Elements and Characteristics", and "Common Structural Systems". These are the fundamental concepts that structural engineering and architectural students are required to learn. Figure 3.1 is a graphical representation illustrating the relationships among the three principal elements.
Chapter 3 defines the three principal elements and describes their importance in the development of the learning module. It is divided into five sections: Section 3.1, *Educational Philosophy*, discusses the characteristics of Constructivism and explains the reason for choosing this educational theory as the SCLM philosophy. Section 3.2, *Methodologies*, is sub-divided into *Interactive Learning*, *Visual Learning*, and *Computer-Based Learning*, and defines the module learning aids and their relationships to the SCLM. Section 3.3, *Module Content*, describes the educational materials covered in general structural courses and the SCLM. Section 3.4, *Connections*, gathers the elements from the
previous sections, and connects them together as a whole. Section 3.5, *Summary*, summarizes this chapter.

### 3.1 Educational Philosophy

There are many learning theories that support different kinds of learning. In this project, Constructivism was chosen to be the scaffold for the learning module development.

#### 3.1.1 Definition of Constructivism

Constructivism is a learning philosophy based on the premise that one constructs one's own ideas or concepts based on personal experiences and current or previous understanding (Holton, Knowles, and Swanson, 1998). Constructivism also emphasizes a cumulative style of learning, that is, knowledge requires understanding wholes as well as parts, yet parts must be understood in the context of wholes. Human beings generate personal understanding during their learning experiences, and then select concepts, transform information, construct hypotheses, and make decisions according to their own rules and models. Effective learning does not merely involve memorizing "right" answers and regurgitating someone else's meaning. In fact, constructivists believe that the purpose of learning is to enable an individual to construct his or her own meaning.

Constructivists promote unique approaches to definite learning. Duffy and Savery (1996) suggest eight constructivist instructional principles:

1. Introduce a large task or problem as learning activity;
2. Assist the learners in developing knowledge ownership during learning;
3. Design an authentic learning activity;
4. Provide a learning environment to reflect the complex environment which the learners should be able to handle at the end of learning;
5. Provide the learners ownership of the process used to develop a situation;
6. Design a learning environment that stimulates and challenges the learners’ understanding;
7. Encourage alternative views and contexts;
8. Support reflection and provide opportunity throughout the learning activity.

In practice, the task of the instructors, or the facilitators in web-based learning, is to foster new understanding in a format appropriate to the learners’ current state of understanding, then help learners to understand the connections between concepts and facts. At the same time, instructors should utilize teaching strategies that promote exploration, investigation, interpretation, and prediction. Curriculum should be arranged in a well-organized manner so that learners can readily grasp target information, and are able to continually build upon what they have previously learned.

3.1.2 Constructivism and the Learning Module

The impact of Constructivism on the learning module can be felt in these three areas: curriculum, instruction, and assessment.

- Curriculum: Constructivism promotes curriculum flexibility and encourages both engineering and architectural students to customize personal curricula based on their prior knowledge. The proposed module makes use of multimedia technological supports to present knowledge to students in a pleasant, empathic learning environment. The students follow their working pace and interests to customize the structural curriculum; thus, they are no longer passive players in the process but active players capable of constructing their own learning styles.

- Instruction: Engineering and architectural students use the learning module in a self-learning environment which requires them to interact with a computer instead of learning with the assistance of instructors. Carefully designed interactive
activities and instant personal feedback from the module are important elements for engaging students’ attention.

- Assessment: Constructivism does not stress traditional grading and standardized testing. Instead, self-assessment exercises play a major role in the learning process because they determine if students are meeting their goals. Students learn through doing the quizzes and exercises which the proposed module provides, thereby improving and reinforcing their structural understanding.

3.2 Methodologies

The learning aids used in the SCLM include interactive learning, visual learning, and computer-based learning. This section describes the definitions, backgrounds and characteristics of these disciplines.

3.2.1 Interactive Learning

Interactive learning plays a significant role in the module. This section explains the meaning of this methodology and its importance to the learning module.

3.2.1.1 Definition

According to Struchiner (1996), an interactive multimedia teaching-learning environment contains the following characteristics:

- Interaction: This allows users their choice of learning material and working patterns in accordance with the possibilities given by the course facilitator;
• Integration of diverse learning styles: The learning materials is presented in various ways, thus, allowing for multiple styles and learning preferences;

• Non-linearity of the information: Learning materials are not presented in a predetermined sequence. Instead, users have the chance to design personal sets of curriculum based on previously learnt material.

In order to for a tool to be interactive, it must allow for a continuous two-way transfer of information between a computer and the person using it. For example, the tool must support a two-way information transfer as the user clicks buttons, selects an object, or enters certain information on the computer screen. This reciprocally active performance requires the user's mental and physical engagement. Many tools or websites that are available for educational purpose categorize themselves as "interactive", but some provide only a one-way information transfer as the user passes through a prescribed route by aimlessly clicking buttons. This kind of computerized learning does not meet the interactive definition described above.

3.2.1.2 Interactive Learning and the Learning Module

Interaction is an important part of the SCLM, and it forms the aim of this thesis: to develop an interactive web-based environment for structural and architectural students. As described above, the major characteristic of an interactive element is the ability to support reciprocal information transfer in a non-linear path between a computer and user. One of the interactive components of the SCLM is shown in Figure 3.2. This is an interactive chart that allows users to click onto a particular topic to access the information that they require. Information is not shown until users send a command to the computer by clicking a cell. For instance, when a user places the cursor at the Element / Stiffness cell, that cell is highlighted in pink (Figure 3.2a). This indication is generated from the computer and tells users that after clicking a cell, the corresponding information will appear (Figure 3.2b). Users are not forced to go through all the listed topics; instead, they are welcome to explore all the elements by choosing the cells one by one, or by choosing particular cells for their own reference.
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3

(a)

(b)

Figure 3.2: Screen shots of an interactive element: (a) Cursor is on a target cell, Element / Stiffness; (b) Target cell, Element / Stiffness, is selected.
3.2.2 Visual Learning

Visual learning plays a significant role in module development. This section explains the meaning of this methodology and its importance to the learning module.

3.2.2.1 Definition

Traditional teaching-learning material is prominently textual with language as an essential tool. However, in certain disciplines, sophisticated concepts or theories can be more accurately understood when students come into contact with visual illustrations. Words can sometimes be ambiguous or hard to understand. It is difficult to construct the full description of a situation or object only in words. As the old adage says, “a picture is worth a thousand words.” If words are not enough for a description, a visual presentation is able to help. For instance, a visual element is able to strengthen the meaning of a principle, replace a lengthy paragraph, and eliminate wordiness. As a result, people understand each other and reach common ground during their communicative and collaborative activities.

One of the most prominent uses of visual modeling tools is in the field of Applied Science education (LETSNet, 1996). Structural engineering researchers and educators have developed virtual representations to capture critical aspects of complex structural phenomena. These representations have the power to introduce phenomena in ways that make them easily understandable, thus, improving students’ understanding of structural situations. For example, complex structural behaviours can be demonstrated with carefully chosen symbols and colours, such as red for a compression area and blue for a tension area. The West Point Bridge Designer, which is discussed in section 2.1.2, uses such visual techniques to identify clearly the structural behaviour of a bridge subjected to its dead load, live load, and dynamic load (Figure 2.3).

There are two types of visual representations, static and dynamic illustrations, and they are able to accurately mimic the structural systems they represent. The static illustrations include
graphs and photos and replace verbal representations, while the dynamic illustrations include movie clips and computer generated animations, as well as represent time-dependent structural situations. Both have the power to provide connections between students' knowledge and real world situations.

3.2.2.2 Visual Learning and the Learning Module

As discussed above, there are two types of visual illustrations: static and dynamic. The SCLM utilizes both illustrations to demonstrate structural concepts, relationships, behaviours, etc. For example, Figure 3.3 shows a visual example of a load path migration, with the interactive principle embedded. After choosing a particular structural system from the selections on the left, the user clicks the screen on the right to initiate the animation of load migrating from a designated location to the ground (Figure 3.3a). The animation shows, with arrows indicating the load direction, where the load path starts and ends (Figure 3.3b). If the load path is explained in words only, it may require a long paragraph in order to complete the job. Moreover, readers may lose their patience when reading the description and give up when they get confused. Another practice is to use an image to show the load path. However, readers may still get confused because the load does not happen instantly in reality but migrates in a progressive manner instead. Arrows can show the directions of the routes, but not the sequence of the multiple routes involved. In conclusion, an animation technique is the most favorable method of presenting time-dependent situations.
Figure 3.3: Screen shots of a visual component: (a) A structural system, "Bearing Wall System", is selected; (b) An animated load path of "Bearing Wall System".
3.2.3 Computer-Based Learning

Computer technologies and the Internet play significant roles in module development. Computer technologies provide technical support to visual and interactive learning, while the Internet provides an informative route between the students and educators. This section explains the meaning of computer-based learning and its importance to the learning module.

3.2.3.1 Computer Technologies

The SCLM requires different kinds of software to facilitate the following tasks:

- Creating graphical images;
- Generating animations and movies;
- Producing interactive elements;
- Providing self-assessment;
- Supporting a web-based environment.

Chapter 4 and 5 conduct an in-depth analysis of each category.

3.2.3.2 Web-Based Learning

A web-based learning environment allows students and educators to perform learning-related tasks on the World Wide Web (WWW). Such an environment is more than a place for distributing information to students; it supports tasks related to communication, student assessment, and class management (McCormack, 1998). Other than communication tools and File Transfer Protocol (FTP), many programs that provide the functionality of this new type of learning environment have very little to do with the web at all. Indeed, the web provides a simple and familiar interface for students and educators in a class to access available educational materials. A web-based tool can be used as a supplement to existing
teaching methods, such as the study site for Engineering Mechanics explained in section 2.3.1, or as a complete replacement for existing methods, such as Architectonics explained in section 2.3.3.

3.2.3.3 Computer-Based Learning and the Learning Module

As teaching and learning styles become computerized, educators turn into facilitators or creators of the learning environment instead of mere knowledge transferors. Their central task is to provide an environment that encourages students to access and utilize learning materials at a self-determined pace. Unlike the traditional teaching-learning method\(^2\), the web-based educational method contains unique characteristics that benefit engineering and architectural students as well as educators. These characteristics can be summarized as follows:

- Location independence: Without the physical restriction of a learning institution, students and educators can get educational materials at any location as long as they have computers with Internet access.

- Time independence: Web-based learning can free the educational experience from the bounds of time, so, students and educators do not need to synchronize their timetables and meet in the same place at the same time.

- Up-to-date educational content: The web facilitators can update the educational content of the site conveniently and frequently. Users can visit the website regularly and expect to learn new materials on a regular basis.

\(^2\) The transitional teaching-learning method is used in formal schools consists of lecturers, students, books, classrooms, etc. Classrooms and lecture halls are highly structured forums for imparting, conveying, gathering, and learning knowledge. This educational environment promotes passive information absorption (Buchal, 1996).
• Student-centered teaching approaches: Computer-based learning provides a front-
row experience for students because they can become active learners and directly
acquire more knowledge than if they were sitting at the back of the classroom
busily scribbling notes.

3.3 Module Content

This section describes the educational materials covered in general structural engineering
courses and the learning module.

3.3.1 Elementary Structural Curriculum

The elementary structural curriculum required by the schools of structural engineering and
architecture generally consists of four main fundamental concepts: "Engineering Mechanics
and Materials", "Statics and Mechanics of Materials", "Structural Elements and
Characteristics", and "Common Structural Systems". Figure 3.4 is a flow chart that
delineates the hierarchy of the general structural curriculum. It was developed according to
the author's previous experience with structural courses in both schools.

"Engineering Mechanics and Materials" contains two sections: "Engineering Mechanics" and
"Structural Materials". The materials covered in these sections are prerequisites.
"Engineering Mechanics" covers the topics of Vector, Force, Moment, Equilibrium, Energy
methods, and Free Body Diagram. In North America, steel, concrete, and timber are the
three major structural materials for building structures ranging from a small hut to a large
infrastructure. "Structural Materials" introduces the basic characteristics of these materials.

"Statics and Mechanics of Materials" is divided into three sections including "Internal Force
covers the technique for drawing a Shear Force Diagram (SFD) and Bending Moment
Diagram (BMD). These diagrams are essential visual illustrations during a structural analysis. This section requires prior knowledge learnt from “Engineering Mechanics”, as does “Mechanics of Materials” which also requires understanding about “Structural Materials”. The topics of “Mechanics of Materials” include stress, strain, axial force, shear, tension, compression, and bending. Lastly, “Material Properties” is an extension of the previous section, “Structural Materials”, and investigates specific types of building material from a microscopic perspective. Elastic, plastic, brittle, isotropic, and anisotropic materials are investigated.

“Structural Elements and Characteristics” gives students a strong sense of structural engineering concepts by introducing two sections, “Structural Elements” and “Structural Characteristics”. Fundamental structural elements include beams, columns, beam-columns, connections, cables, arches, plates, and shells, and the ways they react differently under various load and support systems. The structural members have their corresponding characteristics, such as strength, stiffness, stability, and ductility, based on their material properties.

Finally, “Common Structural Systems”, explores practical structural applications, including frames, trusses, horizontal building systems, and vertical building systems. These are the fundamental structures that structural and architectural students should to be familiar with. Of course, the modules could be expanded to cover other structures like frames and arches, cables, shells, etc., but these are advanced structural systems that are taught at graduate level.
Figure 3.4: Hierarchy of basic structural knowledge for structural and architectural students.

3.3.2 Structural Content of the Learning Module

The SCLM will partially cover the fundamental structural concepts which were discussed in section 3.3.2. The sections and topics chosen are ones which allow the module designer to
demonstrate the characteristics of each theoretical framework. Figure 3.5 shows the modified curriculum for this project.

Figure 3.5: Modified hierarchy of basic structural knowledge for structural and architectural students.
3.4 Connections

Figure 3.1 was introduced at the beginning of this chapter as a graphical representation of the relationships among the three principal elements of the SCLM: educational philosophy, methodologies, and module content. Based on the investigation of the previous sections, this section gathers all the findings presented, and connects them together as a whole.

Constructivism is the central philosophy of this module development and it encourages self-exploration, flexible curriculum, and self-assessment. In order to actualize these ideas, three learning aids are used: interactive learning, visual learning, and computer-based learning. Each aid supports Constructivism in the following way:

- Interactive learning $\leftrightarrow$ Constructivism: The main characteristic of interactive learning is the ability to provide a reciprocal information transfer between users and computers. Interactive components in the SCLM help users to self-explore knowledge during the learning process.

- Computer-based learning $\leftrightarrow$ Constructivism: Constructivism does not use traditional grading and standardized testing, but self-assessment exercises which evaluate students' learning process instead. With the help of computers, evaluations are automatically generated, so users can determine their level of understanding immediately.

- Visual learning $\leftrightarrow$ Constructivism: When learning with the SCLM, users study in an individual manner without the assistance of instructors. Pure textual content may not be able to fully convey the scope of the learning materials. In this case, visual elements are used to illustrate sophisticated structural concepts and theories.

Each methodology not only supports Constructivism, but also connects with the other two aspects in the following way:
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- Visual learning $\leftrightarrow$ Interactive learning: Visual learning allows students to absorb the underlying knowledge through participating in interactive activities. Like the example given in section 3.2.1.2, *Interactive Learning and the Learning Module*, users are able to choose what to read by clicking an image to signal to the computer to show the corresponding information.

- Computer-based learning $\leftrightarrow$ Visual learning: Images and animations are created by computer software. Additionally, computers provide the necessary technical support to display static and dynamic illustrations.

- Interactive learning $\leftrightarrow$ Computer-based learning: Interactive components, such as quizzes and practice exercises, are created by computer software. Additionally, computers provide the technical support for displaying interactive components.

As a result, Constructivism and the three methodologies work together to produce the final product - the SCLM.

3.5 Summary

This chapter covered the principal elements required for the development of the SCLM, including module philosophy, module learning aids, and module content. Their principles and importance towards the module development were discussed in detail in each section. Finally, their connections were discussed to link the big picture together. Through its careful design considerations, the module allows students to interact visually with their computers and self-explore the underlying fundamental structural concepts in a web-based environment.
4.0 VISUAL ELEMENTS

This chapter discusses the visual design criteria for the development of the SCLM. The chapter begins with a discussion of the visual design considerations for selecting colours, fonts, and graphics. The second half of the chapter describes the general page layout and SCLM photo gallery page layout.

Section 4.1, Appearance Design Consideration, illustrates the importance of maintaining colour consistency and tone contrast, as well as the techniques for choosing appropriate colours to denote different purposes in the SCLM. Also, this section discusses how the types of font styles and sizes were chosen according to guidelines drawn from research done on website design. Finally, this section describes how the graphical file formats were selected to accommodate different requirements, and how the file sizes were controlled to minimize the loading time, and how the graphics were designed to perform specific function.

Section 4.2, Page Layout of the Interface, describes the two kinds of page layout. In the general layout, the main module interface is divided into five separate frames named “Top”, “Bottom Left”, “Centre”, “Centre Right”, and “Bottom Right”. The “Top” frame contains a toolbar with buttons that are useful for operating the module. The “Bottom Left” frame has four tabs: “Contents”, “Index”, “Search”, and “Glossary”. These tabs contain tools to assist users in finding information during the learning process. The “Centre” frame encloses a navigation bar which has two navigation buttons and a dropped down “Chapter List”. The “Centre Right” frame encapsulates a “Sequence Browser” that allow users to identify their present location in the SCLM. The “Bottom Right” frame is the mainframe and it displays all the teaching-learning material. This frame is also where users spend most of their time interacting with the SCLM. Section 4.2 also discusses the page layout of a photo gallery, which consists of a mainframe for photo displays and a frame for navigating buttons.
4.1 Appearance Design Consideration

Designing the SCLM's appearance serves an important non-cosmetic purpose. The interface is where users spend most of their time when learning with the module. If the interface is poorly designed, users will have difficulty following the materials or finding the information in which they are interested. This section discusses the considerations used in selecting colours, fonts, and generating graphics when designing the SCLM's visual appearance. These considerations were based on various research sources and the designer's own experience.

4.1.1 Colours

A set of colours was selected when building the SCLM. There were several considerations involved when choosing these colours such as consistency, tone contrast, and purpose:

- Consistency: A colour should be used for a specific purpose to indicate a particular task, action, or piece of information (McCormack, 1998). For example, to achieve visual clarity, the colour of the textual content could be black and shown on a white background; the buttons of the interactive components could be orange and gray, and the colour of a beam usually light blue. Consistency controls the legibility and clarity of the module because users will become familiar with the purpose of the colour system and understand the annotations easily just by distinguishing the different colours.

- Tone contrast: Colour can be used to convey information; however, this principle can only apply to users who do not have difficulty reading colours on the computer screen. Colourblind users and users with computer devices that display limited colours cannot receive the complete information behind each colour. Also, not every user has the same level of computer equipment or capability. What one sees on one's browser is not always what other people see due to
different settings and preferences in their computers. For example, if foreground and background colours are close to the same hue, they provide insufficient tone contrast on monochrome screens and pose difficulties for people with certain types of colour deficits. To ensure that all users are able to view the SCLM without any difficulty, colour combinations should be contrasting (Chisholm, Vanderheiden, and Jacobs, 1999).

- **Purpose**: Sometimes, a task is assigned to a particular colour to serve a function. For example, the font colours used for links should be different than the colours used in other textual content. In the learning module, the font colour of the general text is black and its links are blue. To make sure users view all possible links within the learning module, the colours of the links should be changed after users have visited the site (McCormack, 1998). Because bright colours are usually more eye-catching than dull colours, a bright colour, blue, shows links that have not been visited; a less bright colour, purple, can be used to highlight previously visited links.

### 4.1.2 Fonts

A particular set of font styles is used consistently throughout the module content. There were several considerations involved when choosing the styles and sizes of the fonts:

- **Style**: Arial was chosen to be the font style when displaying the content because it is a web safe font which most operating systems recognizes. However, when designing the module, more than one particular font is specified. Thus, if a user’s browser fails to display the specified font, another font can act as a replacement. In the SCLM, if Arial fails, Helvetica is the first replacement; if Helvetica fails, sans-serif is the second replacement.
• Size: 10-point was chosen to be the font size when displaying the content because research has shown that a viewer achieves the best reading performance when reading a 10-point text from a computer screen (Tullis, Boynton, and Hersh, 1995). Any font smaller than 10-point elicits slower performance from users. However, for people over the age of 65, a 12 or 14 point is preferable. Since the target users of the SCLM are engineering and architectural students who are in their 20’s to 30’s, 10-point is used.

• Heading: The font of all headings remains Arial, bold, and black, but their sizes are different in order to distinguish them from the rest of the content. For example, the name of each topic, like “Vector” and “Force”, is in 18-point; the name of each sub-topic, like “Rules of Manipulating Vector” and “FBD-Example”, is in 12-point. Additionally, the name of each topic is an animated text that flies across the screen from the right to left, and then stays at the designated position. The animated texts serve as openings of a new concept, and distinguish themselves from other sub-topics.

4.1.3 Graphics

Other than the textual content, both static and dynamic illustrations play an important role in the module. There were several considerations involved when designing graphics in the SCLM, including file format, loading time, purpose, visual clues, and consistency:

• File format: Graphics displayed in the module are in GIF, JPEG, or SWF format and each has its own properties and characteristics. Firstly, GIF images are only good for displaying line artwork, because they can only show a limited colour range; JPEG images are good for displaying colour photographs or figures with fine detail; SWF files display animated graphics created by Flash. Their file sizes are reasonably small; therefore, the time required to load and then show the graphics on a computer screen is short. GIF and JPEG formats are universally
recognized by all computers and do not require plugin to open the files, while the SWF format requires a Flash player to view animation clips. Note that, in the SCLM, the designer used Flash to create not only animated graphics, but also static images, and they are shown in a SWF format as “non-animated animation clips”.

- Loading time: Fancy images that require long periods of time to load may annoy users and prevent them from utilizing the module again. In the SCLM, most of the static and dynamic graphics were created by Flash. As mentioned earlier, the graphical files created by Flash are usually compact; therefore, the time needed to load an image or animation is reasonably short. If it is necessary to load a large graphical file, users are given the chance to choose whether or not they want to view it.

- Purpose: Graphics in the SCLM, both static and dynamic, serve significant purposes. For example, static graphics enhance or replace textual content and lead to a better understanding of the information being presented; second-by-second animated graphics and movie clips describe structural behaviour; an interactive button send a command to the computer after the button has been clicked. Users may only be willing to download graphics that add value to the learning process because large graphical files require time to load and may slow down one’s computer. Moreover, irrelevant graphics distract users’ attention; therefore, the SCLM only shows graphics that fulfill a function and avoids decorative graphics.

- Visual clues: The amount of people who use a particular interactive element is directly influenced by how well the elements provide users with clear visual clues (McCormack, 1998). For example, the buttons in Figure 4.1 have a button-like appearance and give users clues about the features they can expect upon pressing or clicking on icons. Figure 4.1a is a button with a black arrow pointing to the right and “NEXT” below the button. Figure 4.1b is a button without a black
arrow and "NEXT" below the button. If both buttons are used as "Next" buttons for sending commands to computers to display the following page, users probably can immediately identify the purpose of the button with an arrow, but cannot tell the purpose of the button without an arrow. This proves that an indication or label at an appropriate location can help explain the purpose of an interactive element.

Figure 4.1: The buttons: (a) Button with indication; (b) Button without indication.

- Consistency: By being consistent throughout the module, users will become familiar with the behaviour of interactive objects and be able to predict how to perform tasks. Unexpected changes in the interactive behaviour will confound and confuse users. For example, one clicks the "Next" button to proceed to the following page (Figure 4.2). This button has two phases, active and inactive. The active button is bright orange (Figure 4.2a) and users can proceed after clicking on it. The inactive button is in faded gray (Figure 4.2b) and users cannot proceed until completing the requirement(s) stated on the current page. If the appearance or location of the button is not consistent, users probably need to spend time searching for it in order to proceed to the next page.
4.2 Page Layout of the Interface

The page layout must be consistent and match the purpose of the page. The page layout of the module is divided into 5 separate frames (Figure 4.3), and each contains different elements to serve different purposes. To illustrate how the interface is divided, the frames are named as follows: “Top”, “Bottom Left”, “Bottom Right”, “Centre”, and “Centre Right”.

Figure 4. 3: The page layout of the SCLM.
4.2.1 Top Frame

The "Top" frame (Figure 4.4) is located at the top of the interface, and has a toolbar with "Hide/Show", "Back", "Forward", and "Print" buttons.

![Figure 4.4: "Top" frame elements.](image)

- The "Hide/Show" button: It allows users to control the existence of the "Bottom Left" frame. If the "Bottom Left" frame is part of the interface, the "Hide" button becomes available to conceal such a frame. Alternately, if the "Bottom Left" frame is not in the interface, the "Show" button becomes available to reopen this frame.

- The "Back" button: It enables users to view previous topics, and the "Forward" button allows users to return to the original topic before moving backward.

- The "Print" button: It allows users to print a hard copy of the module content for self-reference purposes. The SCLM automatically converts the selected content into full-featured printed documentation complete with text formatting, styles, and images. Although dynamic presentations, such as animation clips, will turn out static, the rest of the content is printed neatly on the hard copy. To print, users just have to click the "Print" button on the toolbar, causing a dialog window to pop up (Figure 4.5) up and ask users to determine if they want to print the selected topic or print the selected heading including all subtopics.
4.2.2 Bottom Left Frame

The “Bottom Left” frame is located at the left of the interface below the “Top” frame, and shows the table of contents in the “Contents” tab, index in the “Index” tab, full-text search tool in the “Search” tab, and list of terms in the “Glossary” tab. The tools in the tabs provide ways for users to access and traverse the module. The tools are described below:

- The “Contents” tab (Figure 4.6a): This tab contains the expandable and collapsible table of content that is organized in a hierarchical structure. The hierarchical structure has a group of elements at the first level and each element may be divided into a group of sub-elements. To locate a topic using the table of content, users click on a “book” to expand a list of available topic(s), and then click on a “page” to view the corresponding learning material in the “Bottom Right” frame.

- The “Index” tab (Figure 4.6b): This tab contains the index for users to search for the location(s) of a particular piece of information. Users either enter a keyword in the text field area or choose a keyword from the existing list, and then a list of related topics is displayed in a new pop-up window. Users then choose a topic to view in the “Bottom Right” frame.
• The “Search” tab (Figure 4.6c): This tab contains a full text search engine to locate every occurrence of a word or phrase in the SCLM. Users enter the word or phrase in the text field area to find matches to their queries. When the list of topics is displayed in the bottom pane, users double-click a specific topic to view the content in the “Bottom Right” frame.

• The “Glossary” tab (Figure 4.6d): This tab contains a glossary with a list of terms and definitions related to the subject matter in the SCLM. When users access the glossary, they scroll down the list of terms in the top pane and then click to select a particular term. The corresponding definition is shown automatically in the lower pane.
Figure 4.6: "Bottom Left" frame elements: (a) Contents tab; (b) Index tab; (c) Search tab; (d) Glossary.
4.2.3 Centre Frame

The "Centre" frame (Figure 4.7) is located at the centre of the interface surrounded by four other frames. It shows the navigation bar which consists of "Previous" and "Next" buttons as well as a dropped down "Chapter List".

![Figure 4.7: "Centre" frame elements.](image)

- The "Previous" and "Next" buttons: These buttons allow users to transverse through a series of topics arranged in a specific linear order, which is graphically shown in the "Sequence Browser" in the "Centre Right" frame. The "Previous" button brings users backward and the "Next" button brings users forward according to the recommended sequential order.

- "Chapter List": This list contains links to the first page of each chapter, and acts as a quick reference and navigational guide within the module. Users can choose the chapter they wish to study by clicking at the corresponding link, and then the "Sequence Browser" will refresh itself to locate the new position, and the "Bottom Right" frame will display the first topic of the requested chapter.

4.2.4 Centre Right Frame

The "Centre Right" frame (Figure 4.8) is located at the right of the interface below the "Top" frame, and it displays the "Sequence Browser".
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• The “Sequence Browser”: Other than locating information with the tools in the four tabs situated in the “Bottom Left” frame, the “Sequence Browser” provides users with an additional way to view the content. The material shown in such a browser is arranged in a linear sequence. Users are recommended to follow the fixed order if they want to fully cover the curriculum. Additionally, users can skip to a particular page by clicking the images in the browser, and then the “Bottom Right” frame will show the chosen topics and the browser will refresh itself to display the latest location. The “Sequence Browser” has pointers to highlight the location users are at in relation to the rest of the content, the upcoming structural concepts they will study in the current chapter, and the material they have learnt previously.

4.2.5 Bottom Right Frame

The “Bottom Right” frame is located at the right of the interface below the “Centre” and “Centre Right” frames. It is the mainframe that displays all the teaching-learning material, and it is where the users will spend most of their time interacting with the SCLM.

• The following four books were used as a reference manual when creating the SCLM: Bedford, Fowler, and Liechti, Static and Mechanics of Materials (2003); Coleman, Structural Systems Design (1983); Cowan, Architectural Structures (1980); Gere and Timoshenko, Mechanics of Materials (1997).

• Page length: Each chapter is divided into topics and sub-topics, and teaching material is shown under sub-topics only. For example, chapter 1, “Engineering Mechanics”, has six topics. Its second topic, “Units”, has 3 sub-topics: “Units”,

Figure 4. 8: “Centre Right” frame elements.
“Units-Example”, and “Conversion of Units”. The sub-topics are displayed in three separate pages inside the “Bottom Right” frame. The length of each page depends on the length of the sub-topic.

- Textual content: Readability improves when sentences and paragraphs are relatively short (Bailey, Koyani, and Nall, 2000). Most of the sentences in the content have twenty or fewer words and paragraphs have fewer than five sentences. Long paragraphs are broken up into point-form presentation to allow users to skip over the text they consider not essential and to enable them to find important information.

4.2.6 Page Layout of the Photo Gallery

The page layout remains the same throughout the learning module. If it is necessary to display a different layout, a new window pops up. For example, the page layout of a photo gallery (Figure 4.9) consists of a mainframe for photo displays and a frame for navigating buttons at the upper portions of the window.
This chapter discussed the visual design criteria involved during the development of the SCLM. The considerations involved when selecting colours, fonts, and graphics were explained in detail. The second half of this chapter described two kinds of page layout of the module interface. The interface is divided into a certain number of frames and each frame contains elements that assist users in operating the module during the SCLM learning process. With the abovementioned design criteria and considerations, the goal when designing the module was to create an enjoyable and user-friendly learning environment that would facilitate the to self-learning of fundamental structural concepts.

Figure 4. 9: Screen shot of the photo gallery of beam structures.

4.3 Summary
This chapter discusses the SCLM’s interactive element design. The chapter begins with a
discussion of the software programs, including RoboHelp and Macromedia Flash, used to
construct the SCLM and the technological concerns involved when constructing a web-based
learning environment. The rest of this chapter gives detailed descriptions of module’s
interactive teaching and practice components, including their locations, descriptions,
instruction, and characteristics.

Section 5.1, Technological Support, describes the two software programs, RoboHelp and
Macromedia Flash, that were chosen as the SCLM’s main construction tools. Both are
computer software programs that are widely used for publishing computer applications on the
Internet. However, implementing the learning module on the WWW has a number of
restrictions. For example, the module designer needs to be concerned about the types of
platforms adapted by potential users and the resolution of their computers.

Section 5.2, Interactive Teaching Components, explains the settings, uniqueness, and
characteristics of the three types of interactive teaching components in the SCLM: animation
clips, interactive displays, and interactive illustrations. The animation clips are “Vector
Addition”, “Beam Bending”, and “Load Paths”. The interactive displays are “Structural
Characteristics vs. Structural Level” and “Section Properties”. The interactive illustrations
are “Interactive Internal Force Diagrams”, “Load tree”, “Support Systems”, and “Structural
Hierarchy”.

Section 5.3, Interactive Practice Components, explains the settings, uniqueness, and
characteristics of the six types of interactive practice components in the SCLM: true or false
(“Vector & Force”), multiple choice (“Free Body Diagram”), fill in the blank, (“Unit”), hot
object (“SFD & BMD”), drag and drop (“Support Conventions”), and hot spot (“Trusses”).
Chapter 5 Interactive Element Design

5.1 Technological Support

RoboHelp and Macromedia Flash were the tools used to construct the SCLM. This section explains the advantages of using these programs as well as the technological considerations involved when building the module.

5.1.1 RoboHelp

RoboHelp is a help-system authoring tool that is widely used by online technical writers, software designers, and web developers to construct online help systems for many computer applications (Knopf, 2002). RoboHelp uses Hyper Text Markup Language (HTML) to deliver text information over the Internet. The SCLM, generated by RoboHelp, has a familiar appearance, setting, and functions that are similar to the help systems of many computer applications such as Microsoft Word and Excel. The SCLM's interface design was discussed in chapter 4, Visual Elements. Due to the popularity of the help interface that RoboHelp generates, the module designer has chosen RoboHelp to build the SCLM.

If the SCLM's users have been exposed to a similar interface from other computer applications, like Microsoft applications, they should be familiar with the module's setting and be able to operate the SCLM without major difficulty. If users are first exposed to the help interface, the relative simplicity of the tool requires only a minimum learning effort. Additionally, the help system's popularity means that once users know how to operate it, that knowledge can be helpful for them in operating help systems installed in other software applications.

5.1.2 Flash

Macromedia Flash MX is a design tool for creating animated graphics, long-form animated movies, online navigation controls, websites, etc. in an interface that is compatible on
different platforms such as Windows 98 and Windows XP. The major reason for employing Flash to build the module is to generate graphical presentations and interactive instructional elements.

Flash is one of the most popular tools for creating animation to the Internet. Flash animations are easy to create and compact in size. For example, Figure 5.1 shows several Flash animation frames of a block moving from one location to another. In the animation, a set of frames is displayed in rapid succession, which creates the illusion of movement. To play a Flash movie or animation in a web browser, one must first open an HTML document, which activates Macromedia Flash Player and then run the movie. The Flash player can be downloaded from many Internet locations.

![Frame 1](image1) ![Frame 2](image2) ![Frame 3](image3) ![Frame 4](image4)

![Frame 5](image5) ![Frame 6](image6) ![Frame 7](image7) ![Frame 8](image8)

Figure 5.1: Consecutive frames of an animation, created by Macromedia Flash, showing a block moving from one location to another.

Besides animation, Flash creates interactive instructional elements, such as exercises and quizzes, for the SCLM. Furthermore, Flash is able to help evaluate quizzes, tests, or surveys with its “Learning Management System”. This system does all the grading and analysis automatically, and the results of the learning exercises can be exported directly to the
registrar in spreadsheet format (Nelson, 2002). Therefore, the time previously spent on grading students' performance, formulating statistical information, and analyzing students' assessments can be used for other academic purposes. However, implementing the "Learning Management System" into the SCLM is beyond the scope of this project and is not discussed in this thesis.

5.1.3 Technological Consideration

People surfing the web have various levels of computer facilities. The level of their facilities can sometimes be very primitive. In building the module, the designer must consider the following common technological limitations:

- Platforms adapted by users: It is important to consider carefully how to deliver projects in ways that are compatible with users' technological resources. It is important to select a platform that is likely to be used by targeted users or else the designer may miss a large group of potential users who use different types of supporting platforms. Many existing computer applications are specific to a particular computer operating system, such as Windows, Macintosh, or UNIX. The SCLM is compatible with certain types of operating systems which are most likely to be used by targeted users. Table 4.1 shows the viewers or browsers recommended to support the SCLM. Internet Explorer 4.0 or later versions are recommended for users whose computers run in Windows 95 and NT 4. A built-in viewer is available for users whose computers run in Windows 98, 2002, ME, and XP. However, no viewer or browser is available for users whose computers run in Windows 3.1, UNIX, and Macintosh (RoboHelp, 2002).
5.2 Interactive Teaching Components

The SCLM’s interactive teaching components allow users to customize personal learning patterns based on their preferences and interests. These components were constructed according to the module philosophy and three learning methodologies that were discussed in chapter 3, Planning. The module philosophy is Constructivism, and the learning methodologies are interactive learning, visual learning, and computer-based learning.

There are three types of interactive teaching components in the SCLM, and each of them has its own settings, uniqueness, and characteristics. These three interactive teaching components are animation clips, interactive displays, and interactive illustrations. The animation clips include “Vector Addition”, “Beam Bending”, and “Load Paths”. The interactive displays include “Structural Characteristics vs. Structural Level” and “Section
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Properties". The interactive illustrations include “Interactive Internal Force Diagrams”, “Load Tree”, “Support Systems”, and “Structural Hierarchy”.

5.2 Animation Clips

This section describes the three animation clips in the SCLM: “Vector Addition”, “Beam Bending”, and “Load Paths”.

5.2.1.1 “Vector Addition”

- Location: Ch 1 Engineering Mechanics → Vector → Graphical Representation

- Description: This animation clip shows two demonstrations about vector addition. The total length of this clip is 15 seconds.

- Instructions: The animation clip does not start automatically until users click inside the display area which is situated within a dotted border (Figure 5.2). Throughout the presentation, brief captions are given on the right of the screen. The clip pauses after showing the first example, so users can digest the material they have just learnt. They are then asked to click inside the display area again to continue the animation when they are prepared to study the second example.

- Characteristics: The captions are presented along with the animation to describe the action on the screen. They are presented one after another and viewers are given sufficient time to read and understand their meaning. After the entire animation sequence ends, users are welcome to replay it by clicking inside the display area to restart the clip. Therefore, they can watch it as many times as necessary to strengthen their understanding.
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5.2.1.2 “Beam Bending”

- Location: Ch 2 Mechanics of Materials → Bending → Bending of Beams

- Description: This animation clip shows the bending behaviour of a beam in isotropic, side and cross-sectional views. The total length of this clip is 5 seconds.

- Instructions: As in “Vector Addition”, users are asked to start an animation clip by clicking inside the display area which is situated within a dotted border (Figure 5.3). After the animation sequence ends, users are welcome to restart it by clicking inside the same area again.
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- Characteristics: The bottom of the screen shows the enlarged side and cross-sectional views of the beam (Figure 5.3). Blue and red colours are used to represent the internal forces the beam is subjecting. As loads are applied to the beam, side and cross-sectional views simultaneously becomes blue and red to indicate tension and compression respectively. Additionally, the color intensity shown indicates the change of force magnitude. The colours near the neutral axis, denoted as “NA”, are close to white, while the colours near the top and bottom edges are bright. This indicates that the internal forces are greater near the top and bottom edges compared to the forces near the neutral axis.

- Screen shot:

![Figure 5.3: Screen shot of “Beam Bending”](image)
5.2.1.3 “Load Paths”

- Location: Ch 4 Common Structural System → Load Path → Load Paths in Different Structural Systems

- Description: “Load Paths” contains five animation clips to show the load paths of four different structural systems: 1) floor and roof assembly, 2) frame, 3) bearing wall system, and 4) braced frame. The average length of the clips is approximately 5 seconds.

- Instructions: First, users need to indicate which structural system they wish to learn by clicking onto a system from the list of selections on the left. After this action, the display area on the right will show the selected structure. To start it, users click inside the display area, which is situated within a dotted border on the right of the screen (Figure 3.3a), to initiate the animation clip of a load migrating from a designated location to the ground. The animation shows, with arrows indicating the load direction, where the load path starts and ends (Figure 3.3b). After the animation ends, users are welcome to restart it by clicking inside the same area again or to study another system.

- Characteristics: As explained in section 3.2.2.2, Visual Learning and the Learning Module, the animation technique is a favorable method to present time-dependent situations. There is no confusion caused by reading a plain text, and the time needed to study how each load path travels from one point to the ground is just a few seconds long. Therefore, this teaching-learning technique is effective and saves time.

- Screen shot: See Figure 3.3
5.2.2 Interactive Display

This section presents two interactive displays in the SCLM: "Structural Characteristics vs. Structural Level" and "Section Properties".

5.2.2.1 "Structural Characteristics vs. Structural Level"

- Location: Ch 3 Structural Elements and Characteristics → Structural Characteristics → Structural Characteristics - Summary

- Description: This interactive chart contains the definitions of four structural characteristics at three kinds of structural level. The structural characteristics include 1) strength, 2) stiffness, 3) stability, and 4) ductility, and the structural levels include 1) material, 2) element, and 3) system.

- Instructions: Users can access the required information by clicking onto a particular cell. Such action generates a command to the computer to show the corresponding information. For instance, when a user places the cursor at the Element / Stiffness cell, that cell is highlighted in pink (Figure 3.2a). After clicking a cell, the corresponding information appears at the pre-designed location (Figure 3.2b).

- Characteristics: As explained in section 3.2.1.2, *Interactive Learning and the Learning Module*, users are not forced to go through all the topics in the chart; instead, they can study the underlying structural concepts by choosing the cells one by one. This chart can also act as a quick reference; users have the freedom to seek information based on their interests.

- Screen shot: See Figure 3.2
5.2.2.2 "Section Properties"

- Location: Ch 2 Mechanics of Materials \rightarrow Bending \rightarrow Section Properties

- Description: This interactive chart contains the section property equations of five geometrical shapes: 1) rectangle, 2) triangle, 3) circle, 4) semicircle, and 5) trapezoid. This interactive chart contains equations to calculate the 1) area, 2) distance to centroid along x-axis, 3) distance to centroid along y-axis, 4) moment of inertia with respect to the x-axis, and 5) moment of inertia with respect to the y-axis of one of the shapes.

- Instructions: First, users need to indicate which geometrical shape they are interested in by clicking onto a shape from the list of selections on the left (Figure 5.4). After this action, the display area on the right will show the selected choice as well as the corresponding section property equations.

- Characteristics: As in "Structural Characteristics vs. Structural Level", "Section Properties" allows users to click onto a particular topic to access the information that they require. However, the module designer found this component an undesirable tool that demonstrates the misusage of interaction. The equations of all the shapes shown on one page might be more convenient to users, because they can simultaneously point out equations for different shapes and compare the findings. "Section Properties" shows a set of equations at a time, and users may be annoyed by the fact that they are not able to view all equations all at once.
5.2.3 Interactive Illustrations

This section explains the four interactive illustrations in the SCLM: “Interactive Internal Force Diagrams”, “Load Tree”, “Support Systems”, and “Structural Hierarchy”.

5.2.3.1 “Interactive Internal Force Diagrams”

- Location: Ch 2 Mechanics of Materials → Internal Force Diagrams → Diagrams- Example 1 to Diagrams- Example 4
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- Description: The SCLM explains four different beam systems with their interactive internal force diagrams\(^3\). There are two kinds of internal diagrams: shear force diagram (SFD) and bending moment diagram (BMD).

- Instructions: In an interactive SFD, users can read the shear force along the beam by placing the cursor at a desired location. Figure 5.5a shows a sample beam systems in the SCLM. When one places the cursor inside the SFD, the computer reads the x and y coordinates of the cursor's instant position. The readings are automatically converted into the location and shear force on the graph expressed in meters (m) and kilonewtons (kN) respectively. Those values are shown at the top right corner of the frame.

- Characteristics: A cross, which is attached to the cursor, consists of two orange hairlines that intersect perpendicularly with each other (Figure 5.5b). This cross assists users to locate a particular point precisely. When the computer reads the exact shear force value of the beam, the diagram turns orange (Figure 5.5c). It implies that the cursor is currently pointing at the exact shear force value that the beam is subjecting.

\(^3\) Appendix A lists the beam systems and their corresponding internal force diagrams in "Interactive Internal Force Diagrams".
Figure 5.5: Screen shots of "Interactive internal force diagrams": (a) A sample beam system; (b) The cursor points away from the shear force curve; (c) The cursor points at the exact shear force value.
5.2.3.2 "Load Tree"

- Location: Ch 3 Structural Elements and Characteristics → Load → Load

- Description: This tree diagram shows the sources of building loads. The loads are mainly divided into two major categories, dead load and live load, and they are subdivided into sub-categories.

- Instructions: The size of the tree is large and users are probably unable to view it in detail if the graphic is not zoomed in (Figure 5.6a). Users can view the detail of a specific branch by clicking on a topic to enlarge the view (Figure 5.6b). At the same time, the thumbnail of the tree, on the upper left corner, maps out the exact locations of the zoomed area. Users can return to the original view by pressing the "back" button at the bottom of the screen.

- Characteristics: Although a practical structural design only considers a few types of loads, the "Load Tree" utilizes a tree diagram to show many load possibilities, which are divided into two major categories. The tree diagram is a visual learning technique that pictorially illustrates how ideas are connected, organized and prioritized. Moreover, it is able to reveal patterns, represent interrelationships, and clarify interdependencies between concepts (Coffman and Randhawa, 1978).

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4 Appendix B shows the tree diagram of "Load tree".
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- Screen shots:

![Diagram of Sources of Building Loads](image)

(a)

![Diagram of Sources of Building Loads](image)

(b)

Figure 5.6: Screen shots of “Load Tree”: (a) Home view; (b) Enlarged view after clicking the “Dead Load” button.
5.2.3.3 “Support Systems”

- **Location:** Ch 3 Structural Elements and Characteristics → Supports → The Pin Support, The Roller Support, and The Fixed Support

- **Description:** “Support Systems” shows the contrasting behaviours of the bars when they utilize four different support systems: 1) pin, 2) roller, 3) sliding, and 4) fixed supports.

- **Instructions:** Users can drag, rotate, or slide the bars according to the instincts of their support systems. To rotate, one places the cursor within the sensitive area situated within the dotted border, and then the bar automatically points in the direction of the cursor. To drag or slide, one places the cursor on any point of the system, and then left click-and-hold one’s mouse to drag or slide the bar along a restricted direction.

- **Characteristics:** This interactive illustration demonstrates how support systems work in reality. The bar connected to the pin support in Figure 5.7a can only rotate with respect to a fixed axis. (Note that the fixed axis is located along the bolt that connects a member and a support system. In Figure 5.7, all axes are perpendicular to the page and point out of the page.) The bar connected to the roller support in Figure 5.7b is not only able to rotate with respect to a fixed axis, but also to transverse horizontally. Like the roller support, the bar connected to the slider in Figure 5.7c can rotate with respect to a fixed axis and slide horizontally. However, the bar secured with the fixed support in Figure 5.7d cannot rotate nor move. Additionally, rotation is restricted to 180° above the ground, but not 360°. The members stop rotating after they reach these limits.
5.2.3.4 "Structural Hierarchy"

- Location: Ch 4 Common Structural System → Structural Pattern → Structural Hierarchy a Floor System

- Description: This interactive illustration shows the structural hierarchy of a typical floor system.
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- Instructions: "Structural Hierarchy" starts with an animation clip which explicitly explain a typical floor system, then, users are directed to the second part of this activity, which allows them to dissect and study the floor system by "removing" the floor element one by one. To "remove" an element, users need to put the cursor on the targeted object, and left click-and-hold the mouse to drag it away (Figure 5.8). If users wish to return the system back to its original arrangement, they can press the "Reset" button at the bottom right of the frame.

- Characteristics: A typical floor system in North America consists of a plywood floor surface, joists, beams, and columns, and they are arranged in structurally sound direction and position. "Structural Hierarchy" is a 3-D pictorial demonstration that shows clearly how the floor is composed. The interactive behaviour allows learners to study the floor elements level by level.

- Screen shot:

![Figure 5.8: Screen shot of "Structural Hierarchy".](image)
5.3 Interactive Practice Components

Like the teaching components, the interactive practice components are based on the module’s philosophy and learning methodologies. These practice components are self-assessing quizzes and exercises to determine if learners are meeting their studious standards and goals. These carefully designed quizzes and exercises require users to interact with their computers which provide instant personal feedback along the practicing process.

There are six types of interactive practice components created by Flash in the SCLM, and they have common as well as distinctive settings, instructions, and characteristics. These six components are true or false (“Vector & Force”), multiple choice (“Free Body Diagram”), fill in the blank (“Unit”), hot object (“SFD & BMD”), drag and drop (“Support Conventions”), and hot spot (“Trusses”).

5.3.1 Common Characteristics

Practice exercises and quizzes are interactive components displayed inside the “Bottom Right” frame, and they have several common characteristics:

- All interactive practice components start with a welcome page that displays the instructions of the exercise. It is recommended that users read the instructions thoroughly before they proceed.

- All interactive practice components are situated within a solid border with the navigation button, “Next” button, located at the right. One can only proceed to the next page after answering the question(s) or fulfilling the requirements listed on the current page.
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- Most of the interactive elements, such as buttons and comments, are located at the bottom portion of the frame. The “Reset” button is to modify answers, while the “Check Answer” button is to evaluate answers.

- Comments are automatically generated by the computer and then shown at the bottom of the frame. Users can expect to uncover directions or hints by reading the comments when working on a practice exercise.

- At the end of a quiz, the computer calculates the result and shows the total number of correct answers, total number of incorrect answers, as well as the final score in percentage (%).

5.3.2 True or False - “Vector & Force”

- Location: Ch 1 Engineering Mechanics → Force → Vector & Force- Quiz

- Description: In this quiz, users respond to ten true or false questions.

- Instructions: There are a total of twenty-two questions\(^5\) about vector and force in this exercise, and the computer randomly selects ten questions in a quiz. Each question is a statement and users are asked to choose whether it is “true” or “false” by clicking the corresponding radio buttons on the left (Figure 5.9).

- Characteristics: The true or false questions in “Vector and Force” cover the material taught in chapter 1 in the module. One should be able to answer them without the help of other external sources. Since questions in this quiz are randomly generated, users will unlikely answer the same set of questions in the exact order the next time they take the quiz again. When answering a true or false

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\(^5\) Appendix C lists the true or false questions asked in “Vector and Force”.

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question, the computer accepts either “true” or “false”, but not both. If “true” is chosen, the radio button of “false” automatically becomes clear, or vice versa. Users can only answer a question once, a second attempt is not allowed.

- Screen shot:

![Question 1: A force exerted on an object by the earth's gravity is called normal force.](Figure 5.9: Screen shot of “Vector and Force”)

5.3.3 Multiple Choice - “Free Body Diagram”

- Location: Ch 1 Engineering Mechanics → FBD → FBD - Exercise

- Description: In each exercise, users respond to four multiple-choice questions about a structural system. There are three to five choices for each question.

- Instructions: In the opening page, users are asked to choose and then study a system among the six cases in “Free Body Diagram”. There are four questions in
each case\(^6\): The first question asks about the types of external forces that contribute to the system; the second question asks about the free body diagram of the system; the third and fourth questions ask about the equilibrium equations of the system. Users indicate their answers by clicking onto the check boxes to put check marks inside (Figure 5.10).

- Characteristics: In designing the questions for this interactive component, the module designer needs to decide upon the number and kinds of choices to offer, understand students' potential thinking processes, and recognize likely misconceptions about a particular FBD. Some questions have more than one answer; users have to put multiple check marks in order to answer those questions correctly. Users are given three chances to answer a question. If the first attempt is incorrect, the “Check Answer” button at the bottom left becomes the “Reset” button to clear the check mark(s). If the second response is incorrect again, the model answer will be shown at the bottom of the frame where the comments are displayed.

\(^6\) Appendix D lists the multiple-choice questions asked in “Free Body Diagram”.

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Chapter 5 Interactive Element Design

- Screen shot:

**Figure 5.10: Screen shot of “Free Body Diagram”**.

5.3.4 Fill in the Blank - “Unit”

- Location: Ch 1 Engineering Mechanics → Units → Units – Quiz
- Description: In this quiz, users answer a set of questions by typing their responses in the given text fields.
- Instructions: There are a total of thirty-six questions about units in this exercise, and the computer randomly selects ten questions in a quiz. Users respond by typing their answers into the entry text field which is located at the centre of the frame (Figure 5.11).

7 Appendix E lists the fill in the blank questions asked in “Units”.
• Characteristics: As in "Vector and Force", the questions in "Units" are randomly generated so users can expect a new set of questions the next time they take the quiz again. Many questions have more than one correct answer; therefore, the module designer needs to take other possible answers into account. This quiz is able to accept three correct answers. For example, the answer to this question "What is the unit of mass in SI units?" is "kilograms", but "kilogram" and "kg" are also acceptable. Users are given two chances to answer a question. If the first response is wrong, the “Check Answer” button at the bottom left becomes the “Reset” button to clear the text field. If the second response is wrong again, the computer will reveal the model answer at the bottom of the frame where the comments are displayed.

• Screen shot:

![Quiz - Units](image)

**Question:** 2

What is the prefix for $10^{-6}$?

**Enter your answer here:**

micro

![Check Answer](image)

Click the Check Answer button.

Figure 5.11: Screen shot of "Units".
5.3.5 Hot Object - “SFD & BMD”

- Location: Ch 2 Mechanics of Materials → Internal Force Diagrams → SFD & BMD Exercise

- Description: In this exercise, users respond by choosing the correct SFD and BMD of a beam system. There are three SFDs and three BMDs to choose from for each system.

- Instructions: In the opening page, users are asked to choose a beam system out of the three choices in “SFD & BMD”\(^8\). Users study the beam carefully and determine both SFD and BMD by the method taught in the SCLM. To respond, users choose their answers by clicking onto the diagrams, which are tinted in orange after being selected (Figure 5.12).

- Characteristics: The module designer purposely offers three similar SFD and three similar BMD to test students’ understanding about drawing internal diagrams. The shapes of the incorrect choices are either up side down, left side right, or right side left, of the correct diagrams. However, there is only one correct SFD and BMD for each system. During the middle of the exercise, users can clear the selection by clicking the “Reset” button, which becomes activated after the first diagram has been selected. Users are given two chances to answer a hot object question. If all the responses are incorrect, the model answer will be shown at the bottom of the frame where the comments are displayed.

\(^8\) Appendix F lists the hot object questions asked in “SFD & BMD”.
5.3.6 Drag and Drop - "Support Conventions"

- Location: Ch 3 Structural Elements and Characteristics → Supports → Support Convention - Exercise

- Description: In this exercise, users drag support conventions to the supports of a beam system. There are six support conventions in each system; they are named A, B, C, D, E, and F.

- Instructions: In the opening page, users are asked to choose a set of questions among the three sets in “Support Conventions”. There are three beam systems in...
each set\textsuperscript{9}. To answer a question, users “pick up” a support convention by left-click-and-hold the mouse to drag it across the screen. When the dragged object gets near to a targeted support, it automatically snaps to the target after the mouse is released. However, if the dragged object is not near any target, it snaps back to its original position.

- Characteristics: The six choices offered by this drag and drop exercise cover many possibilities of the support conventions. However, there is only one correct match for each support. During the middle of the exercise, users can clear the present answer by clicking the “Reset” button, which becomes activated once users start dragging a support convention. They are given two chances to complete a drag and drop question. If all the responses are incorrect, the model answer will be shown at the bottom of the frame where the comments are shown displayed.

\textsuperscript{9} Appendix G lists the drag and drop questions asked in “Support Conventions”.
5.3.7 Hot Spot - “Trusses”

- Location: Ch 4 Common Structural Systems → Trusses → Trusses · Quiz

- Description: In this quiz, users determine which members of the trusses are subjected to tension, compression, or zero force by clicking onto the members.

- Instructions: In the opening page, users are asked to choose a set of questions among the three sets in “Trusses”. There are five case studies in each set. Users study each truss carefully and use the methods taught by the SCLM, such as the method of joints, method of sections, or visual inspection, to determine which

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10 Appendix H lists the hot spot questions asked in “Trusses”.

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members are subjected to which type of internal force. To respond, users choose and then click onto a particular member. If the question asks for tension members, a member turns blue after being selected (Figure 5.14). If the question asks for compression members, a member turns red after being selected. If the question asks for zero force members, a member turns white after being selected.

- Characteristics: The five trusses within a set of case studies are very similar to each other, but with different load locations, support conditions, and member orientations. These differences cause the internal forces in the members to vary. During the middle of the quiz, users can deselect their choices by clicking the “Reset” button, which becomes activated after the first member has been selected. Users are given two chances complete a hot spot question. If all the responses are incorrect, the model answer will be shown at the bottom of the frame where the comments are displayed.

- Screen Shot:

Figure 5. 14: Screen shot of “Trusses”. Member AC, BC, and CE are selected and turn blue.
5.4 Summary

This chapter discussed the SCLM’s interactive element design. The advantages and considerations of using software programs, RoboHelp and Macromedia Flash, to create an interactive learning environment were also discussed. The chapter also explained in detail the two types of interactive components created by Flash. They were constructed based on the principles of Constructivism, interactive learning, visual learning, and computer-based learning. The interactive teaching components include animation clips, interactive displays, and interactive illustrations. On the other hand, the interactive practice components include true or false, multiple choice, fill in the blank, hot object, drag and drop, and hot spot options.
6.0 SUMMARY AND CONCLUSION

6.1 Background

The integration of new technologies into traditional education assists educators in teaching and students in learning. This development ideally enhances the educational quality in the area of structural engineering; however, the effectiveness of many existing teaching-learning units is in fact questionable. In the schools of structural engineering and architecture, many instructors who teach structural classes are frustrated with unsuitable teaching applications which fail to perform interactively or lack the user-friendly characteristics they had promised. One major problem is that many existing structural learning tools lack a guided context, instructive content, and/or practice opportunities for students.

6.2 Purpose and Methodology

This thesis described the development of an interactive web-based learning tool, named "Structural Concepts Learning Module" (SCLM). This module covers most of the fundamental structural concepts taught in a preliminary structural class. During the development process, the module designer studied a number of existing teaching-learning tools and used their positive features to construct a learning environment that has the ability to assist in and encourage self-learning. When creating visual elements, RoboHelp was used to customize a user-friendly interface, while Macromedia Flash was used to produced graphics and interactive components. The SCLM contains many learning opportunities, practical activities, and supplementary assessments for users to strengthen and evaluate their understanding of structural concepts.
6.3 Theoretical Framework

The SCLM draws upon an educational theory known as constructivism. Constructivism is a theory that encourages learning through exploration. It also has a significant impact on the curriculum, instruction, and assessment of the module. On the other hand, interactive learning emphasizes the communication between computers and the SCLM learners, visual learning provides graphical support for the module, and computer-based learning utilizes technologies in structural learning. These three types of learning aspects contribute to the creation of a web-based environment that allows students to interact visually with their computers and self-explore underlying fundamental structural concepts.

6.4 Limitation

Although the development process is time consuming and laborious, this research has demonstrated the guidelines and techniques for integrating various learning methods into a primary structural curriculum. However, there are several limitations to the SCLM.

Firstly, as mentioned in section 5.1.3, Technological Consideration, only users whose computers run in Windows 95m, NT4, 98, 2002, ME, and XP have the viewers or browsers required to view the SCLM. The module is not compatible with platforms such as Window 3.1, UNIX, and Macintosh. If the platform is independent of the types of computer facilities, nobody will be restricted from using the SCLM.

Secondly, the topics chosen to be included in the SCLM are ones that allow the module designer to demonstrate the characteristic of the three aspects of learning; however, the level of teaching material available does not cover all the critical topics shown in figure 3.4. An ideal module would cover all the fundamental structural concepts for targeted users.

Finally, there was no actual testing done to evaluate the effectiveness of the module. Such a test would certainly make a preferable extension to this project. To perform a test, one can
implement an SCLM prototype as an extra curriculum activity or accompaniment to structural classes of both junior civil engineering and senior architectural students. Their self-assessment results and feedback could be collected for further analysis. This extended research will prove whether the SCLM is able to enhance students' understanding of the material it contains. Moreover, since this research excludes the implementation process, the module designer did not include a “Learning Management System”, as discussed in section 5.1.2, Flash. This management system has the ability to grade students’ work, analyze their performance automatically, and export the evaluation directly to the registrar in a spreadsheet format. Therefore, educators can spend more time concentrate on improving teaching material rather than carrying out other administrative chaos and repetitively grading student’s work. It is strongly recommend that the “Learning Management System” become part of the SCLM when conducting future research.

6.5 Implication

Building an ideal web-based learning environment for engineering education is not a simple task. In order to achieve qualitative assurance of the end product, a group of knowledgeable experts is required from the areas of education, graphics design, computer technology, and structural engineering to work corporately during the development process. The SCLM designer fulfilled the tasks of the above-mentioned disciplines and perceived several critical implications during the development process.

An important aspect of this project was exploring the possibility of interaction in structural learning. One should be aware that interactive activities require reciprocal communication between computers and the people using them. Plus, computers should support non-linear navigation paths for users to control their choice of knowledge and working pace, and at the same time, provide informative feedback to engage and guide users.

Some students are visual learners and some study through practice. If they utilize a self-learning unit, it should contain multiple ways of teaching methods to accommodate diverse
ways of learning. Therefore, they will be more able to take control of the curriculum according to their academic competence. For instance, the SCLM demonstrates how to carefully design the visual elements to fulfill various teaching purposes, so visual learners will find the material easy to follow.

The graphical presentations generated by modern technologies suggest numerous visual possibilities; however, for educational purpose, they should exemplify realistic situations only. The designer of these presentations must clearly understand and be aware of the modeling elements and their conditions; otherwise, the results may become ambiguous or misleading. When modeling a structural element, one should be familiar with its theoretical behaviour as well as its boundary conditions, such as the support system, external loading, and surrounding temperature.

There are many exciting ways of developing this research in the near future. Hopefully, future projects will continue the essence of building an educational environment that engages participation, sharpens autonomy, inspires curiosity, stimulates creativity, encourages exploration, and allows for challenges. It is necessary to refine existing educational methods, including the SCLM, in order to achieve excellent results, and it is the responsibility of future researchers to establish this goal.
Bibliography


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Bibliography


APPENDIX A: INTERACTIVE INTERNAL FORCE DIAGRAMS
Example 1:

Beam system 1

Beam system 1- SFD

Beam system 1- BMD
Example 2:

Beam system 2

Beam system 2 - SFD

Beam system 2 - BMD
Example 3:

Beam system 3

Beam system 3 - SFD

Beam system 3 - BMD
Example 4:

Beam system 4

Beam system 4 - SFD

Beam system 4 - BMD
APPENDIX C: TRUE OR FALSE QUESTIONS IN "VECTOR AND FORCE"
Appendix C: True or false questions in “Vector and Force”

Questions on vectors:
1) Scalar is a real number with no information on direction. (True)
2) Time is a vector. (False)
3) Mass is a scalar quantity. (True)
4) Length is a vector. (False)
5) A vector is described by a magnitude and a direction in space. (True)
6) Two vectors can be called equal only if their magnitudes are equal. (False)
7) When adding more than two vectors, you don't need to worry about the order in which you add them. i.e. \( \mathbf{U} + \mathbf{V} = \mathbf{V} + \mathbf{U} \) (True)
8) Vector Subtraction: \( \mathbf{U} - \mathbf{V} = \mathbf{U} + \mathbf{V} \) (False)

Questions on forces:
9) A force is a vector with both direction and magnitude. (True)
10) System of Forces contains 2 forces only. (False)
11) Line of Action is the infinite straight line defined by extending along the direction of the force from the point where the force acts. (True)
12) A system of forces is coplanar if the lines of action of the forces are parallel. (False)
13) A system of forces is concurrent if the lines of action of the forces intersect at a point. (True)
14) A system of forces is parallel if the lines of action lie in a plane. (False)
15) A given object is subjected to an external force if the force is exerted by a different object/media. (True)
16) When one part of a given object is subjected to a force exerted by a different object, it is subjected to an internal force. (False)
17) The gravitational force on an object is a body force. (True)
18) Gravitational constant \( g \), is equal to 9.81m/s. (False)
19) A surface force can be exerted on an object by contact with another object. (True)
20) The magnitude of an object's weight is related to its volume. (False)
21) A force that result from contacts between objects is called a contact force. (True)
22) A force exerted on an object by the earth's gravity is called normal force. (False)
APPENDIX D: MULTIPLE CHOICE QUESTIONS IN "FREE BODY DIAGRAM"
Appendix D: Multiple-Choice Questions in "Free Body Diagram"

System 1:
The post anchors a cable that helps support a tension force of magnitude T.

Question 1:
To calculate the tensions in cable AB and AC, the ring at A is isolated from the system for drawing the FBD. The ring is subjected to external forces which are caused by:

A. Cable AB
B. Cable AC
C. Tension, T
D. The ground
E. The post

Answers: A, B, C

Question 2:
Which diagram represents the FBD of the ring?

A. Figure A
B. Figure B
C. Figure C

Answer: A

Question 3:
Which equilibrium equation represents the sum of forces in x-direction?

A. \( T \cos 20^\circ - T_{AB} \sin 35^\circ + T_{AC} \cos 50^\circ = 0 \)
B. \( T \cos 20^\circ - T_{AB} \cos 35^\circ - T_{AC} \cos 50^\circ = 0 \)
C. \( T \cos 20^\circ - T_{AB} \cos 50^\circ - T_{AC} \cos 35^\circ = 0 \)

Answer: B
Question 4:
Which equilibrium equation represents the sum of forces in y-direction?

A. $T \sin 20^\circ + T_{AB} \sin 35^\circ - T_{AC} \sin 50^\circ = 0$
B. $T \sin 20^\circ - T_{AB} \sin 35^\circ + T_{AC} \sin 50^\circ = 0$
C. $T \cos 20^\circ + T_{AB} \cos 35^\circ - T_{AC} \cos 50^\circ = 0$

Answer: A
Appendix D: Multiple-Choice Questions in “Free Body Diagram”

System 2:
A block of mass \( m \) rest on a surface inclined at an angle 30° to the horizontal.

Question 1:
What are the forces acting on the block?

A. Mass, \( m \)
B. Weight of the block, \( mg \)
C. Normal force, \( N \), exerted by the incline
D. Frictional force, \( f \), between the block and inclined surface

Answers: B, C, D

Question 2:
Which diagram represents the FBD of the block?

A. Figure A
B. Figure B
C. Figure C

Answer: C

Question 3:
Which equilibrium equation represents the sum of forces in x-direction?

A. \( N \cos30° - mg = 0 \)
B. \( mg \cos30° - f = 0 \)
C. \( mg \sin30° - f = 0 \)

Answer: C
Question 4:
Which equilibrium equation represents the sum of forces in y-direction?

A. \( N - mg \cos 30^\circ = 0 \)
B. \( N - mg \sin 30^\circ = 0 \)
C. \( N = 0 \)

Answer: A
Appendix D: Multiple-Choice Questions in "Free Body Diagram"

System 3:
A picture of weight 8N is hanging down from the roof by two wires.

Question 1:
What are the forces acting on the picture?

A. The tension in the wire 1, T₁
B. The tension in the wire 2, T₂
C. The anchorage provided by the roof, S
D. Weight of the picture, 8N

Answers: A, B, D

Question 2:
Which diagram represents the FBD of the picture?

A. Figure A  
B. Figure B  
C. Figure C

Answer: B

Question 3:
Which equilibrium equation represents the sum of forces in x-direction?

A. T₁ cos30° - T₂ cos60° = 0
B. T₁ sin30° + T₂ sin60° - 8N = 0
C. T₁ cos30° + T₂ cos60° = 0

Answer: A
Appendix D: Multiple-Choice Questions in "Free Body Diagram"

Question 4:
Which equilibrium equation represents the sum of forces in y-direction?

1. $T_1 \sin 30^\circ + T_2 \sin 60^\circ = 0$
2. $T_1 \sin 30^\circ + T_2 \sin 60^\circ - 8N = 0$
3. $T_1 \cos 30^\circ + T_2 \cos 60^\circ - 8N = 0$

Answer: B
Appendix D: Multiple-Choice Questions in “Free Body Diagram”

System 4:
A bar of weight $W$ is suspended from the roof by three springs, $A$, $B$, and $C$. The spring constants are $k_A$, $k_B$, and $k_C$, respectively. The unstretched lengths of the springs are equal.

Question 1:
What are the forces acting on the bar?

A. Weight of the bar  
B. The anchorage provided by the roof, $S$  
C. Spring $A$  
D. Spring $B$  
E. Spring $C$

Answers: A, C, D, E

Question 2:
Which diagram represents the FBD of the picture?

A. Figure A  
B. Figure B  
C. Figure C

Answer: C

Question 3:
Which equilibrium equation represents the sum of forces in x-direction?

A. $F_A + F_B + F_C - W = 0$  
B. $0$  
C. $F_A + F_B + F_C = 0$

Answer: B
Appendix D: Multiple-Choice Questions in "Free Body Diagram"

Question 4:
Which equilibrium equation represents the sum of forces in y-direction?

A. \( F_A + F_B + F_C - W = 0 \)
B. \( 0 \)
C. \( F_A + F_B + F_C = 0 \)

Answer: A
Appendix D: Multiple-Choice Questions in “Free Body Diagram”

System 5:
The equilibrium system consists of four frictionless pulleys, a bar, and a force F. Neglect the weight of the pulleys.

Question 1:
What are the forces acting on the bar?

A. Weight of the bar
B. Tension forces in the cords.
C. Reaction of weight on pulley A.
D. Reaction of weight on pulley C
E. Force F

Answers: A, C, D

Question 2:
Which diagram represents the FBD of the picture?

A. Figure A
B. Figure B
C. Figure C

Answer: A
Appendix D: Multiple-Choice Questions in "Free Body Diagram"

Question 3:
Which equilibrium equation represents the sum of forces in x-direction?

A. \( F_A + F_C - F = 0 \)
B. \( F_A + F_C - W = 0 \)
C. 0

Answer: C

Question 4:
Which equilibrium equation represents the sum of forces in y-direction?

A. \( F_A + F_C - F = 0 \)
B. 0
C. \( F_A + F_C - W = 0 \)

Answer: C
Appendix D: Multiple-Choice Questions in “Free Body Diagram”

System 6:
A force $F$ holds a 100N block in the equilibrium position.

![Diagram of system 6](image)

**Question 1:**
To calculate the forces in the cables, separate the cable juncture from the system. What forces are acting on the juncture?

A. Mass of the block  
B. Weight of the block, 100N  
C. Tension forces in the cables AB  
D. Tension forces in the cables AC  
E. Tension forces in the cables AD

**Answers:** C, D, E

**Question 2:**
Which diagram represents the FBD of the juncture?

A. Figure A  
B. Figure B  
C. Figure C

**Answer:** A

**Question 3:**
Which equilibrium equation represents the sum of forces in x-direction?

A. $T_{AC} \cos 20^\circ - T_{AD} \cos 60^\circ = 0$
B. $T_{AC} \cos 20^\circ - T_{AD} \sin 60^\circ = 0$
C. $T_{AC} \cos 20^\circ + T_{AD} \sin 60^\circ = 0$

**Answer:** B
Appendix D: Multiple-Choice Questions in “Free Body Diagram”

Question 4:
Which equilibrium equation represents the sum of forces in y-direction?
A. $T_A \cos 60^\circ + T_{AC} \sin 20^\circ - W = 0$
B. $T_A \cos 60^\circ - T_{AC} \sin 20^\circ - T_{AB} = 0$
C. $T_A \sin 60^\circ - T_{AC} \sin 20^\circ - W = 0$

Answer: B
Appendix E: Fill in the Blank Questions in “Units”

Type 1a (2 types of answers are acceptable)

23) What is the prefix of $10^{-9}$?  
24) What is the prefix of $10^{-6}$?  
25) What is the prefix of $10^{-3}$?  
26) What is the prefix of $10^{-3}$?  
27) What is the prefix of $10^{-6}$?  
28) What is the prefix of $10^{-9}$?  

Answers: nano, nano-  
micro, micro-  
milli, milli-  
kilo, kilo-  
mega, mega-  
giga, giga-

Type 1b (2 types of answers are acceptable)

1) What is the prefix of multiple $10^{-9}$?  
2) What is the prefix of multiple $10^{-6}$?  
3) What is the prefix of multiple $10^{-3}$?  
4) What is the prefix of multiple $10^{-3}$?  
5) What is the prefix of multiple $10^{-6}$?  
6) What is the prefix of multiple $10^{-9}$?  

Answers: nano, nano-  
micro, micro-  
milli, milli-  
kilo, kilo-  
mega, mega-  
giga, giga-

Type 1c (only 1 answer is acceptable, Case sensitive)

1) What is the abbreviation of “nano-“?  
2) What is the abbreviation of “milli-“?  
3) What is the abbreviation of “kilo-“?  
4) What is the abbreviation of “mega-“?  
5) What is the abbreviation of “giga-“?  

Answers: n  
m  
k  
M  
G
Appendix E: Fill in the Blank Questions in “Units”

**Type 2 (1-3 types of answers are acceptable)**

1) What is the unit of length in US Customary units?  **Answers:** feet, ft
2) What is the unit of force in SI units?  newtons, newton, N
3) What is the unit of force in US Customary units?  pound, pounds, lb
4) What is the unit of time in SI units?  second, seconds, s
5) What is the unit of time in US Customary units?  second, seconds, s
6) What is the unit of mass in SI units?  kilogram, kilograms, kg
7) What is the unit of mass in US Customary units?  Slug

**Type 3 (3 types of answers are acceptable)**

1) How many feet in 42 inches?  **Answers:** 3.5, 3.5 feet, 3.5 ft
2) How many feet in 5 meters?  16.4, 16.4 feet, 16.4 ft
3) How many miles in 10560 feet?  2, 2 miles, 2 mi
4) How many kilometers in 2 miles?  3.2 km, 3.2 kilometers
5) How many slug in 73 kg?  5, 5 slug
6) How many pounds in 4448 newtons?  1000, 1000 pounds, 1000 lb
7) How many tonnes in 31136 newtons?  3.5, 3.5 tonnes, 3.5 ton
8) How many inches in 76mm?  3, 3 inches, 3 in
9) How many feet in 102 inches?  8.5, 8.5 feet, 8.5 ft
10) How many metres in 20 feet?  6.1, 6.1 metres, 6.1 m
11) How many seconds in 4 hours?  14400, 14400 seconds, 14400 s
12) How many kip in 3500 pounds?  3.5, 3.5 kip
Appendix F: Hot Object Questions in "SFD & BMD"

Case 1:

![Beam Diagram with Loads](image)

SFD:
- A
- B
- C

BMD:
- D
- E
- F

Answers: A and F
Appendix F: Hot Object Questions in “SFD & BMD”

Case 2:

![Beam Diagram]

SFD:
- A
- B
- C

BMD:
- D
- E
- F

Answers: B and D
Appendix F: Hot Object Questions in “SFD & BMD”

Case 3:

\[
\begin{align*}
&10 \text{kN} \\
&2 \text{m} \\
&15 \text{kN} \\
&2 \text{m} \\
&5 \text{kN} \\
&2 \text{m}
\end{align*}
\]

SFD:
- A
- B
- C

BMD:
- D
- E
- F

Answers: C and F
APPENDIX G: DRAG AND DROP QUESTIONS IN "SUPPORT CONVENTIONS"
Appendix G: Drag and Drop Questions in “Support Conventions”

Set 1:

Support conventions:

Question 1:

Answers: Support 1 = B
Support 2 = E

Question 2:

Answers: Support 1 = B
Support 2 = C

Question 3:

Answers: Support 1 = C
Support 2 = E
Appendix G: Drag and Drop Questions in “Support Conventions”

Set 2:

Support conventions:

A B C D E F

Question 1:

Answer: Support 1 = A

Question 2:

Answers: Support 1 = C
Support 2 = B

Question 3:

Answers: Support 1 = F
Support 2 = C
Appendix G: Drag and Drop Questions in “Support Conventions”

Set 3:

Support conventions:

Question 1:

![Diagram of a force acting on a tilted support]

Answers: Support 1 = F
Support 2 = B

Question 2:

![Diagram of a force on a horizontal support]

Answers: Support 1 = D
Support 2 = C

Question 3:

![Diagram of a force on a support with a spring]

Answers: Support 1 = C
Support 2 = B
APPENDIX H: HOT SPOT QUESTIONS IN “TRUSSES”
Appendix H: Hot Spot Questions in "Trusses"

Set 1:

Case 1: Select all the tension member(s).

Answers: AC, BC, CE

Case 2: Select all the compression member(s).

Answers: AC, BE, CE
Appendix H: Hot Spot Questions in “Trusses”

Case 3: Select all the zero force member(s).

Answer: BD

Case 4: Select all the compression member(s).

Answers: AB, BD

Case 5: Select all the zero force member(s).

Answer: CE
Set 2:

Case 1: Select all the compression member(s).

Case 2: Select all the tension member(s).

Case 3: Select all the compression member(s).

Answers: AC, AD, AE

Answer: AD

Answers: AC, AE
Appendix H: Hot Spot Questions in “Trusses”

**Case 4:** Select all the zero force member(s).

![Diagram of a truss structure with labeled points: A, B, C, D, E, F.]  

**Answer:** All members

**Case 5:** Select all the tension member(s).

![Diagram of a truss structure with labeled points: A, B, C, D, E, F, P.]  

**Answers:** AD, BD, CE
Appendix H: Hot Spot Questions in “Trusses”

Set 3:

Case 1: Select all the compression member(s).

Case 2: Select all the compression member(s).

Case 3: Select all the tension member(s).
Appendix H: Hot Spot Questions in "Trusses"

**Case 4:** Select all the tension member(s).

Answers: AD, AE, CF

**Case 5:** Select all the zero force member(s).

Answer: All members
Appendix I: Structural Concepts Learning Module (SCLM)

The attached CD-ROM contains the Structural Concepts Learning Module (SCLM). The SCLM is built with RoboHelp and Macromedia Flash.

The file in the attached CD-ROM: SCLM.chm (2704kB)

March 2003
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