AC 2007-1707: MULTIMEDIA AIDED PROTOTYPE E-LEARNING (MAPEL) MODULES FOR TEACHING THE FUNDAMENTALS OF THE FINITE ELEMENT METHOD

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Multimedia Aided Prototype e-Learning (MAPeL) Modules for Teaching the Fundamentals of the Finite Element Method

Abstract

Development and deliverance of multimedia aided e-Courses through Virtual Learning Environment (VLE) in engineering education, offers a great potential for improving student learning outcomes and overcome existing educational challenges. This paper presents the development of an open access online Finite Element Method Learning environment (FEML) which is a part of bigger effort to develop Finite Element Method universal resource (FEMur) website. FEMur is an open access resource developed for teaching the basics of the finite element method. A brief discussion on FEMur resources consisting of computer codes, reference books, discussion groups, professional societies, etc., is also included.

FEML consists of static and interactive Multimedia Aided Prototype e-Learning (MAPeL) modules on topics such as linear algebra, degree of freedom, spring element, truss element and beam element. Each of these e-Learning modules includes five parts, e-Content, e-Lecture, e-Assessment, e-Computation and e-Simulation. A new approach of developing integrated animated pedagogical agents to deliver online finite element method prototype e-Lecture will be briefly discussed. Using multimedia components, such as graphics, animations, digital sound, etc., in developing interactive learning modules for teaching engineering can help students to effectively engage in the learning process and better understand the subject concepts. In the recent years, this approach has proven to be a benefit for instructors and students.

Introduction

In recent years continual growth of Instructional Technology (IT) in engineering education, has led to the development and deliverance of multimedia aided e-Courses through Virtual Learning Environment (VLE). Multimedia aided e-Courses include both content and elements of IT for effective dissemination of subject matter. They have gained importance as a way to solve existing educational challenges[1]. Use of multimedia elements, such as graphics, animations, digital sound digital video etc., to improve the student-content interaction promotes the use of e-Learning in engineering education. e-Learning is defined[1] as the mapping of traditional teaching and learning practices to the Virtual Learning Environment (VLE). It not only follows a student centered approach but also helps the instructors in creating effective teaching modules easily and quickly.

Finite Element Method universal resource

FEMur is a multimedia based open access online resource developed for teaching the basics of the Finite Element Method. Although a brief introduction of FEMur has been presented elsewhere[2], an extended discussion on its general FEM resources and open access online Finite Element method Learning (FEML) environment will be presented here.

General FEM Resources

The general FEM resource is a compendium of useful information on FEM from computer codes and articles to professional societies and reference books available on World-Wide Web. It is anticipated that these resources provide a comprehensive knowledge on FEM for novice, intermediate and advanced learners. The following eight resources also include links to various other websites which significantly contributes to the development and online learning of FEM.

a. *Computer Codes.* This resource lists various finite element codes that are used in industry, national laboratories and educational institutions throughout the world.
b. *Events.* This resource is a compendium of links to various professional committee's and societies that publicize conferences in the computational mechanics community.
c. *Articles*. This resource contains list of journals and periodicals where articles on the FEM are published.
d. *Discussion Groups.* This resource includes different newsgroups, mailing lists and other Internet communications that address discussions on FEM.
e. *Professional Societies.* This resource lists different professional societies/clubs/committees that are active in addressing applications and research developments of the finite element method.
f. *Consulting Firm.* This resource lists various consulting firms in the USA and other countries that are active in the field of FEM.
g. *Other FEM Websites.* This resource consists of links to homepages containing FEM resources on the World-Wide Web.
h. *Reference Books.* This resource lists reference books, bibliographies and handbooks on FEM.

Based on the above eight resources, a survey on open access online resources for teaching and learning finite element method is shown in Table 1. It is also observed that except for the FEMur developed in reference[11], no resource contains extensive information on FEM.

The above eight resources are presented as hyperlinks in a horizontal fashion on the top of the research resource home page of the FEMur website. The research resource is a category under the resources link in the FEMur home page.

Finite Element Method Learning (FEML) environment

Finite Element Method Learning (FEML) can be defined as an open access virtual learning environment containing various online and offline resources essential for learning and improving the finite element method subject matter. FEML currently includes static and interactive Multimedia Aided Prototype e-Learning (MAPeL) modules on topics such as linear algebra, degrees of freedom, spring element, truss element and beam element.

Each of these e-Learning modules (hereon referred as e-learning digital content) is divided into following five categories[1]:

- *e-Content*. Deals with the subject matter similar to a textbook in the form of an e-Book.
- *e-Lecture*. Represents virtualized version of traditional lectures.
- *e-Assessment*. Replaces traditional tests and surveys with the web-based ones.
- *e-Computation*. Stand alone and web-based numerical and symbolic computational tools.
- *e-Simulation*. Represents/imitates real life problems within engineering.

The focus of the discussion will be on the e-Content of a full-scale case study for a uniformly distributed simply supported beam with geometric discontinuities, prototype e-Lecture on Degrees of Freedom, prototype e-Assessment on Degrees of Freedom and prototype e-Simulation of uniformly distributed simply supported beam with geometric discontinuities.

A media literature review revealed that apart from the hypertext, incorporation of media elements such as digital sound, graphics, animation and digital video into e-Learning digital content [1] increases the learning effectiveness of students. Based on the above five categories of e-Learning digital content, a survey on open access online resources for teaching finite element method is shown in Table 2. One will observe that past work has mainly focused on only two categories of e-Learning digital content (modules), i.e., e-Content and e-Assessment. The other categories have not been fully implemented to represent a complete e-Learning methodology. It is also observed that except for the FEMur developed in reference[11], no course contains an e-Lecture.

Table 1: A sampling on open access online e-Resources for learning finite element method.

University or Resource	e-Resources							
	Computer Codes/ Software	Events	Articles	Discussion Groups/ People	Professional Societies	Consulting Firms	Other FEM Web-sites	Reference Books
University of Saskatchewan[25]	X	X		X	X	X	X	X
Tennessee Technological University[26]							X	
Linkopings Universitet[27]			X					X
Indiana University[28]	X							
Engineering Development Associates[29]	X						X	
Finite Element Method universal resource[30]	X	X	X	X	X	X	X	X
University of Colorado[31]				X[People]				
Vienna University of Technology[32]	X						X	
Steelnyx[33]							X	
University of Florence[34]	X						X	

Table 2: A sampling on open access online resources for teaching finite element method.

University/Resource	e-Learning Digital Content				
	e-Content	e-Lecture	e-Assessment	e-Computation	e-Simulation
Berner Fachhochschule, University of Applied Sciences[3]	X				
Carnegie Mellon University[4]	X			X	
Dattaraj Rao[5]	X				X
Luleå tekniska universitet, Luleå[6]	X				
Massachusetts Institute of Technology[7]	X		X		
New Mexico Institute of Mining and Technology[8]	X		X		X
Penn State University[9]	X		X		
Southern Illinois University[10]	X		X		
University of Arkansas[11]	X	X	X	X	X
University of Colorado[12]	X		X		
University of Colorado[13]	X		X		
University of Colorado[14]	X		X		
University of Colorado[15]	X		X		
University of Cincinnati[16]	X		X		
University of Leeds[17]	X				
University of Memphis[18]	X		X		
University of Maryland[19]	X				
Vector Space Programming[20]	X		X		
Norwegian University of Science and Technology[21]	X			X	X
The University of Aizu[22]	X				X
The University of Tokyo[23]	X				
NPTEL, Indian Institute of Technology[24]	X	X			

It is observed that IT offers a paradigm shift in students learning and lecture dissemination methodology. The rate of growth in IT is far high compared to the rate of IT adoption in engineering education. The standard S-shaped curve[35] is plotted in Figure 1 for analyzing the growth rate of new IT methods in engineering education with time. Successful implementation and growth of any new technology or tools in instruction demands time based on its compatibility, versatility and feedback from developers, instructors and students. The later sections in this paper discuss the use of such new tools and techniques for developing e-Learning content. Some of these have already made strides in the modern IT and are expected to revolutionize the way instruction being delivered online in the future.

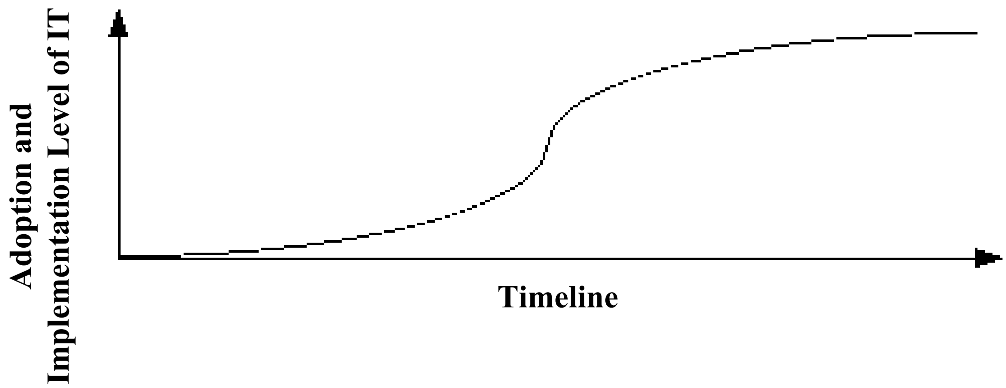

Figure 1: Standard S-curve[35] showing the projected IT adoption and implementation level in education with time.

Although the outcome of using multimedia elements in teaching subject matter is beneficial for students and instructors, a large number of instructors do not follow this approach. We found that the following six shortcomings can be attributed to the low rate of IT adoption in engineering education by instructors:

a. *Time Expensive.* To create graphics and animations for various e-Courses in engineering education consume ample time. Illustrations in courses include figures with complex shapes and sizes. Only few softwares' offer standard library objects with pre-defined shapes and that are commonly used in engineering.
b. *Cost.* Development of multimedia aided e-Courses requires the use of sophisticated commercial software that is expensive. Also, outsourcing of e-Courses development to commercial organizations is very expensive. But, educational/student version of these soft wares' might cost less compared to the professional version.
c. *Lack of Prior Knowledge.* Prior knowledge of the content creation software tools is necessary for developing effective e-Courses easily and quickly. Lack of this leads to time consuming and labor intensive work. Orientation or training of required software can overcome this challenge.
d. *Motivation.* Lack of motivation from instructors and students does not promote the adoption and implementation of multimedia in engineering education. This indirectly inhibits the growth rate of IT.
e. *Necessity.* Necessity of using multimedia elements is not observed for some courses in engineering. Although the use of these elements is recommended for effective dissemination and learning not every course demands their usage.

f. *e-Learning Awareness.* Lack of awareness about the potential applications and advantages of e-learning for students and instructors may result in ineffective or no use of multimedia elements in traditional courses.

g. *Adopting Change.* Few instructors offer resistance to change their traditional teaching methodology. This hinders the adoption of multimedia elements into courses.

This paper makes an attempt to overcome the above shortcomings through the development of e-learning digital content of FEML using commercially available software tools.

FEML Creation Process

Finite Element Method Learning environment consists of five learning modules, linear algebra, degrees of freedom, spring element, truss element and beam elements presented as five hyperlinks in the vertical fashion on the left hand side of the FEML home page of FEMur website. The digital content of these learning modules is divided into five sub-categories e-Content, e-Lecture, e-Assessment, e-Computation and e-Simulation, presented as five sub-hyperlinks in horizontal fashion on the top of each FEML learning module home page. Each of these five sub-categories constitutes multimedia components created using the state-of-the-art web content development software tools. These tools ensure ease of content creation in an organized style recommended by World Wide Web Consortium[36] in a shorter period of time. The multimedia components and software tools used to create the e-Learning digital content for FEML are shown in Tables 3 and 4.

The four multimedia components that can be used to create e-learning digital content of FEML are as follows:

- Hypertext (includes hyperlinks)
- Graphics (Images, photographs and vector-based drawings)
- Digital Sound
- Animation/Digital Video

The hypermedia components used to create the e-Learning objects for FEML are summarized in Table 3.

Table 3: Multimedia Components used to create e-Learning digital content for FEML.

Multimedia Components		**e-Content**	**e-Lecture**	**e-Assessment**	**e-Computation**	**e-Simulation**
Hypertext		X	X	X	X	X
Graphics	Images	X	X	X	X	X
	Vector-based Drawings					
Digital Sound	Text-to-Speech		X			
Animation/Digital Video			X			X

The hypermedia components and the software tools used to create the e-Learning digital content for FEML are summarized in Table 4.

Table 4: Multimedia Components and software tools used to create e-Learning digital content for FEML.

Hypermedia Component		**Software Tool**	**Software Tool Company**
Hypertext		Macromedia Dreamweaver MX[37]	Adobe-Macromedia
		MathType[38]	Dessica
Graphics	Images	Macromedia Fireworks MX[39]	Adobe-Macromedia
	Vector-based Drawings	Macromedia Freehand MX[40]	Adobe-Macromedia
Digital Sound	Text-To-Speech	VoiceText™ [41]	Neospeech, Inc.
Animation		Sculptoris Voices Lite[42]	Sculptoris Voices Studio
		Macromedia Captivate[43]	Adobe-Macromedia
Digital Video		ANSYS 10.0[44]	ANSYS, Inc.
		Macromedia Captivate	Adobe-Macromedia

A short review on these software tools is presented elsewhere[1]. From Tables 3 and 4 it appears that several software tools are necessary for development, depending upon the use of hypermedia components in the e-learning digital content.

e-Learning Digital Content

Among the five categories of e-Learning digital content, prototypes of four (e-Content, e-Lecture, e-Assessment and e-Simulation) will be presented here.

1. *e-Content.* Deals with the subject matter similar to a textbook in the form of an e-Book. The e-Content of learning modules spring element, truss element and beam element are divided into sub-modules which can be viewed separately. These sub-modules are element definition, assumptions, sign convention, element formulation, solution characteristics, element rigid body modes, example problem and references presented as hyperlinks in a horizontal fashion on the top of each learning module home page.

   The example problems will be the case study of a relevant model consisting of case study introduction, theory, solution and simulation[45]. The case study introduction provides the student with material and geometric data about the problem and the objective of the case study. Case study theory will include the three element types (i.e., beam, plane and solid) coupled with a review of sophomore level mechanics of materials. The case study solution will introduce the students on how to model the problem using each element type. In the case study simulation, a commercial FEM code (here ANSYS) is used to analyze each element type. The mathematical equations in the e-Content are developed using the commercial math editing software MathType. The equations written in Mathematical

Markup Language (MATHML) can be translated in to web page attribute within the Math Type software to make it compatible with the HTML/XHTML editor Macromedia Dreamweaver. More significantly, by using this mark up language, the content file size is fairly small.

A full-scale case study on a uniformly distributed simply supported beam element with geometric discontinuities is conducted as a prototype for the e-Content. The case study solution consists of three phases. The steps in each phase are essentially the same and require a comparison of each element (beam, plane and solids elements) type solution to the mechanics of materials solution. The overall design concept of the study module is focused on the integration of fundamental mechanics of materials and practical finite element analysis. Figure 2 shows a screenshot of the simply supported beam element case study introduction web page.

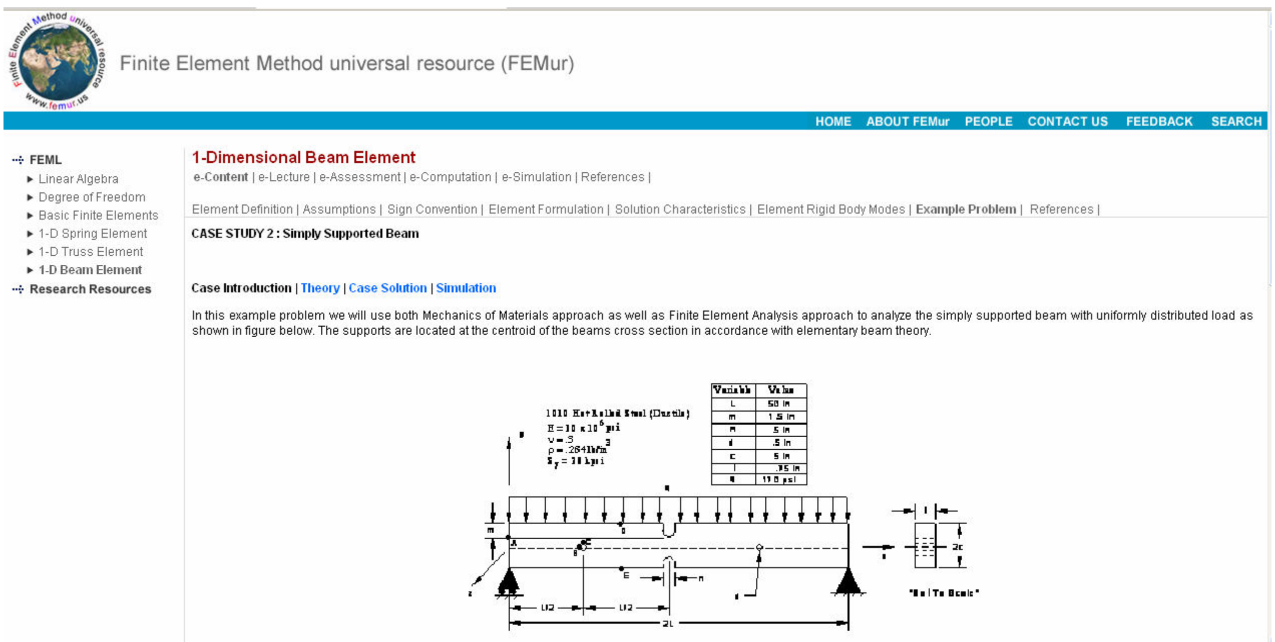

Figure 2: Sample view of prototype e-Content webpage.

Figure 3 shows the screenshot of deformation image of quarter-symmetry finite element analysis of the roller support end of the simple supported beam using eight-noded brick elements.

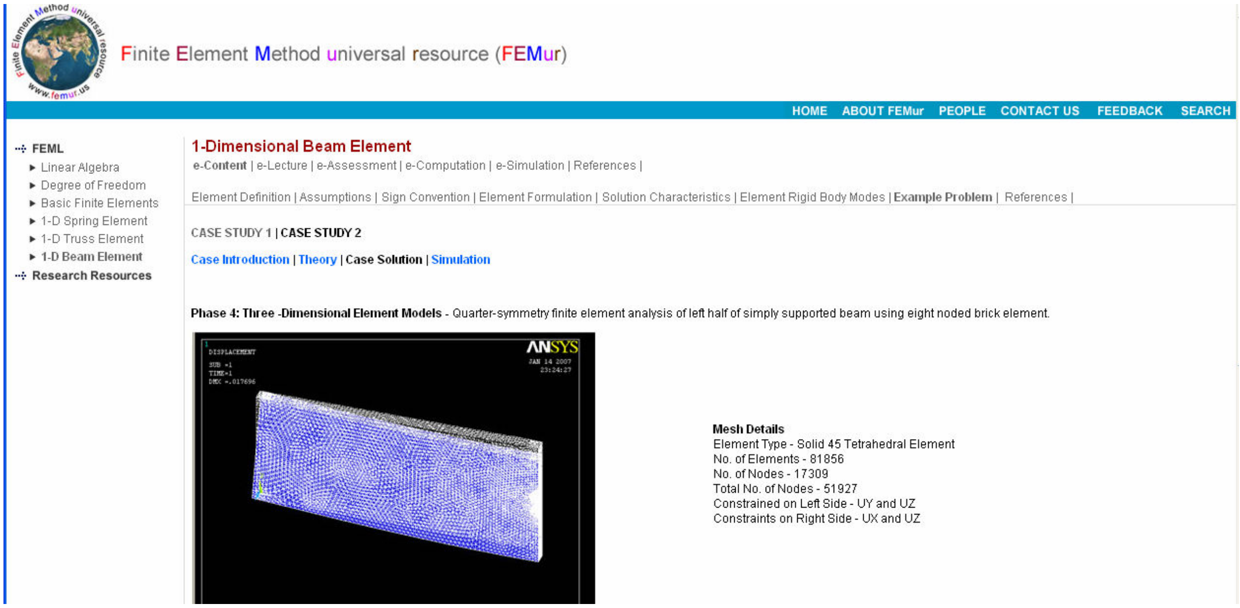

Figure 3: Screen shot of quarter-symmetry finite element analysis using eight-noded brick elements.

2. *e-Lecture*. It is the virtual equivalent of a conventional lecture or oral presentation that is enriched with integrated interactive elements and access to additional learning resources. e-Lectures of various e-Courses are available on the web in different formats that includes MS Word documents, PDF files, MS PowerPoint presentations, Macromedia Flash presentations, HTML files and online sound and video based e-Lectures. We found that these e-Lectures carry shortcomings[1,46]. To overcome these shortcomings FEML follows a unique approach of incorporating a human-like animated pedagogical agent called Mr. FEMur with in the e-Lectures developed in macromedia flash file format.

The prototype e-Lecture developed on "Degree of Freedom" using Mr. FEMur, demonstrates the concept of "Degree of Freedom" as used within finite element stress analysis. This prototype e-Lecture can be used as a teaching aid within any course on the finite element method. There are a total of nine slides within this prototype e-Lecture and a sample slide is shown in Figures 4. Figure 4 shows a sample slide that describes the "Translational Degrees of Freedom at Node". It is anticipated that this approach proves to be an easy way to create an effective e-Lecture with interface that is interesting, interactive.

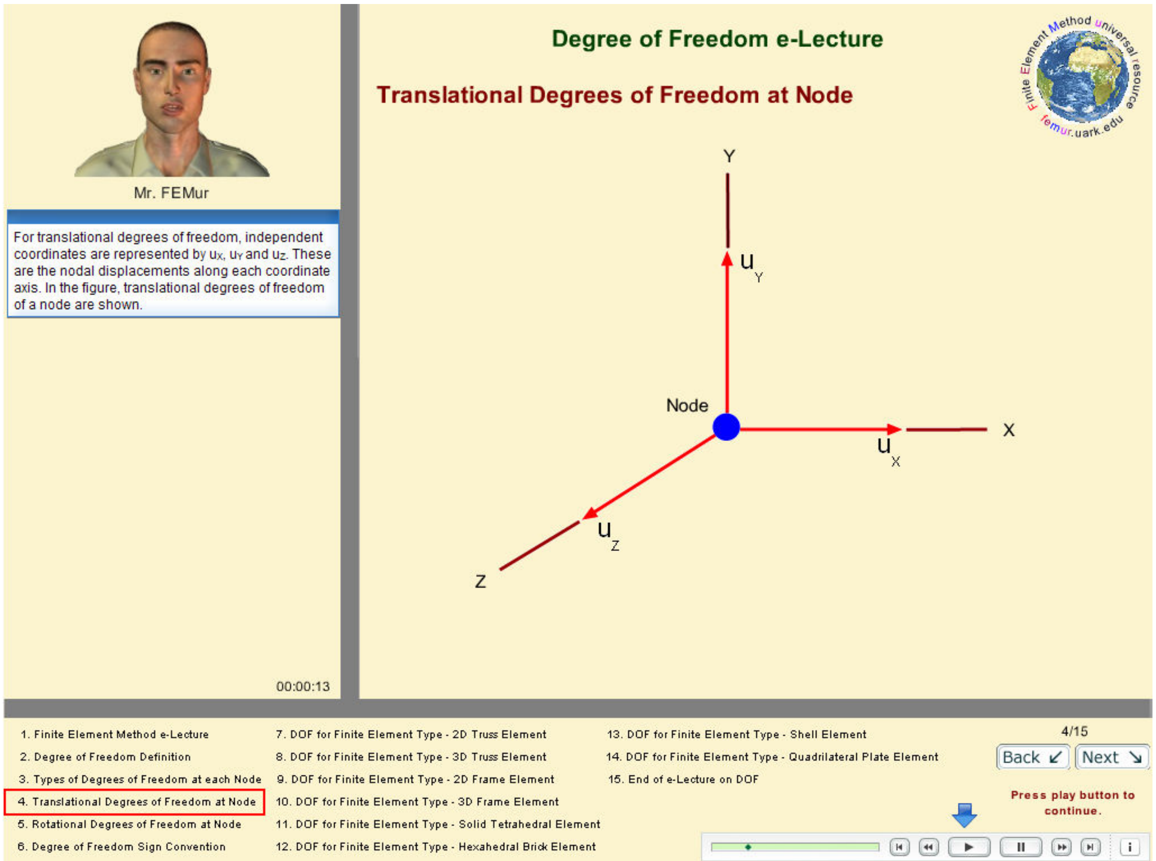

Figure 4: Sample slide of prototype e-Lecture slide.

3. *e-Assessment.* Research shows that, apart from interactive and innovative instructional techniques, assessment is an effective tool to improve student learning outcomes. The use of multimedia tools in e-Assessment helps create more interactive questions and improve student learning outcomes. Although its use in e-Assessment is less prevalent, the usage of graphics, animations, audio and video clips attract student's attention, helps in subject retention and better understanding of concepts by easily correlating with the domain knowledge.

In the FEML, a formative type multiple choice quiz is developed for the e-Assessment of the prototype e-Lecture on 'Degree of Freedom'. Over the completion of e-Lecture, the student takes the online test for assessing his/her knowledge and subject retention. The quiz consists of hypertext based multiple-choice questions with four answer choices for each question. The student selects the best answer for each question. The quiz is time independent, i.e., the student can spend as much time as they need to answer the questions. Once the test is completed, the software provides the student with the number of correct and incorrect answers out of the test total questions. A review of correct responses for all the questions is also provided. Macromedia Captivate was used to create the multiple choice type quiz.

The e-Assessment on the prototype e-Lecture "Degree of Freedom" demonstrates the self-assessment exercises on "Degree of Freedom." There are a total of seven slides within this prototype e-Assessment module and one sample slide is shown in Figure 5.

Figure 5 shows a sample slide with a question on "sign convention for nodal rotation." There are four choices for the answer out of which the student has to select a single answer.

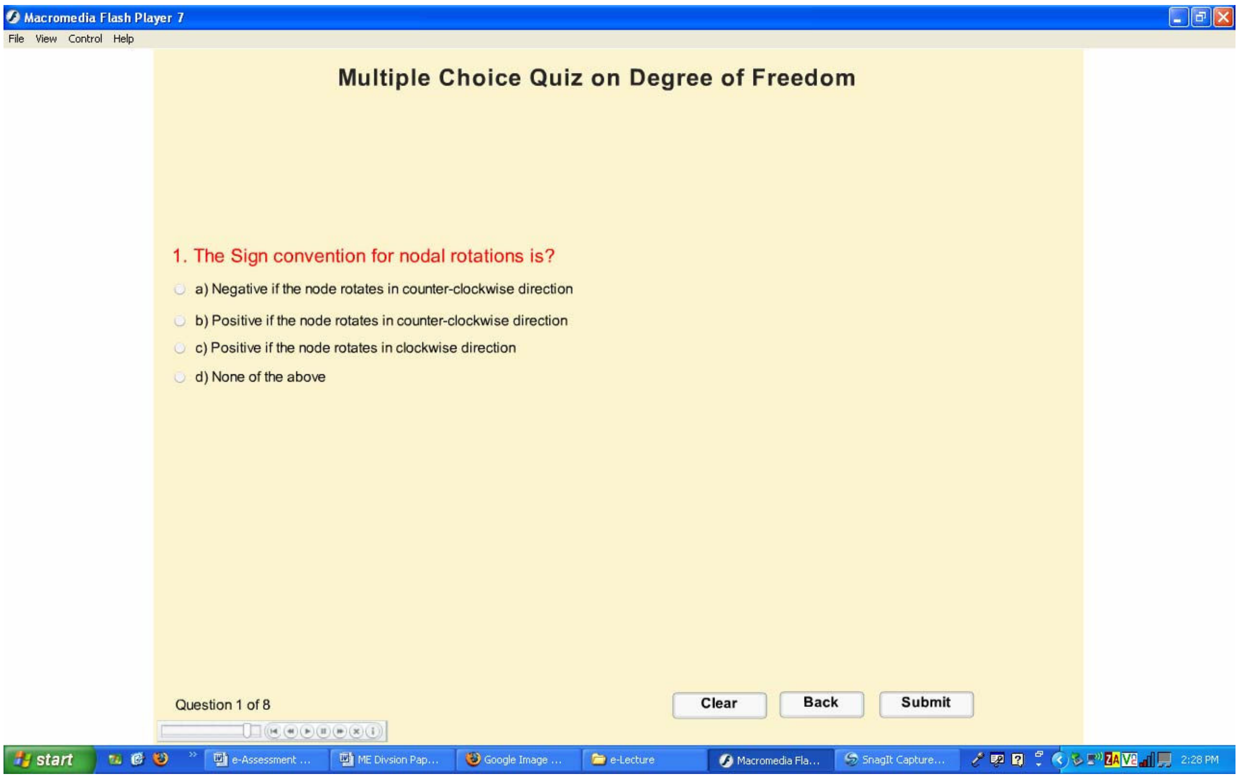

Figure 5: Sample slide of e-Assessment quiz on the prototype e-Lecture "Degree of Freedom".

4. *e-Simulation*. As stated before, e-Simulation represents/imitates real life problems within engineering. The visualization created enables the student for better understanding and retention of subject matter. From Table 1 it can be observed that very little work is carried in e-Simulation category of e-Learning digital content. e-Simulations can be created using many commercial and open source software tools in multiple formats such as Java, GIF, Macromedia Flash and video files. The prototype e-Simulation is created by conducting the finite element analysis on a uniformly distributed simply supported beam element with geometric discontinuities using FE commercial code ANSYS. The commercial code generates the e-Simulation in a video file format. The size of the video file is small for easy uploading or downloading from the website.

Figure 6 shows a screenshot of prototype e-Simulation of beam deformation in negative 'y' direction due to applied boundary conditions and loads on a half-symmetry simple supported beam. The characteristics of the mesh are shown on the right-hand side of the the image. The maximum stress is found to be high at notch than at the hole ad this is in agreement with the mechanics of materials solution.

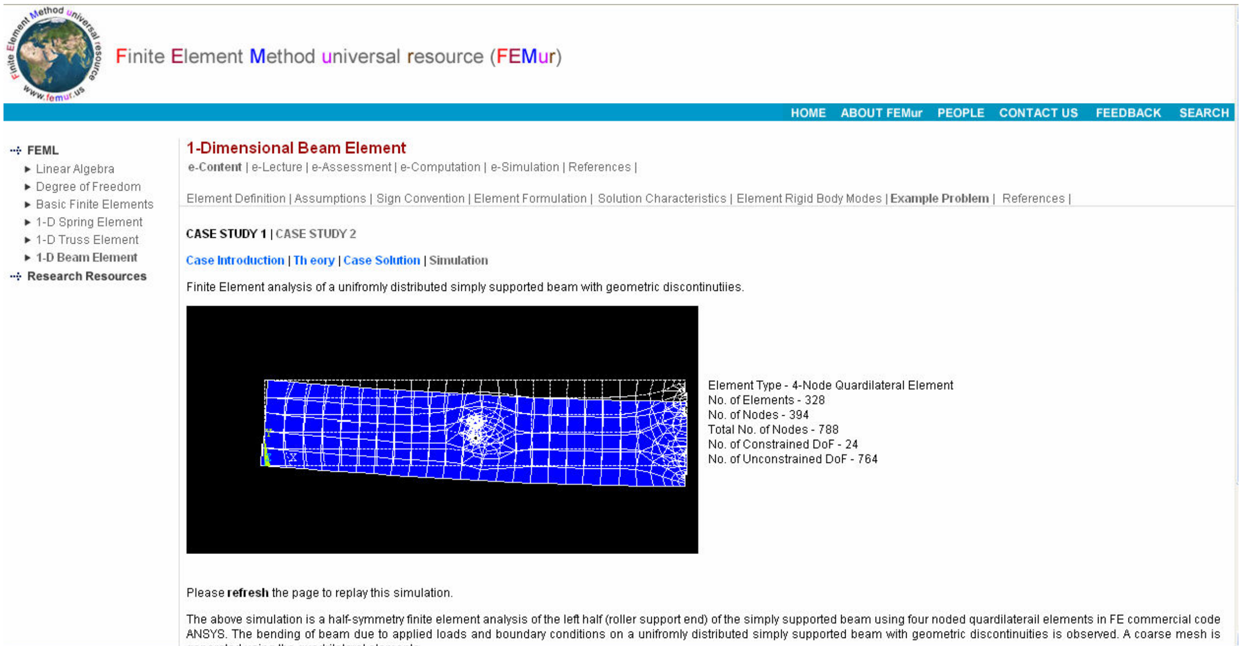

Figure 6: Sample view of prototype e-Simulation webpage showing the simply supported beam deflection created during half-symmetry finite element analysis.

Dissemination of FEMur

The discussed FEM general resources and Finite Element Method Learning environment are a part of bigger effort to develop the open access Finite Element Method universal resource. They are integrated into the FEMur website using Macromedia Dreamweaver. The sitemap of the FEMur website is created based on concept map using the open sources software Cmap tools of HCMI for easy access to various sections of FEMur site.

Conclusion and Future Work

In this work, an attempt to develop the e-Learning digital content for teaching finite element method using multimedia components was accomplished to overcome existing shortcomings addressed in this paper. The research and learning resources of FEMur provides a comprehensive knowledge of FEM which includes subject concepts coupled with example problems. Developing e-Lectures in Macromedia Captivate by integrating human-like animated pedagogical agent is fairly straightforward and simple requiring less time and effort. It is anticipated that the adoption and implementation of pedagogical agents in VLE for delivering e-learning digital content might revolutionize the future IT. In the future more e-Learning content will be created on various concepts used for teaching and learning finite element method using this approach.

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