E-Learning Platform for Teaching Courses Of Dynamics and Fluid Mechanics by X3D

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***Abstract* - This study adopts the interactive web- and broadcast-based 3D software standard "extensible 3D"(X3D) to construct the 3D virtual reality simulation examples for dynamics and fluid mechanics courses. An interactive web-based e-learning platform is shown. The e-learning platform is designed by the problem-based learning (PBL) methodology. Dynamics and Fluid Mechanics courses are divided into several modules, each divided into three levels , namely 3D e-simulation, a real time and interactive system using X3D. Problem-solving core knowledge references are also integrated in the platform. The content of the 3D simulation is expected to enhance the motivation and learning effect for the studying of dynamics and fluid mechanics. The subject areas of dynamics are particle dynamics, particle motion in plane, conservation of momentum, rigid body motion, motion of pendulum, gyroscopic motion, vibration and conservation of angular momentum. Additionally, the fluid mechanics topics are fee jet, application of Bernoulli equation, laminar and turbulent boundary-layer flows of a flat plate, basic concepts of streamline and path-line, the phenomena of hydraulic jump and flow in a pipe such as Orifice and Venturi meter. The e-learning platform and all scriptable animations are also free for non-commercial use on http://x3d.esoe.ntu.edu.tw/pbl.**

Key Words - PBL, e-learning, Dynamics , Fluid-Mechanics; VRML/X3D, 3D Visualization, Interactive ,XML,JSTL

INTRODUCTION

A competing vision in the PC industry based on an extensive analysis of the industrial value chain is shown in Figure 1 which is referred to as smiling curve [1]. The smiling curve indicates that the industrial high added value activities are shifted away from system assembly. The greatest added value comes from manufacturing key technologies on the one hand and from brand, marketing, services and software on the other.

The evolution of human learning also has a smiling curve based on the learning media and learning effect as shown in Figure 2. Learning in prehistoric times was from nature. For example, learning to be a hunter involved going to the jungle to trace and practice killing animals if learning to be a farmer involved going to the field to plant wheat or rice ,and learning how to fertilize and harvest. The learning was very important for survival ,food and reputation. Therefore ,the learning effect was strong. The invention of writing tools such as characters and paper made the learning easily acquired and available. However, the meaning s of black characters on white paper are hard to visualize. The process of learning from reading is tedious and boring and the learning effect is limited. The invention of television led to teaching programs ,which have been welcomed because the learner can learn more from the colorful , dynamic and pleasant images than from textbooks .The computer age has led to the adoption of computer-based teaching or training. For instance, the university of Minnesota has presented a "Computer-based multimedia" course for the fundamentals of fluid mechanics [1]. E-learning on the Internet has been a widely discussed topic for education and training since the Internet started to became widely used in 1996.Web-based e-learning can provide a learning-on-demand model without time or location constraints.

Various studies have considered the next stage in the development e-learning on the Internet as 3D e-simulation on the Internet. Blaisetet .al.[2] stated that the strong growth in 3D graphics, Web accessibility and networking creates new opportunities for education.

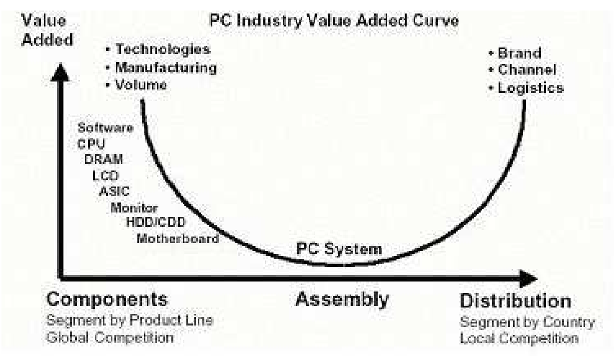

FIGURE 1
SMILING CURVE OF PC INDUSTRY [1]

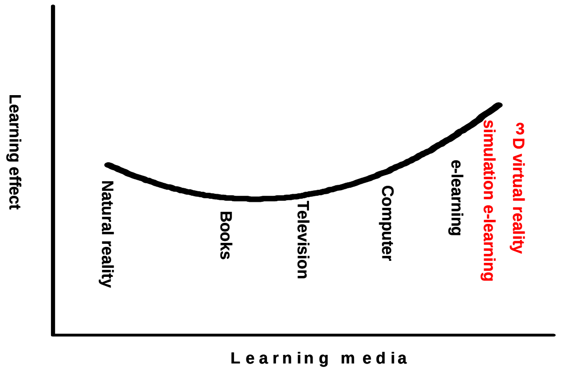

FIGURE 2
SMILING CURVE OF HUMAN LEARNING

The 3D virtual reality simulation on the Web can provide the learning environments that simulate natural reality. Learner can learn various subjects via the 3D simulation since they have strong motivation on the specific topics. The 3D simulation and learning on Web open a wide range of opportunities to enhanced educational experiences [2]. Teaching methodologies in engineering should evolve by following the development of the information technology to enhance the efficiency and effect of the learning by the students.

This study develops an e-learning platform based on problem based learning (PBL).This platform divides Dynamics and Fluid Mechanics into several topics each of which is divided into three levels thus helping a new learner to learn from the fundamental stage to the difficult and then complex problems .Conversely, an experienced learner can select topics arbitrarily. When a learner has solved a problem, the platform shows a 3D simulation of the solution on the Web. Additionally, this platform provides a problem-solving knowledge base, including both Dynamics and Fluid Mechanics for learners.

LEARNING METHODOLOGY

I. Problem-Based Learning Mode

Modern engineers are required to have strong communication capability and interpersonal skills, problem-solving skills, creative thinking skills , and the ability to function on multi-disciplinary teams [3, 4].Traditional discipline teaching methodologies do not enable students to develop these skills. The problem-based learning model proposed by Barrows and Tamblyn[5] for medical education provides a new methodology for engineering students to develop them. Problem-based learning in engineering involves the development of effective and efficient problem-solving skills ,self-directed learning skills and team skills the skills.

Problem-based learning has the following features:

(a) Learning is initiated by a problems based on the real world
(b) Learners work in small groups with the access to the knowledge database and instructors.
(c) Learners identify and find the resources required to solve the problems.
(d) Learning should be integrated from the wide range of disciplines related to understanding and solving the problem.
(e) Collaboration is essential.

Many engineering colleges in universities have adopted the problem-based learning methodology. For example, the capstone course at North Dakota State University [6], the introductory course of computer at Iowa State University [7], and the power engineering basics at the State University of Campinas, Brasil [8] are designed based on the problem-based learning model.

II. Methodology of Learning Effect

Michael Allen first introduced the $e = m^2 ci$ methodology as shown in Figure.3. In this equation , e denotes the user's learning effect, m represents user's motivation , c is learning content and i indicates interactivity .Notably m is squared ,where the first m is expected to excite the user's interest in a course and the second m maintains a user's motivation. The term "i" studying interactivity, emphasizes communication between the user and learning content. In an external circle, this study focuses on the technology of 3D simulation on the Web, its application in learning content interactively, and immersion in a 3D environment. As PBL mentioned above , User-Centric and 3D Simulation, those factors promote the cooperation between motivations.

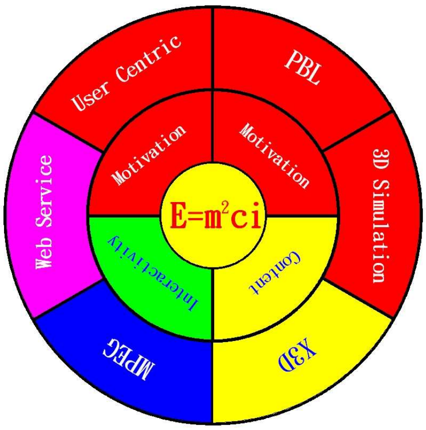

FIGURE 3
LEARNING EFFECT

III. Problem-Based Learning System

Considering the benefits above, this study develops a problem-based learning system as shown in Figure 4. The first step is to present a problem situation or core knowledge of courses. Problems are classified into three levels. The first level is designed to understand the core knowledge relating to a specific topic. The second level combines core and auxiliary knowledge to solve problems. A third-level problem is a complex real-world problem needing two or more items of auxiliary knowledge integrated with core knowledge base to solve the problem. In the second step, the learner identifies the problem and discovers the required knowledge. In the third step, the learner studies the core knowledge base and auxiliary knowledge that are needed to solve the problem. The final step is to apply the knowledge to solve the selected problem. If the learner solves the problem, then he can view the solution by 3D simulation on the Web and then go to next level of the problem. Otherwise, the learner should return to previous step. Notably, each 3D simulation example has been constructed for a user to choose a design parameter interactively from a range of possible values based on stated criteria and intuition to make sense of the solution in real time. This technology further amplifies the "*m*-power" in learning effect.

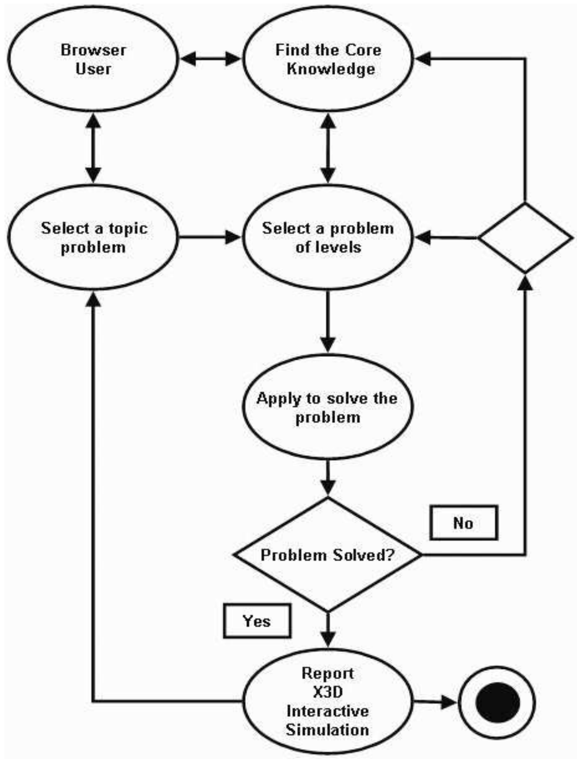

FIGURE 4
PROBLEM-BASED LEARNING PROCESS.

SYSTEM ARCHITECTURE

I. E-Learning Platform: Web-Based System

A 3D simulation Web has three core parts as shown in Figure.5. The first part is the physical model of the problems, including the dynamics and fluid mechanics. The physical model is adopted to find the solutions of the problems. These solutions can be either analytical or numerical solution. The second component renders the 3D simulation using X3D. The third component is the dynamic web ,which is adopted to integrate all in one.

XML (Extensible Markup Language) technology is applied to support the accessibility and interactivity of the Web. XML is proposed by W3C (World Wide Web Consortium) as the major language for representing Web content. XML allows the flexible development of user-defined document types, making XML data model suitable for designing e-learning courses involving multiple problems[9]. The dynamic web often adopts the MVC model .The Java Server Page Standard Tag Library (JSTL), which is also family of XML and encapsulates core functionality common to many JSP applications[17]. Java is a flexible, general-purpose programming language. JSP is based on Java but hides some of the hard details of writing full-fledged programs and JSTL is build on top of JSP, making web deployment highly practical.

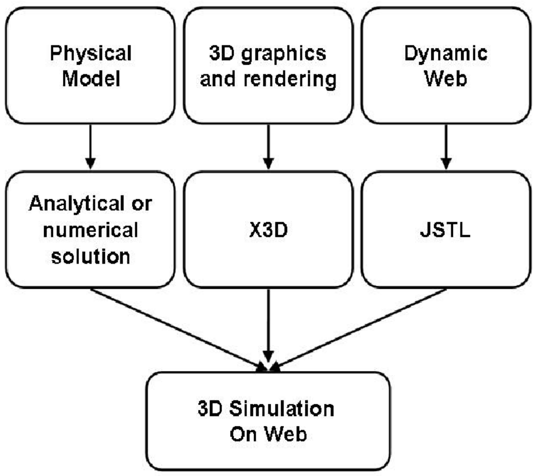

FIGURE 5
ARCHITECTURE OF 3D SIMULATION WEB

II. Web 3D System

X3D is intended to be adopted in a broad range of applications such as engineering and scientific visualization, multimedia presentations, entertainment and educational titles, and web pages. X3D is also intended to be a universal interchange format for integrated 3D graphics and multimedia. The major design objectives of X3D are (1)to separate the runtime architecture from the data encoding,(2)to support a variety of encoding formats, including the XML and VRML, and (3)to provide alternative application programmer interfaces (APIs) for the 3D scenes. The X3D standard has three parts. The first part is called X3D framework and SAI(Scene Access Interface) which has been approved as the ISO/IEC 19775 standard [10]. The X3D framework defines the standardized components and profiles as well as the scene access interface to the X3D runtime system. The second part is called X3D encoding which adopts the ISO/IEC 19776 standard [14]. The encoding contains the XML and VRML encoding specifications. The third part is the X3D language binding which adopts the ISO/IEC 19777 standard [16]. The language binding contains the JAVA and ECMA Scripting programming languages. The X3D content is dynamic and is driven by a rich set of interpolators, sensor nodes, scripts, and behaviors. Figure 6 shows the X3D system architecture. The X3D browser parses the X3D files into a tree of nodes. The scene graph manager of the X3D browser renders the scene and the geometries of the X3D file. The X3D scripting engine accepts the SAI events from the internet user, and responds to the rendering Web page. The content of the X3D file is an XML format text file which can be edited by a plain text editor, such as Notepad, or by the open source browser X3D-Edit [15].

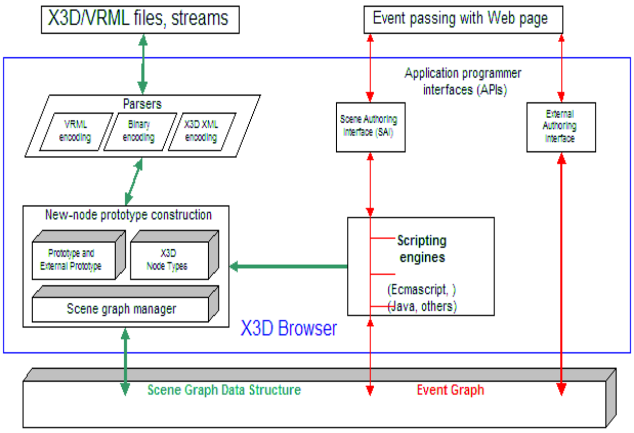

FIGURE 6
X3D SYSTEM ARCHITECTURE

III. Three Tiers Architecture

Figure 7 displays three tiers of architecture that are adopted in designing the 3D simulation web . The first tier is the Internet browser tier. The Internet Information Server (IIS) program from
Microsoft is adopted to the response to the http requests. The second tier is the application server tier. An Apache Tomcat server is adopted to handle the interactive requests and to render the dynamic behaviors of the graphs. The third tier is the native XML database which is applied to store the X3D files as well as the PROTOTYPE defined by the X3D authors. Apache's native XML database system Xindice [16] is adopted in this study.

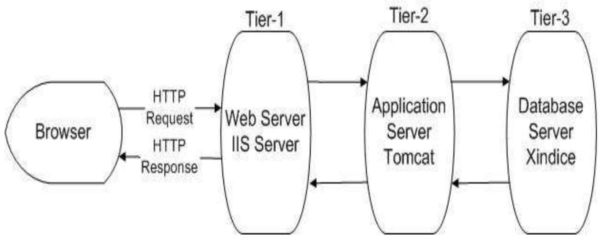

FIGURE 7
THREE TIERS OF X3D SIMULATION WEB

E-LEARNING PLATFORM

The proposed e-learning platform comprises three tutorials, namely Dynamics, Fluid dynamics and X3D programming. Dynamics and Fluid dynamics are the core targets. The client user initially reads a brief introduction to the course then chooses a topic problem continuously and studies a knowledge base item related to the topic problem as shown in Figure 8.

I. Topics Problems

The targets of the 3D simulation are the dynamics and fluid mechanics courses. The selected topics in dynamics :

- particle dynamics
- particle motion in plane
- conservation of momentum
- rigid body motion
- oscillations

Additionally, the fluid mechanics topics :

- application of Bernoulli equation,
- basic concepts of streamline and path-line
- the phenomena of hydraulic jump
- flow in a pipe such as Orifice and Venturi meter.
- laminar and turbulent boundary-layer flows of a flat plate

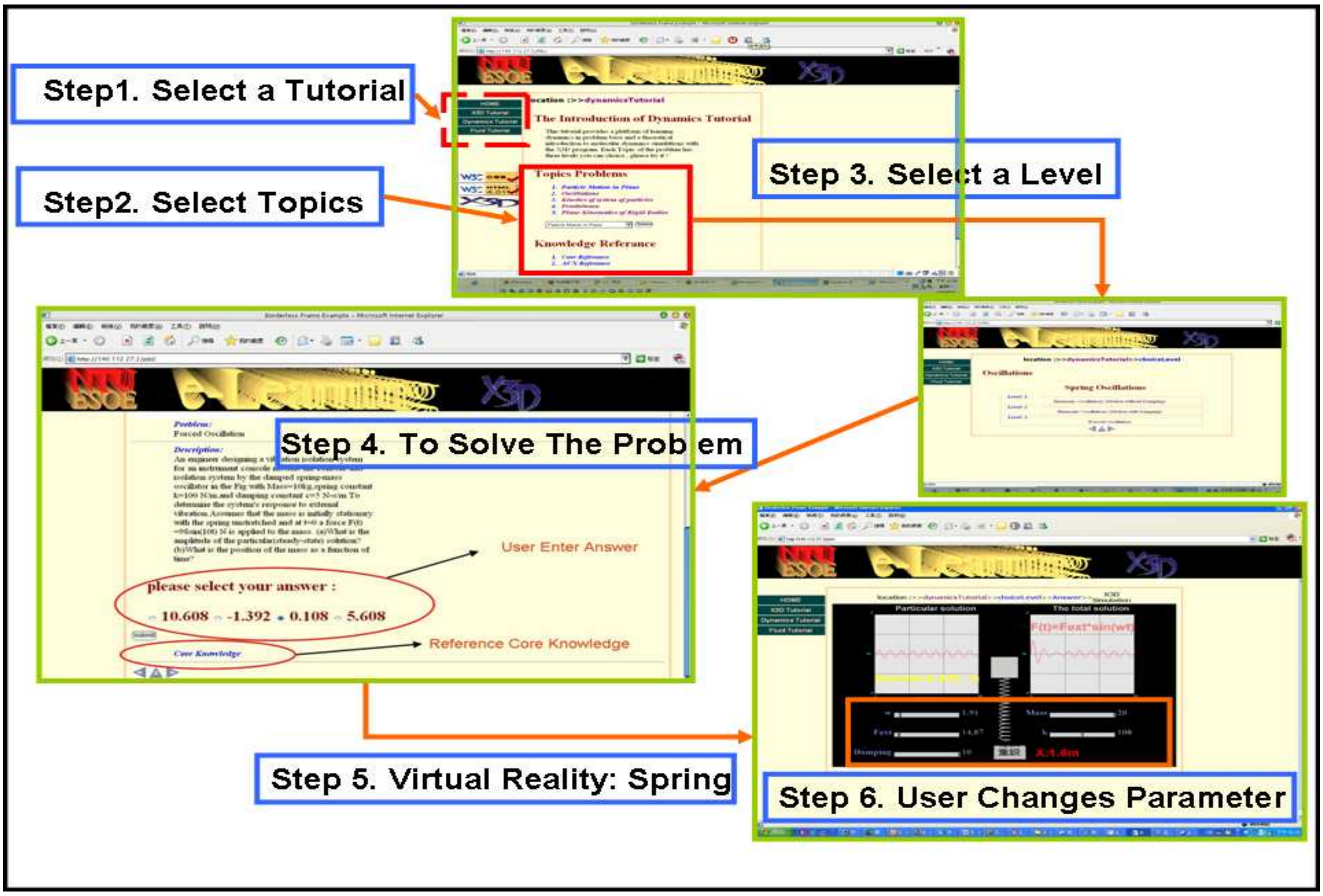

FIGURE 8
A SUCCESSION OF STEPS FOR LEARNING SPRING OSCILLATIONS

II. Sample of Three Levels of Dynamic Tutorials

For example ,an example of three levels of spring oscillations. The first level and the second level are harmonic oscillations, namely motion without damping and with damping respectively. The third level is a complex and with external forced oscillation. This is a very good example for teaching classical mechanics.In the three levels problem of oscillation ,the user confronts challenge and/or returns the reference on the go. If problem is solved , correct solution and relative interactive simulation in real time are visualized for the user to identify the solution in 3D Web Visualization . As shown in Figure 8, the 3D Web Visualization is the same as the real world ,user must move the box to give an initial condition before starting the simulation. Additionally, the user adopted the slide bar to enter the key parameters such as the mass of the spring, spring constant, damping constant and the intensity of external force. The 3D geometry of the spring motion depends on physical parameters.

The homogeneous, particular and complete solutions are plotted in real time. The complete solution has an initial transient phase due to the homogeneous part of the solution. As the homogeneous solution attenuates, the complete solution approaches the particular or steady-state solution. This phenomenon is intuitively and comparatively visualized.

III. Sample of Three Levels of Fluid Tutorials

The model of the Fluid mechanics is the same as that in the dynamic tutorial. Figure 9 shows a free jet, which demands the student to determine the initial velocity in the level-1 problem. In the level 2, the student is required to calculate the distance that the water falls. The final level requires the student to compute the maximum height reachable by the free jet when the pitch angle of the jet is turned upward by 30°.

CONCLUSION

The e-learning platform is a simulation and modeling program that allows students to visualize engineering problems. Students can adopt program to calculate the effects of forces on an object and animate the results in real time. Moreover, students can to experiment with their own ideas in X3D by providing real-time parameters to the governing equation. The web-based visualization of this e-learning applications will be particularly useful in improving understanding. Modern students are familiar with high-speed Internet access providing media-rich digital content and interactive experiences. The interactive 3D simulation web site developed in this study meets the preferences of this new generation students. The learning effect of the discipline-style engineering courses, such as dynamics and fluid mechanics, are likely to improve significantly. This approach can be implemented in various engineering tutorials on the Web.

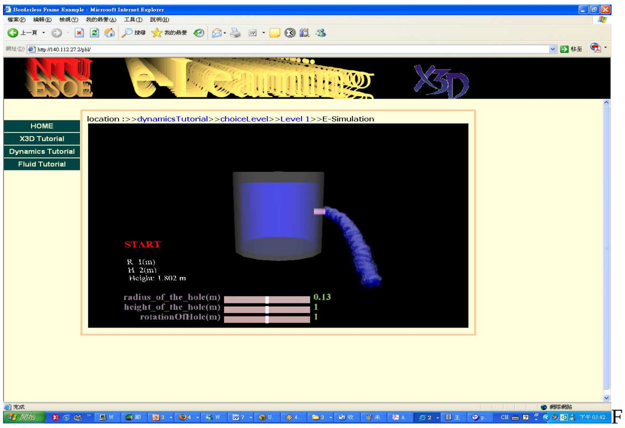

FIGURE 9
A FREE JET

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