The Multimedia Approach in Visualizing Engineering Concept

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Abstract: *Various levels of interaction in a multimedia development tool for a tutorial topic on Structural Analysis in the engineering mechanics statics course were examined. This study look at how interactive multimedia could be employed to support learners as well as to enhance their understanding and visualization of specific engineering concept. In addition, various design aspects and pertinent issues that were considered during the multimedia development process are discussed. Preliminary evaluation of the prototype tool that was conducted on a group of students taking the course revealed that multimedia technology provided an effective platform to enhance learning and understanding of the subject matter where engineering concepts are presented dynamically through multimedia animations.*

1. Introduction

Multimedia offers many benefits over traditional methods of delivering information. For instance, it allows information to be displayed in various formats (text, graphics, animation, audio and video) within single integrated tool. Secondly the delivery of that information, the order in which it is delivered and the timing of that delivery can be controlled either by the computer or by the user. Finally a user can interact with the material being presented. Thus multimedia has the potential to present information more effectively if compared to the traditional instructional approach such as textbook, lecture, laboratory, and tutorial [1-3].

Animations are used in engineering multimedia learning tools to represent action, such as motion of links, pistons, crankshaft, etc., in order to enhance visualization. As such multimedia has the potential to offer greater flexibility in delivering engineering materials [2]. Most universities and higher learning institutions are now using interactive multimedia and associated learning technologies to deliver part of their curricula to students [3-7]. One project where this delivery approach has been employed and tested is the mechanics statics multimedia tool for undergraduate engineering program at University Tenaga Nasional.

The project goal was to produce an interactive multimedia tool on topics covered in the engineering mechanics statics course. These tutorials are intended to supplement the course as well as to promote learning, primarily targeted at slow learners. Although the development of mechanics statics concepts requires a structured, sequential presentation, the computer ability to present concepts visually and demonstrate the dynamic flow of processes can significantly enhance the learning experience.

The content contained within the multimedia tool is intended to provide students with better understanding of the theoretical concepts taught in class as well as to enhance their ability to apply mechanics concepts in a variety of engineering design situation. The mechanics statics tutorials currently in development are shown in Table 1.

Table 1. Current tutorial topics in multimedia development.

Chapter 1	*Equilibrium of a Body*
Chapter 2	**Structural Analysis**
Chapter 3	*Centre of Gravity & Centroid*

This paper describes the development of a multimedia tool for a tutorial topic on Structural Analysis in the engineering mechanics statics course. In addition, the perception of users as well as the effectiveness of such tool in enhancing learning and understanding of engineering mechanics concepts are discussed.

2. Interactive Multimedia and Visualization

Multimedia has enormous potential in engineering [8]. The possible tools and applications of multimedia are almost unlimited given its current capabilities [9]. The success of multimedia application to engineering education, however, lies in the development of good computer-based teaching packages [10]. It is a well-accepted fact that there is a need for engineering education software [11]. As such a variety of models for teaching and learning have been designed and used by researches of higher learning institutions to deliver part of their curricula to students, mainly due to the following reasons:

- There is a need to improve the quality of learning and promote a student centred approach in which the various needs and circumstances of students are recognized [12].
- There is a growing need to offer greater flexibility in dissemination of knowledge to students because of changing patterns of student learning and the advancement in information technology [6, 13].

Today research and discovery can be an interactive, dynamic and active feedback process with imagination driving action in exploring and interacting with an external environment. This could only take place effectively provided given a suitable supportive environment, able to provide both a rich resource and a flexible motivation. Such conditions can be implemented with the aid of multimedia technology, fundamentally because it permits, in a flexible and gradually more inexpensive way, the storage, processing, presentation, and in general, manipulation of virtually all sorts of information (text, graphics, 2D/3D models, audio and video). Thus this technology enable developers of such visualization tools the freedom to select from a variety of media elements to express a particular message in the form of text or motion to represent a process.

In addition, a given piece of information can be delivered using one or more media element [6]. For example an image can be used to illustrate a text-based description. The information originally presented on screen can be supplemented by the use of audio and video. Audio is useful as text can be minimized on the screen. Multimedia can thus support multiple representations of the same piece of information in a variety of formats as depicted in Figure 2.
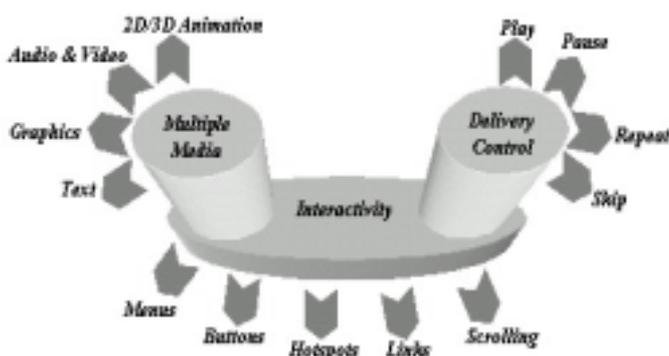

Figure 2. Key attributes model of multimedia.

Every multimedia tool demands some kind of user navigation. The non-linearity offered by many multimedia learning applications provides a learner greater navigational and freedom [6]. Users may move to any section in a multimedia tutorial and in any order. Dynamic media such as video and audio can be controlled i.e. pausing, playing and repeating clips. Another important attribute of multimedia is the capability of interactivity. "Interaction" refers to the reciprocal action of two phenomena and has both a physical connotation (one entity operating on another)

and a psychological connotation (two entities influencing each other's behavior). Interactivity in multimedia assisted learning applications can and should go further than simply allowing a learner to choose their own path through an application by pointing and clicking at various menus and buttons [6]. Any software package provides some interactivity in that it responds to user instructions. What makes the difference even in a simple educational software is whether the software allows the user to work at his/her own pace, in the order desired, repeating sequences at will, manipulate virtual objects on screens and simulation of experiments or industrial processes.

As such multimedia provides the opportunities to meet the aforementioned demands. In addition, it allows the users to experiment safely, enabling them to examine the consequences of taking wrong approaches, as well as correct ones, thereby assisting the user to have a deeper understanding of the theory involve in the particular subject.

Our focus group approaches the topic of technology and education in a broad manner. In the previous study [2], we examined how electronic media (Figure. 3) influences engineering education and how these in turn are changing the very fabric of society and human interaction. This entails looking at the cultural impact of technology and its influence on higher learning institutions.
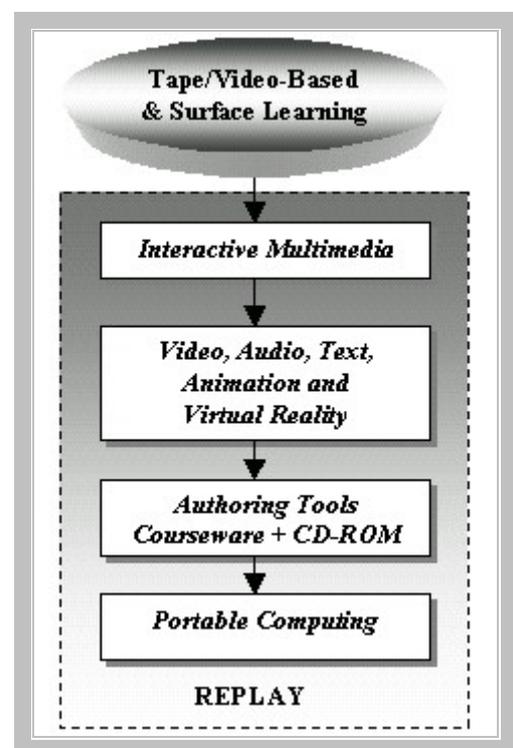

Figure 3. Path in delivering interactive multimedia tools.

3. Students Perception of Posed Problems in Engineering Mechanics Statics

Mechanics statics like many other engineering subjects is fundamentally about problems solving

through the application of scientific principles. However there are many cognitive steps leading from problem to solution and consequently many educational difficulties such as students lack the ability to translate mathematical word problems into the form necessary for effective computation. These engineering problems are often complex, and relationships among the variables of an experiment can be difficult to visualize. In general, problems in mechanics statics are presented to the student as a combination of schematic diagrams and text descriptions. In the traditional method of teaching and learning, the student must immediately apply learned knowledge in order to form an internal model of what the problem means [14]. Normally, the shapes, lines and text that make up the schematic diagram of the problem have very specific engineering meanings. Previous experience [2] showed that an average student would be able to solve the problem at the first try but a weak student would require several trials before solving the problem. The weaker students take a longer time to solve the problem mainly because these students lack the understanding of the theory that has been taught during normal lectures. As such, these students would require an alternative method of instruction to enhance their learning skills.

4. Multimedia Design Process

The development process for a tutorial begins with the generation of preliminary storyboards created based on the brainstorming session conducted in the faculty comprising the respective instructors teaching the mechanics course and faculty members from the IT department. The multimedia development process flow is as shown in Figure 4. In general, the storyboards are scripted into an authoring software operating on a Windows platform such as Macromedia Director. The files are then reworked for organization, clarification, and generation of graphic images and animations.
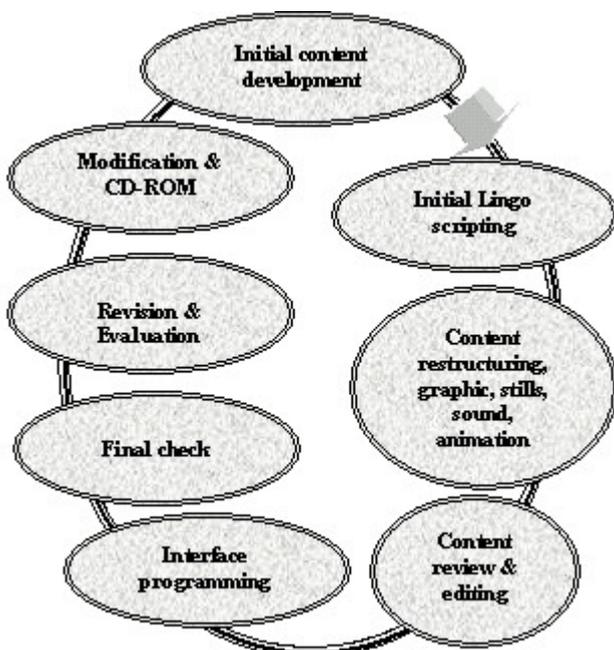

Figure 4. The design process adopted to develop the multimedia tool.

Another iteration follows to ensure readability, font size, color and accuracy of the graphics. When the content passed this quality-control checkpoint, the tutorial is then programmed into the final navigational interface. Feedback is solicited from end-users and faculty and is then synthesized and used to revise the tutorials accordingly. The advantage of this approach is that it leads to a high level of product consistency, in both content and visual presentation, which is essential for sustaining a learner attention in such a technical subject area.

Authoring, graphic, and technical software tool were used to create the tutorial. Each software tool was used to perform a specific function. The primary development software used by the mechanics statics tutorial project includes Microsoft Visual Basic for tutorial integration, Macromedia Director for creating animations and Adobe PhotoShop to create graphics.

5. Instructional Presentation

5.1. Building on an Image

Since mechanics statics concepts build in a linear fashion, the software is structured to present information sequentially. The tutorial contains several sections that are made up of any number of pages. Each page builds a piece at a time, so that a particular concept is built as the user clicks the "Continue" button. While it is intended that learner will proceed through the content in a linear fashion, the capability to skip sections and move forward or backward are also incorporated into the system. As each page builds, several elements such as text, equations, photographs, graphics, digital video, and animations are displayed.

An example of a typical image build is shown in Figure 5. This example is taken from the introduction on the tutorial on Structural Analysis. The opening screen highlights the sub-topics contained within this chapter. A brief introduction of the topic is necessary to set the scene prior to the problem analysis.
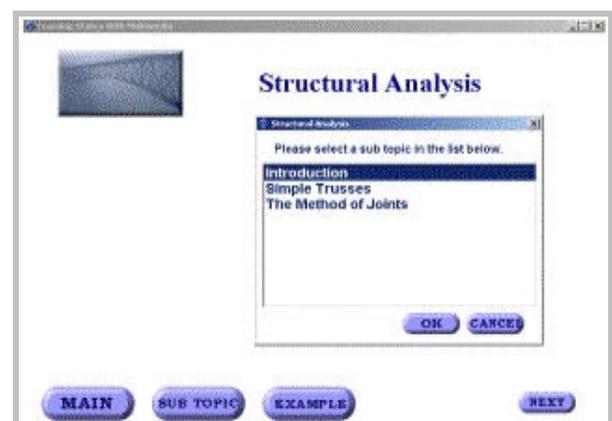

Figure 5. The sub-topics contained under the heading of Structural Analysis.

5.2. Interface Design

Multimedia enables designers to choose from a range of media elements to convey a particular message [4]. The tutorial system is designed in such a way that the user will be taken through the lesson in a step-by-step fashion providing explanation and motion/animation where necessary to enhance visualization. In order to facilitate user control over the lessons, the navigational interface includes the following functions:

- Move forward and backward one screen at a time within the lesson.
- Fast forward to section of interest.
- Search and find related information on solutions that are presented.
- Exit the tutorial easily.

The "Continue" button is used to build information on each screen/page and to advance to the next page. The "Back" button is only used to jump back to the previous screen for clarification, etc. At this point the user can restart the step-by-step analysis if necessary or may advance to the next screen by either clicking on the "Continue" button. Once the user has read and understood the objectives of the problem, the learning process hereafter has been made simple by simply clicking on the "Continue" button to move on to the next screen (Figure 6). A menu comprising the itineraries of the analysis has been included as shown in Figure 7, which enable users to move freely if necessary.

5.3. The Tutorial Lesson

The most effective way of learning the principles of engineering mechanics is to solve problems. To be successful at this, it is important to present the work in a logical and orderly manner [15]. In the case of Structural Analysis, since all the forces acting at a joint must be taken into account, the importance of drawing the free-body diagram (FBD) as shown in Figure 8 before applying the equations of equilibrium to the solution of a problem cannot be overemphasized. However, prior to this the support reactions must be determined.

In the FBD, the forces that are given should be labelled with their proper magnitudes and directions. Letters are used to represent the magnitudes and directions of forces that are unknown, for example in Figure 8, the reactions force components at the supports *A* and *C* are designated as A_y, C_x and C_y. In particular, if a force has a known line of action but unknown magnitude, the "arrowhead," which defines the sense of the force, can be assumed. The correct sense will become apparent after solving for the unknown magnitude. By definition, the magnitude of a force is always positive so that, if the solution yields a negative scalar, the minus sign indicate that the arrowhead or sense of the force is opposite to that which was originally assumed.

At the click of the "Continue" button, the analysis to compute the unknown reactions is executed as typically illustrated in Figures 9 to 11.
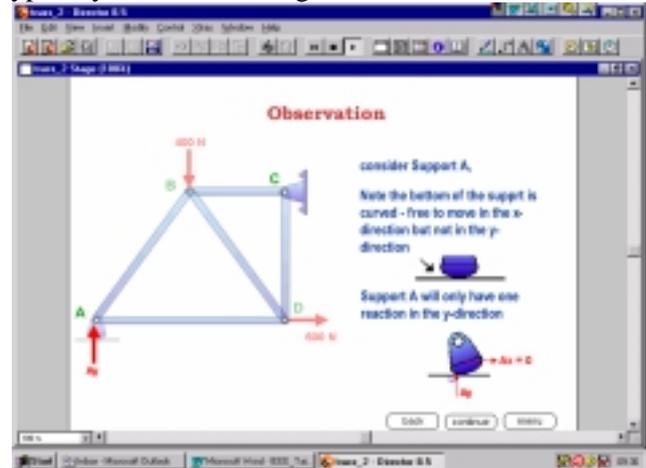

Figure 6. The pages are designed in such a way that explanation and boundary conditions are explained by text and also in motion.
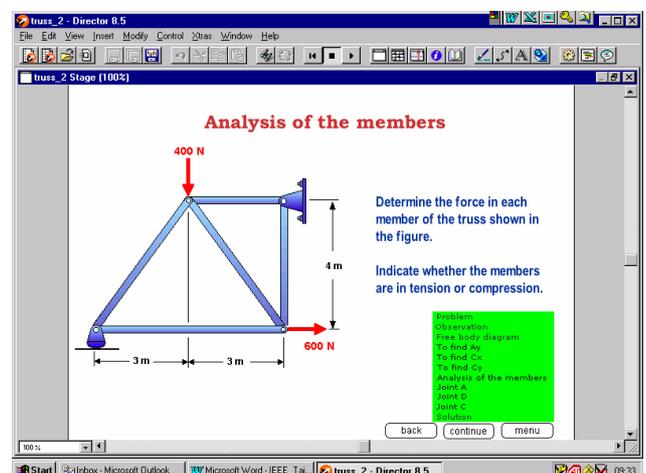

Figure 7. Typical tutorial lesson page. The content of the lesson can be viewed via a menu.
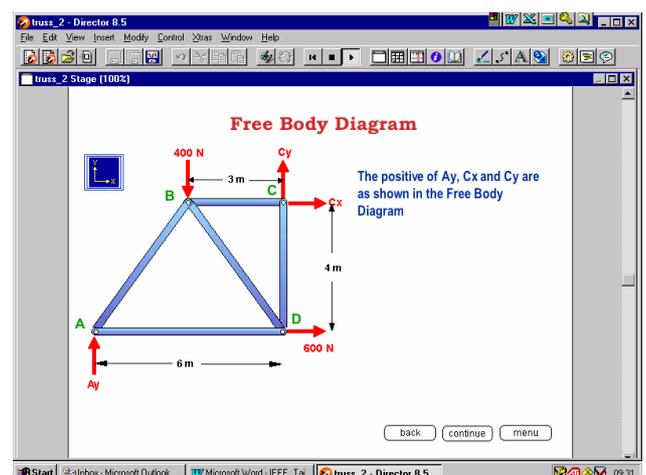

Figure 8. FBD of the structure showing known data.

The ability to build a screen sequentially is extremely important to allow students to see the progression of the derivation and process steps. As the user clicks the "Continue" button, relevant forces causing moments about *C* is written on the screen. Note that the whole sequence is carried out dynamically between each of the screens as shown in Figures 9 to 11.
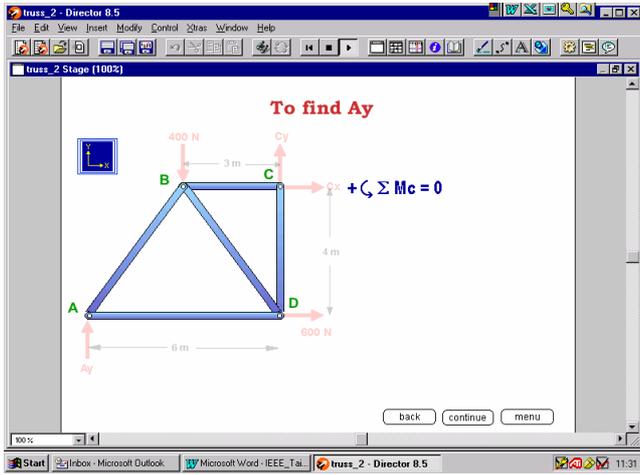
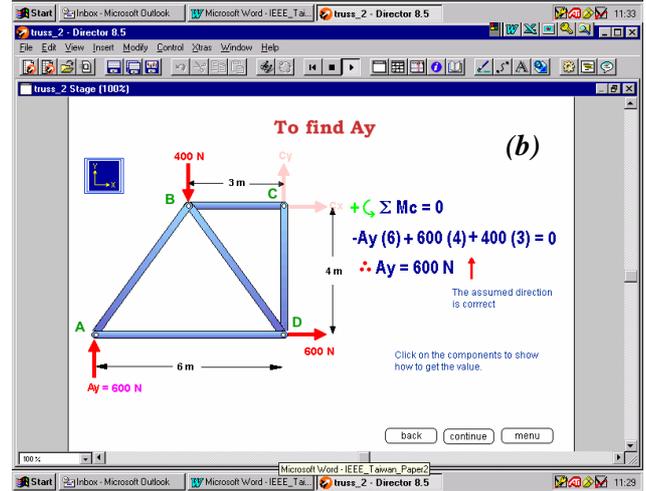Figure 9. Moments are taken at *C* with the assumption that counter-clockwise moment is positive.

Figure 10 (a) and (b). A moment induced by a force in question is then analyzed in sequence whilst other forces become semi-transparent. This allows the student to analyze the action of individual force on the structure.

Every attempt is made to minimize text on the screen and maximize the computer visualization capabilities. One strategy is to link text and graphics to reinforce a concept (e.g. to display a particular segment of an animation as typically shown in Figure 12, provide clarifying text, and so on). Highlighting text using boldface or color is also useful. Animations can also be displayed in sequence with supporting text to highlight each process as typically shown in Figure 13.
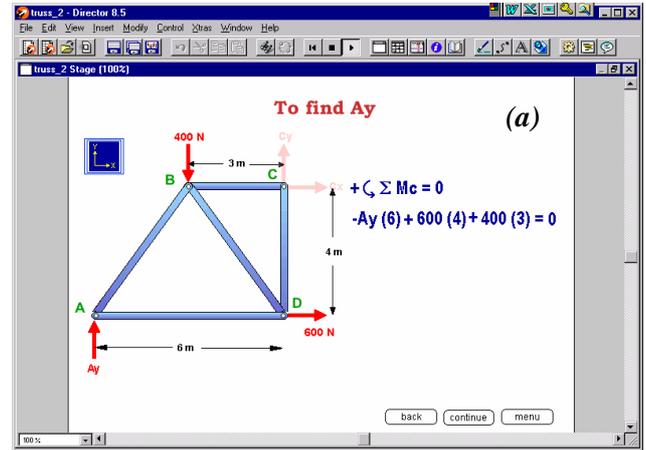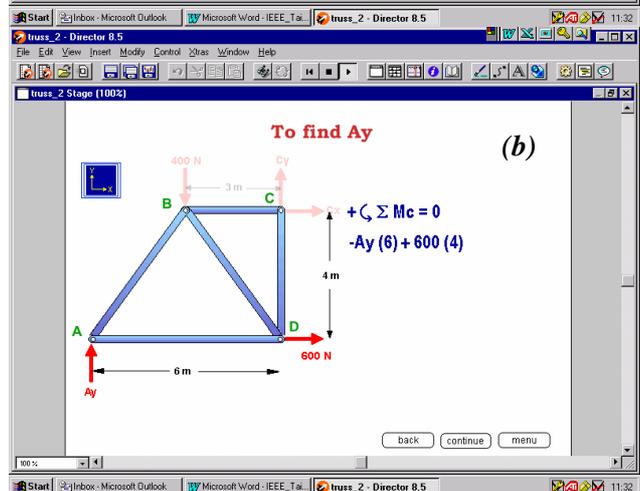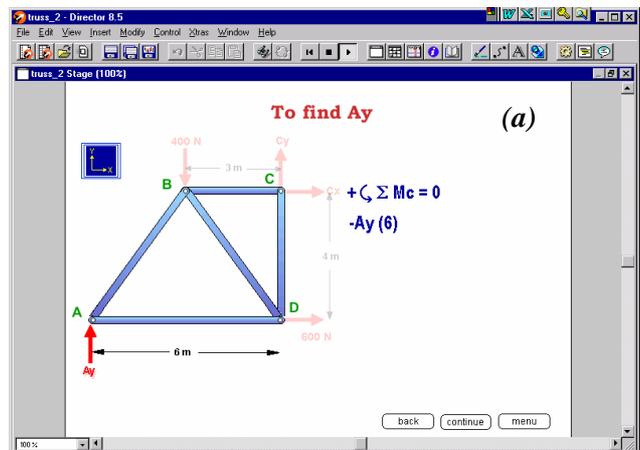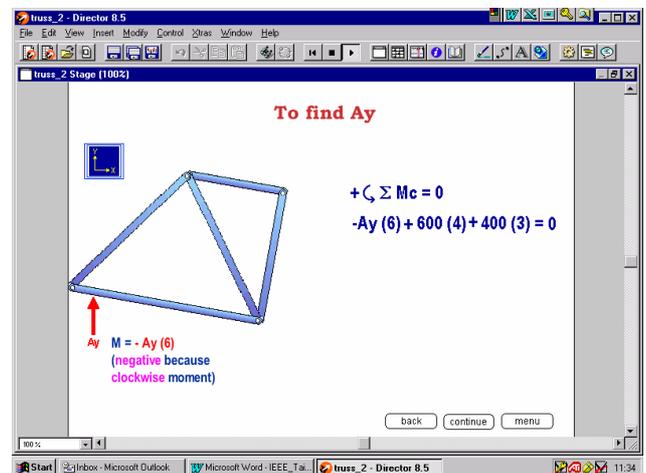

Figure 11. (a). For equilibrium, the sum of all the individual moments must equal zero and (b) the unknown force is then computed. A statement appears on screen to clarify the result.

Figure 12. Animation of the structure swinging about point *C* i.e. force A_y create a clockwise moment about *C*.

6. Effectiveness of the Multimedia Tool

A trial session was conducted with students taking the mechanics statics course. The objective of the session was to evaluate the effectiveness of using multimedia-based tutorials to supplement traditional classroom teaching. The method of evaluation was based on questionnaires administrated at the end of the course whereby each student was asked to provide his/her opinions and feedback about the use of multimedia-based-tutorials in the course.
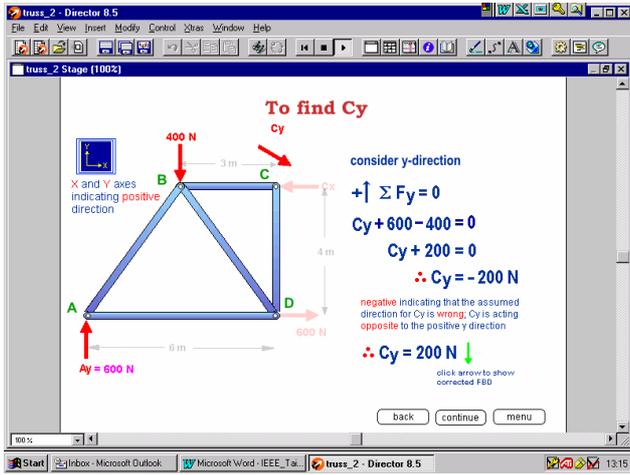
Figure 13. The magnitude of the force C_y was found to be negative indicating that the assumed direction as indicated in Figure 8 is wrong. At this stage the correct direction of the force is rectified by the user as depicted by the dynamic movement of the arrow.

In general, the outcome of the evaluation was very encouraging. The majority of users were in the agreement that the incorporation of animation in the mechanics statics multimedia tool was beneficial in enhancing their understanding of various concepts that has been taught in the lectures. The results as obtained from the student feedback are presented in Figure 14, Table 2 and Table 3.

The beneficial effect of incorporating multimedia in teaching mechanics statics has been revealed. In particular, it can be noted that the level of confidence and understanding of the students in the subject matter greatly improved with the supplement of multimedia technology.
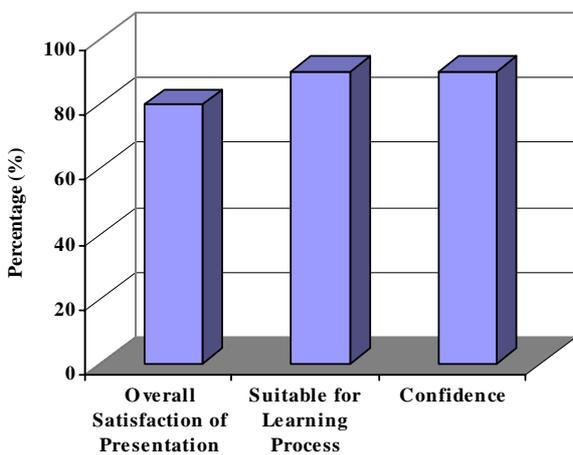

Figure 14. Outcome of student evaluation.

Table 2. Student response on the presentation format and language usage in the multimedia tool.

Response	Percentage
Easy to understand	20%
Can understand	80%
Quite difficult	0%
Very difficult	0%
Difficult	0%

Table 3. Typical student perception of the effectiveness of the developed prototype multimedia tool for Structural Analysis.

Questions	*Yes*	*No*
Do you think that all the facts or details in the learning tool are clearly explained and understandable?	100%	0%
Do you think that the learning tool is interesting?	100%	0%
Are you able to visualize the problem in this experiment?	100%	0%

What is your opinion about this interactive learning tool for Structural Analysis?
Some user responses:

- It is very helpful in the sense that it will enable a person like me who is not knowledgeable in Structural Analysis to understand the concept being explained.
- May enhance the student's understanding but it is more suitable for self-learning activities.
- It is suitable and learnable.

7. Conclusions

Electronic learning uses many technologies including computer-based-multimedia and computer systems for two-way interaction to enhance learning and understanding without regard to time pace.

This paper has described how multimedia functions in an interactive multimedia tool in engineering for visualizing engineering concept and benefits of integrating it into the curriculum. Although multimedia brings many benefits over other methods of disseminating information, it can take several hours to develop one hour worth of interactive multimedia learning. The following are some of the conclusions drawn from the current work:

- For the students, enormous interactivity is available at the click of a mouse. This can support the user to navigate freely while interacting with the system.

- For the department, while up-front design and development time is usually increased, the technology-enhanced tutorial is easier to update and easier for users to participate in.

- For both users and faculty, feedback and evaluation can be instant and transparent.

- The use of multimedia supports conceptualization of the material being presented.

- A range of media elements can be used to convey a given message and users can control the delivery of that information.

- The learning material is more consistent. The use of multimedia shifts the balance in favor of capturing better practice in each area of learning. The best instructor lecture, or the best explanation of how to solve a problem can be recorded, and made available to all present and future users.

- The multimedia-based material is richer than that provided through the combination of lectures and textbooks. The multimedia system makes it easy to provide high quality images (rather than slides at lectures), audio (rather than tape-based language laboratories) and video (rather than classroom television). Furthermore material can be interacted with repeatedly, rather than the single opportunity of a lecture.

Multimedia engineering visualization tools provide an effective platform to teach basic engineering mechanics concepts. In general, mastery and retention rates improved when interactive multimedia is used as more interaction is involved simultaneously in the learning process and the process becomes more active with the user being in control.

Acknowledgements

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