

On Computer-Aided Instruction Tools for Teaching College Engineering Mechanics Related Courses

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Summary

In this research, questionnaires are designed to survey among teachers and students the current situation of applying Computer-Aided Instruction (CAI) tools to teaching and learning of college engineering mechanics related courses in Taiwan. The needs for CAI tools for teaching these mechanics related courses are investigated in the survey. Several prototypes of interactive multimedia tools are designed and implemented using information technologies. The applicability and effectiveness of these tools on assisting teaching of engineering mechanics related courses are discussed and evaluated. Moreover, a website for managing and sharing collected and developed CAI resources is constructed.

1 Introduction

The teaching and learning environments for college engineering mechanics related courses have changed little in the past decade. However, the current generation of engineering students do carry a huge difference on their thinking and behavior compared to those a decade ago. Students nowadays have weaker ability to do abstract thinking due to the prevalence of the Internet and Multimedia. They are more inclined to comprehend learning subjects by 3D graphics and videos. The situation gradually manifests itself in the problem of students' low learning motivation for engineering mechanics related courses.

As computers and the Internet become an ubiquitous part of daily lives, the development and application of Computer-Aided Instruction (CAI) tools become more and more indispensable. CAI tools are now bearing a great deal of expectations from teachers, students, and parents with the hope to improve learning interests, assist in-class lecturing and tutor students for self-learning. However, before developing the CAI tools for engineering mechanics related courses, we should ask: 'How the CAI tools have been applied in teaching engineering mechanics related courses?', 'Which parts of engineering mechanics courses require more usage of the CAI tools?', and 'What kind of CAI tools should these courses need individually?'. Furthermore, how to apply rapidly evolving information technology promptly to design and develop CAI tools, especially those multimedia tools with better user interaction, is another subject worth our attention.

This research conducted a survey for college teachers and students who are in the engineering related departments. The purpose of the survey is to gather information on understanding current teaching and learning in mechanics related courses. By characterizing the difficulty and the possible causes of the difficulty for both teachers and students in mechanics related courses, this research analyzes the need for CAI tools. The survey had been distributed to more than a dozen of public and private universities and colleges. In return, there are 87 effective samples of teacher's, and 1,097 of student's. The design and contents of the survey are described and statistical results are analyzed.

This research also employs information technology to design and implement several prototypes of interactive multimedia tools. The applicability and effectiveness of these tools on assisting teaching engineering mechanics courses are also discussed. In addition, a teaching and learning resource website is constructed to achieve the goal of managing and sharing the developed CAI tools.

2 Survey on Applications of CAI Tools

This research employs a questionnaire survey to acquire understandings of current applications of CAI tools in engineering mechanics related courses, and to find out the needs of CAI tools for teaching these courses. A brief description on the design of questionnaire and the survey method is provided below, followed by discussions on the statistic results of the survey.

2.1 Design of Questionnaires and Survey

On the design of the questionnaire, we first composed a draft and invited experienced teachers to review the draft in several seminars. The final version of the questionnaire is officially composed after a series of pre-tests and modifications. There are two questionnaires with similar but slightly different contents designed separately for teachers and students, who have taught and studied in engineering mechanics related courses. The complete questionnaires can be found in (Hsieh, et al., 2003). The questionnaire designed for the teachers is aimed at surveying the following points: (1) which parts of a mechanics related course are difficult to teach? (2) how difficult the courses are? (3) the reasons why the courses are difficult to teach; (4) have teachers ever used any CAI tools in class? (5) do they consider the CAI tools they used in class helpful and necessary? On the other hand, the questionnaire designed for students is aimed at surveying: (1) which mechanics related courses are difficult for them to learn? (2) how difficult the courses are? (3) the reasons why the courses are difficult to learn; (4) have they ever used any CAI tools in class? (5) do they consider the CAI tools they used in class helpful? The questionnaires were distributed to over a dozen of colleges and universities, both public and private, for the job of survey. In the end, there were 87 effective teacher's questionnaires collected, while there were 1,097 effective student's questionnaires collected.

2.2 Statistic Analysis of Questionnaires

First, on the teacher's side, 49% of the 87 teachers are from public universities, 13% are from private universities, 14% are from universities of science & technology, 13% are from institutes of technology, and 11% did not answer the question of their affiliations. 63% of these 87 teachers are teaching in civil engineering department, 14% are in construction engineering, and 9% are in mechanical engineering. The average teaching years of them are 11.7 years. 37% of these teachers are professors, 36% are associate professors, 7% are assistant professors, and 9% are lecturers. 44% of these teachers are in the age of 40-45 while 11% of them are in their thirties and another 11% of them are in the age of 45-50. The first question in the questionnaire asks the teachers to select one of the mechanics related courses they have been teaching. The possible courses include *Applied Mechanics*, *Statics*, *Dynamics*, *Mechanics of Material*, *Fluid*

Mechanics, Soil Mechanics, Thermomechanics, The Theory of Structures. All of the answers for the following questions in the questionnaire should be based on the teaching experience of the selected course. About 17% of the teachers selected *Fluid Mechanics*, 16% picked *Mechanics of Material* and 14% *Soil Mechanics*. These are the three courses with the highest percentage of choice. 70% of the selected courses are the required courses and each has 3 credit hours avaragely.

On the student's side, 41% of the 1,097 students are from public universities, 20% are from private universities, 16% are from universities of science & technology, 10% are from institutes of technology, and 4% are from occupational colleges. 72% of these 1,097 students major in civil engineering, 10% in mechanical engineering, and the others in construction engineering, hydrolic and ocean engineering, and architecture. 59% of them are in their senior year, 23% are in their sophomore year, 13% are in graduate school and only a single digit of students are in their doctoral program. Most (about 97%) of the surveyed students had taken the course of *Mechanics of Material* and 88% had taken *Fluid Mechanics*. Only 11% of these students have taken the course of *Thermomechanics*, which is the least course the surveyed students ever took. 60% of the surveyed students ranked their performance in class at around the 25%~75% of the class; 10% of the students ranked themselves at the last 25% of the class and 30% of these students ranked themselves at the first 25% of the class. Furthermore, the hardest three mechanics courses for the surveyed students are: *Fluid Mechanics* (41%), *The Theory of Structures* (37%) and *Dynamics* (34%). The easiest course according to the the result of the survey is *Statics*.

The statistic results of the survey are summarized below:

- The toughest mechanics courses for the students are *Fluid Mechanics* (41%), *The Theory of Structures* (37%) and *Dynamics* (34%). These are also the courses that entitled to the first consideration of applying CAI tools to help both teachers and students in class. In addition, more than half of the surveyed teachers considered that mechanics related courses are not some easy subjects to arouse students' interests. 80% of the teachers agreed on that "student's lack of motivation" counts for one of the reasons causing bad learning attitudes. Thus, one of the most important needs (or requirements) for developing and applying CAI tools in class is to efficiently improve students' level of interest and motivation in studying mechanics.
- When asking about the level of how the five kinds of CAI tools can help for teaching and learning, the answers from both the teachers and students are, statistically speaking, quite consistent. Both the teachers and students rank the five CAI tools from the most useful to the least in the following order: (1) comercial packages that can be used by students themselves for problem solving, (2) virtual laboratory for mechanics experiments, (3) animations showing the problem solving procedures, (4) computer games for mechanics instructions, and (5) webpages for asynchronous teaching & learning. This result should be considered in future development of CAI tools. Furthermore, more than half of the surveyed teachers and students think that the above five CAI tools could be helpful for teaching and learning mechanics related courses, and exceedingly 60% of them agree that the existence of CAI tools are necessary. It is obvious that CAI tools are very much in need for today's mechanics related courses.
- More than 55% of the surveyed students agreed that "the contents of the textbooks are not lively and interesting enough" and "the textbooks are not plain enough to read" caused difficulty for learning. Thus, how to make teaching and learning easier and more interesting by applying CAI tools becomes an important task when developing future CAI tools for both teachers and students.

- 75% of the surveyed teachers have never used any kinds of CAI tools in class, and the most commonly selected reason is: “couldn’t find any suitable CAI tools“. About 40% of the surveyed teachers think that there are no suitable CAI tools for their classes while the other 30% of them disagree. However, 20% of the teachers have used some CAI tools in class. Besides, from the results of the survey, it shows that most of the universities/colleges are equipped with adequate computer facilities for applying existing CAI tools and the courses are scheduled with enough class time to practice the CAI tools. Moreover, 71% of the surveyed teachers believe they have adequate computer skills to apply CAI tools and over 60% of them disagree that the expense of applying existing CAI tools and the lack of teaching assistant prevent them from applying CAI tools in class. It is obvious that developing suitable CAI tools for mechanics related courses and assisting teachers to find the needing ones for their courses, are the two main issues to be addressed if we would like to promote the application of CAI tools in teaching mechanics related courses.
- When being asked about “the difficulty you encountered in teaching mechanics related courses“, 48% of the surveyed teachers choose “lack of suitable CAI tools“, while the other 27% of them disagree. When being asked about “the reasons that cause student’s bad learning attitude“, 50% of the teachers agree that “lacking suitable softwares to assist learning“ might be one contributing factor. This shows that about half of the teachers consider that learning assisting softwares can increase student’s willingness to learn, however, there are still 20% of the surveyed teachers disagree.
- 66% of the surveyed teachers agree “when teaching mechanics related courses, CAI tools is needed (including “needed“ and “very much needed“).“ Only 10% of the surveyed teachers think they do not need any CAI tools when teaching (including “not needed“ and “absolutely not needed“). The outcome again shows that CAI tools have a fair level of demand in teaching mechanics related courses.
- 39% of the surveyed teachers “have the experience of being unable to find any suitable CAI tools when thinking of using one in teaching mechanics related courses“, but 56% do not agree. This shows that more than half of the teachers think suitable CAI tools do exist for teaching mechanics related courses, but about one third of them cannot find any.
- 49% of the surveyed students agree that “lack of software tools for assisting learning“ contributes to the difficulty of learning (with 14% of them disagree). Over 83% of the surveyed students “have never used any CAI tools when learning mechanics related courses“, and 64% of the surveyed students agree “CAI tools are needed in learning mechanics related courses“. Only 7% of them disagree.

3 Design and Evaluation of Interactive CAI Tools

From the previous section we learn that, although most of the teachers and students think that CAI tools are helpful and needed for teaching and learning, there are still teachers who cannot find any suitable CAI tools to use when teaching. This research uses the Dynamics course as an example to design, implement, and evaluate various kinds of interactive CAI tools.

3.1 Design and Application of Interactive CAI Tools

Six kinds of teaching and learning components are designed and investigated in this research. They are (1) Guided example component, (2) Interactive example animation component, (3) Concept map learning component, (4) On-line noting component, (5) Interactive parameterized example component, and (6) Integrated multimedia presentation component. More detailed description for each of them is given below:

- **Guided Example Component:** This component provides pre-designed examples for learners to practice. When users encounter troubles in problem solving or come out with

wrong answers, the component gives proper hints in time to guide the users moving toward the right track of thinking and find out the key points for solutions. There are also problem solving procedures and skills constructed inside the component for the users to learn. Figure 2.1 is an example of this type of component. Users can receive proper assistance at any time and any stage when they feel needed. Moreover, users can also choose the problem solving sequence they consider fit for themselves. For instance, if the user already has sufficient knowledge about the subject to solve the problem, he or she can directly answer the question and move on to the next one; otherwise, he or she may click on the “guidance“ bottom for help. By providing detailed conceptual guidance, the component is expected to guide the learners on thinking of the fundamentals of a certain subject in order to solve any given questions about the subject.

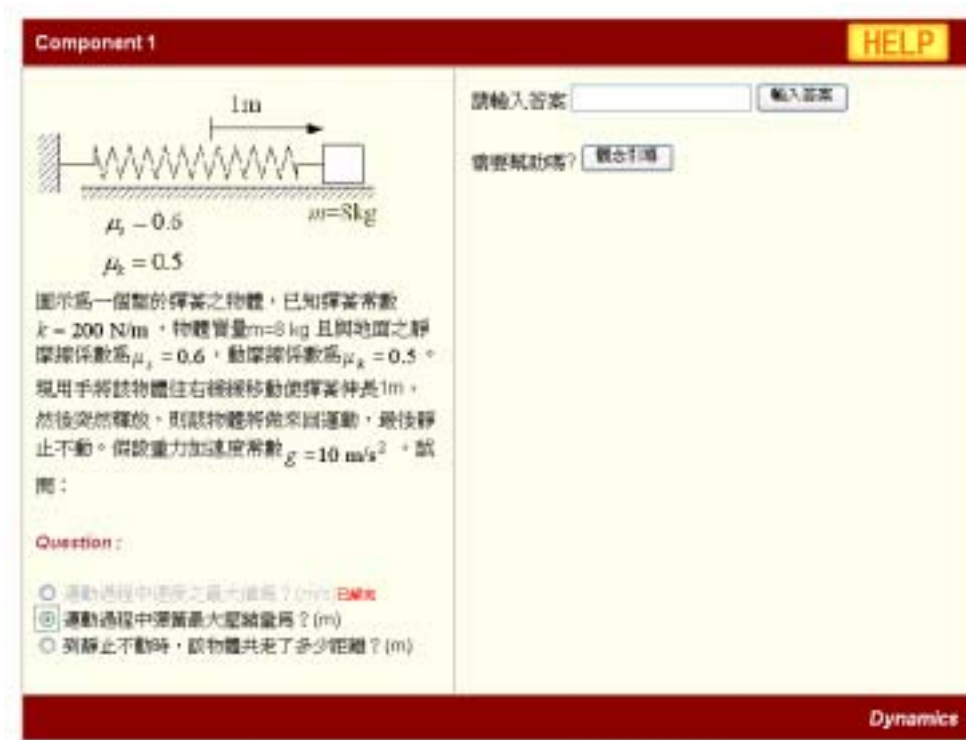


Figure 2.1 Demonstration of Guided Example Component

- Interactive Animation Component:** The main idea of this component is using animations to demonstrate concepts of physics in mechanics related courses. In the past, students usually learned from the notes and drawings on the blackboard as well as texts and figures in the textbooks. However, for demonstrating certain three-dimensional dynamic physical behaviors in mechanics related courses, these kinds of two-dimensional and static media may not be effective enough. Thus, if we can apply animations to the teaching and learning of mechanics related courses, it is positive that the interests and motivations of the learners can be increased and the effects of learning can be improved. However, common animations do not support interaction with the users. Under the situation of poor script, misleading contents, or lacking instructor's narration, it is often easy for the learner to misunderstand the learning contents. Thus, adding interactions into the animation can help more on delivering the concept knowledge and subject contents. It also enriches and broadens the scope of the teaching and learning. Figure 2.2 shows the teaching and learning animation component that illustrates energy transformations at different stages in a conservative system. This component uses dialogue boxes to interact with users and generate verbal descriptions in time to reinforce the animation on delivering the concept knowledge. By doing so, the important details that the animation might have difficulty to

express can be preserved. Moreover, users can adjust the playing speed of the animation according to their own pace, so that the learning can be more efficient individually.

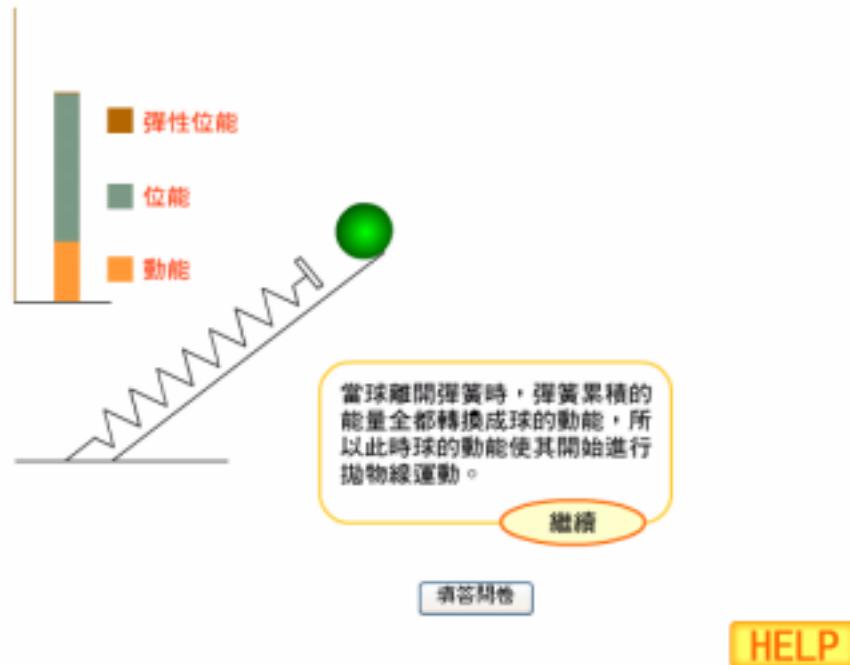


Figure 2.2 Demonstration of Interactive Animation Component

- **Concept Mapping Learning Component:** Concept mapping (Novak and Gowin, 1984) is a process of using a concept map to express the knowledge structure of a certain subject. Concept maps are formed by concept nodes and the relation links between nodes. The relation links between two concept nodes form a proposition. Certain concepts in the concept map exist in hierarchy. The general and inclusive concepts are at the upper level and the more specific and solid concepts are at the lower level. In this research, the concept mapping technique is employed to evaluate what a student has learned about the knowledge concepts and relationships among them in a mechanics related subject. Figure 2.3 shows a concept mapping learning component designed for assisting students to learn the knowledge concepts associated with conservation of energy. The component first asks the user to establish their own concept maps with given concept nodes. It is hoped that the user can have deeper thoughts on the knowledge structure of the subject they are learning by arranging relative positions of every given concept nodes and linking them properly with each other. Then, the component shows the concept map established by the teacher. The user can then compare their own concept map with the teacher's.
- **On-line Noting Component:** Along with the flourishing World Wide Web, information retrieval is getting easier, and this has changed people's way of learning. In the traditional way of learning or information retrieval, people usually drop down notes on papers or books. The written notes enrich the original text by adding new and related information to the original one and are fairly personalized. However, in today's internet environment, facing the enormous amount of text contents, users usually can do no more than browsing. In order for learners who are used to making notes while learning can also do the same on the internet, this research develops a technique to allow for making notes in webpages. Users can add any notes into the webpages when learning on-line, and save the notes into the database when leaving the webpages. The next time when the users visit the webpages again, the notes are automatically retrieved along with the webpages in real time. In this way,

users can customize their own learning materials and even share with others. Figure 2.4 demonstrates the on-line noting component developed. It is hoped that the component can improve the learning efficiency of the users through several on-line noting applications, such as highlighting the key points, adding texts, etc.

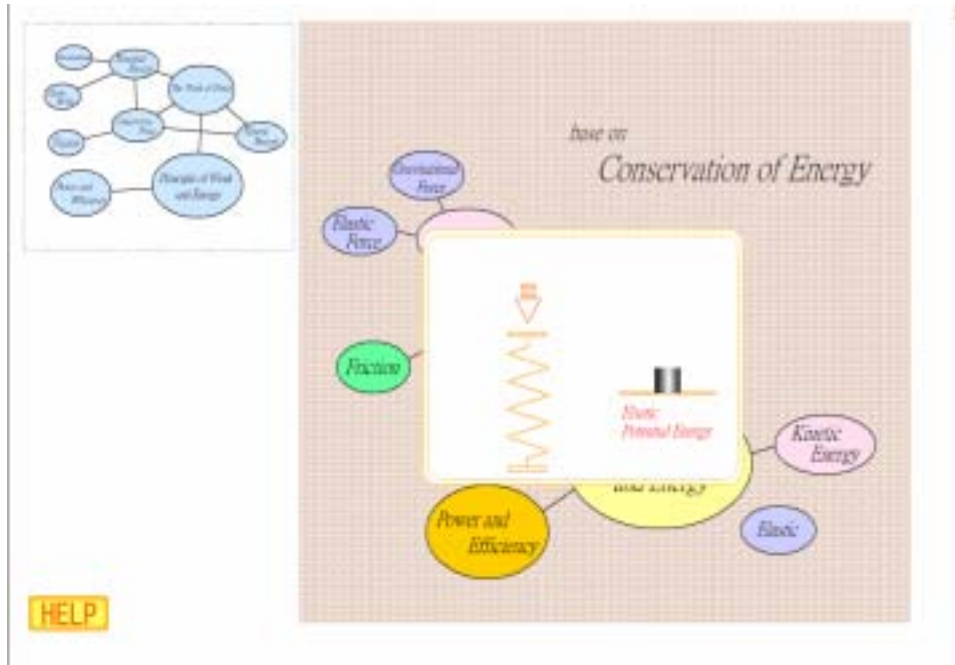


Figure 2.3 Demonstration of Concept Mapping Learning Component

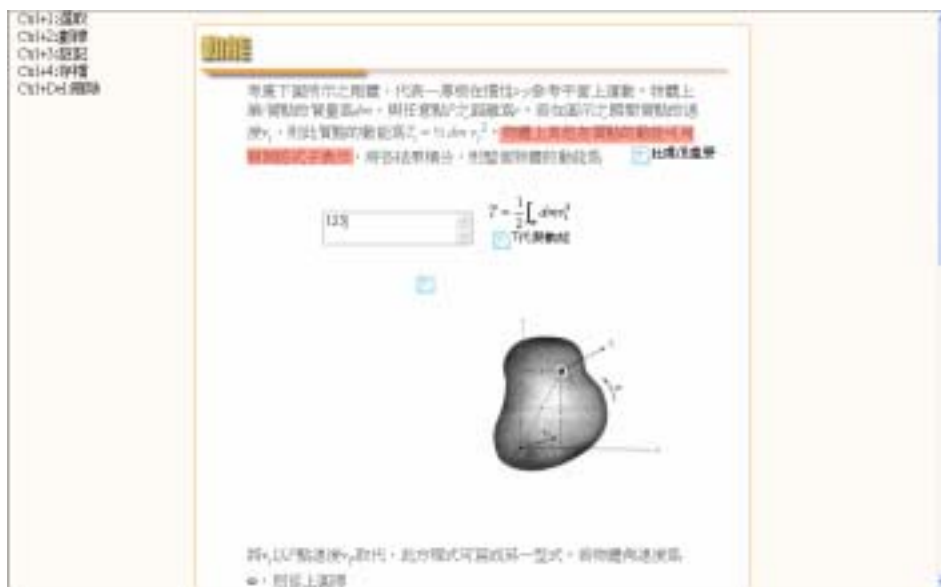


Figure 2.4 Demonstration of On-line Noting Component

- Interactive Parameterized Example Component:** This component employs parameterized simulations to help learners distinguish different mechanics behaviors from various sets of input or control parameters. Through adjusting the parameters that define or control the problem, the learner is hoped to obtain a deeper understanding on the mechanics problem after observing the various results simulated by the computer. Figure 2.5 demonstrates a prototype of this component developed in this research. The component uses entertaining

scripts to enhance learning motivations and provides interactive examples for learners to articulate mechanics concepts.



Figure 2.5 Demonstration of Interactive Parameterized Example Component

- Integrated Multimedia Presentation Component:** Multimedia presentation becomes an indispensable CAI tool for its characteristics of recording information completely without omitting possible details. Besides, along with the increase of Internet bandwidth and the mature of information technology, digital teaching and learning materials nowadays can be easily integrated with other types of materials, so that the teaching and learning process can be more efficient. The integrated multimedia presentation component integrates on-line video and audio streaming, powerpoint presentation, and hyperlinks in order to provide more abundantly the teaching and learning contents. Several commercial packages are available to produce the integrated multimedia presentation component as shown in Fig. 2.6. The class video is displayed on the top left of the screen and the presentation material is shown on the right side of the screen. The display of presentation materials is usually synchronized automatically with the video.

3.2 Evaluation and Discussions

In this research, fifty freshman students in the Department of Civil Engineering are invited to test and evaluate the six components discussed in the previous section. All of the evaluations are performed through Internet. Before the evaluation of each component, documentation on the design objective of the component as well as a simple user's guide is provided. After the test use of each component, the user is asked to complete a simple questionnaire to evaluate the effectiveness of the component. All of the questions in the questionnaire are evaluated by a five-points system.

Table 2.1 shows the overall scores for all of the components. It can be seen that all of the components are very much appreciated by the students. However, the students seem to favor more on the components that are relatively easier to use and with less complexity, e.g., the guided example component, interactive animation example component, and integrated multimedia presentation component. The least favorite one is the concept mapping learning component. This is probably because engineering students seldom have the chance to use

concept maps as their thinking or learning tool and therefore, feel more difficult to use the component effectively.

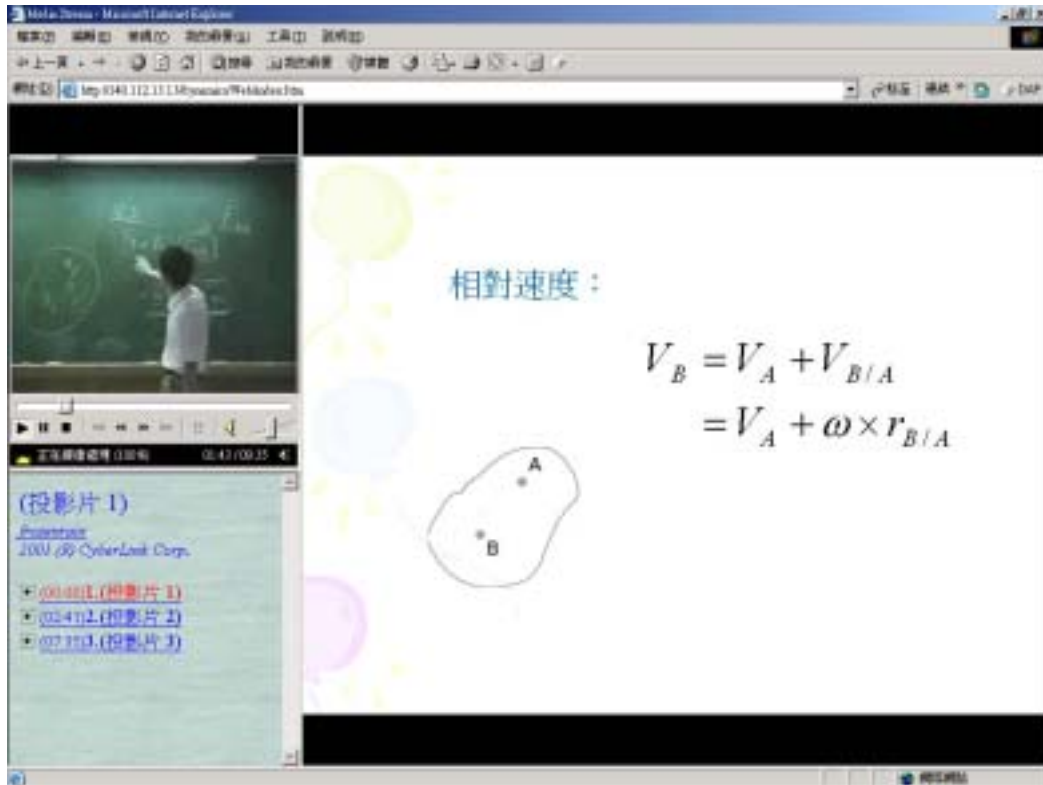


Figure 2.6 Demonstration of Integrated Multimedia Presentation Component

Table 2.1 Evaluation Results of CAI Components

Components	Average Scores
Guided Example Component	4.33
Interactive Animation Component	4.37
Concept Mapping Learning Component	3.59
On-line Noting Component	4.05
Interactive Parameterized Example Component	4.22
Integrated Multimedia Presentation Component	4.30

4 Conclusions

In this research, the current situation of applying Computer-Aided Instruction (CAI) tools to teaching and learning of college engineering mechanics related courses in Taiwan has been surveyed using the questionnaire approach. It is found that most of the surveyed teachers have never used any kinds of CAI tools in their classes and the most commonly selected reason for it is that they cannot find suitable CAI tools. However, a majority of the surveyed teachers and students agree that CAI tools are needed in teaching and learning mechanics related courses.

Therefore, there is a need in developing suitable CAI tools for mechanics related courses and assisting teachers to find the tools they need for their courses.

Six prototypes of interactive multimedia CAI tools have been designed and demonstrated for assisting the teaching and learning of engineering mechanics related courses. The applicability and effectiveness of these tools have also been tested on-line and evaluated using the questionnaire approach. It is shown that all of the tools presented are very much appreciated by the students participating in the evaluation. Moreover, to facilitate management and sharing of collected and developed CAI tools among teachers and students, a resource sharing website has been constructed in this research. The website allows the users to search the CAI tools they need through the hierarchy of the subjects of each engineering mechanics related course as well as the specified keywords.

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