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The Increasing Influence of Computers in Engineering Education: Teaching Vibration via Multimedia Programs*

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The use of computers in education has changed drastically in the last three decades. It would not be possible to relate all the events and activities which have influenced these changes. However, the first part of the paper is intended to provide a review of the educational technology and discuss the three main phases of changes in the methods of teaching and training practices. During this review, the position of the computer-based learning in the individualized learning technique will be pinpointed. After discussing the psychological aspects of learning, the modern theory of cognitive psychology will be reviewed and the theories of Piaget and Bruner will be stated. The role of educational media will be discussed and computer-based learning software will be included among different media. In the second part, using the framework constructed in the first, the main components of modern educational media will be discussed. After setting out the main shortcomings of computer-based learning as used in higher education institutions, the role of interactive multimedia will be discussed. The final part of the paper will explore the possible integration of the interactive multimedia system into the teaching of mechanical engineering. As a case study, the procedure for developing an interactive multimedia courseware in teaching vibration will be discussed. The structure of the program is based on the model suggested by Bruner in order to increase its cognitive effectiveness.

INTRODUCTION

THE PACE of innovation in education has stepped up considerably in the last three decades. A large number of educational institutions have incorporated sophisticated educational technology into their systems of education, and many polytechnics and universities have encouraged innovation through their centres for educational development working with academic departments. From elementary to higher levels of education, there is evidence of the acceptance of interactive multimedia as an integral part of the educational scene. Educational technology refers to the combination of human and non-human resources employed in a systematic way in the design, implementation and evaluation of the total process of learning and teaching. Educational technology links the human resources of specialists in curriculum and educational design, evaluation and media with the non-human resources of education which include printing machines, computer-based teaching and learning hardware and software, television and radio, learning laboratories and learning software. The information explosion prompted by instantaneous electronic communication has radically altered the human environment. Most educational functions can be performed by a variety of media such as educators, printed materials, films and computers. The emerging requirement for students in a rapidly changing environment is 'how to think for themselves'. This is producing a shift in the role of the educator. That is, the educator's task is becoming not the dissemination of information, but the provision of a wide variety of learning experiences and the nurturing of creative responses to education. Print and electronic media have become not merely tools, but the building blocks of a more efficient and interesting learning environment. When more information is communicated by learning media, instructors can direct more of their attention to understanding the needs of individual students and stimulating them to use the information available from educational media. Individualized education is being emphasized in increasing numbers of educational institutions. This approach to teaching requires that students have easy access to a large variety of pre-selected learning materials and periodically call on their educators to check their progress. The use of media to communicate information and skills enables educators to play a different role. That is, helping students to understand themselves and their objectives and to recognize and use

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the most effective means of reaching those objectives. Interactive multimedia learning programs can assist educators and students in accomplishing their educational objectives more effectively and efficiently.

TECHNOLOGY IN EDUCATION

Technology in education embraces every possible means by which information can be presented. It is concerned with everything used in education and training such as computers, projected media, etc. Put simply, technology in education is basically the popular idea of audiovisual aids. Audiovisual aids are composed of two related but distinguishable areas:

- The hardware is concerned with the actual equipment such as computers, slide projectors, overhead projectors, videocassette recorders, etc. One of the earliest phases in the evolution of educational technology was to develop effective educational equipment which was reliable, serviceable and within the budgets of the most educational institutions.
- The software is concerned with the various items that are used in conjunction with hardware such as computer programs, audio tapes, video tapes, overhead transparencies, etc. When hardware became generally available, it was found that there was a shortage of suitable software to use. This triggered off a subsequent software development phase in which particular attention was paid to the development of suitable learning materials often based on the recent theories of learning. For further details Rushby [1].

Technology in education has always had many engineering connotations, since the main thrust of educational technology is concerned with the development of mechanical, optical and electronic equipment for educational purposes.

THE TECHNOLOGY OF EDUCATION

As technology in education developed, people also became aware that their education and training could be improved drastically if all aspects of teaching and learning were carefully considered. Such consideration led to a new, broader interpretation of educational technology—namely that the technology of education should be concerned with the overall quality and efficiency of the teaching and learning process. One of the first people to use the term 'technology of education' was Gilbert [2]. In education and training, efficiency can manifest itself in:

- improving the student/educator ratio without impairing the quality of learning;
- reducing the cost of education and training without affecting the quality;
- improving the depth of learning (degree of mastery);
- reducing the time taken for learners to achieve certain objectives.

The above criteria are not mutually exclusive; for example, certain measures that can improve the quality of learning would reduce the student/educator ratio or increase the cost. However, given a well-defined criterion by which improvement in the efficiency can be measured, the implementation of a technology of education approach can provide the measures by which this improvement can be achieved. In many cases, the approaches are based on a study of a system whose behaviour is governed by findings in psychology, educational research, business management, systems analysis, sociology, optics, acoustics and computer technology. These aspects, which are all part of the technology of education, are called the intangible aspects. Note that in technology of education the emphasis is on the techniques of teaching and learning rather than audiovisual aids. A number of definitions of educational technology have been produced by different bodies and organizations. The Council for Educational Technology for the United Kingdom defines educational technology as 'the development, application and evaluation of systems, techniques and aids to improve the process of human learning'. The National Centre for Programmed Learning for the United Kingdom defines educational technology as 'the application of scientific knowledge about learning and the conditions of learning to improve the effectiveness and efficiency of teaching and training. In the absence of scientifically established principles, educational technology implements techniques of empirical testing to improve learning situations.'

Both these definitions and others are similar in that each emphasizes the primary function of educational technology as improving the efficiency and quality of the process of learning. Each of the definitions advocates a systems approach to the design of teaching/learning situations and the use of techniques that are found to be appropriate in order to achieve the preset objectives. It is necessary to note that in all of the above definitions there is an emphasis on assessing and evaluation. (For further details see [3–5]).

DEVELOPMENT OF EDUCATIONAL TECHNOLOGY

Elton [6] states that educational technology has undergone a progressive change of emphasis since the end of the World War II, when it first emerged as a discipline in its own right. Elton [6] identifies three broad phases which the field of educational technology has evolved:

Mass education

Mass education is the oldest phase, with lectures and expository lessons being the dominant educational techniques in virtually all sectors of education and training. In the period after World War II a systematic effort was made to improve the efficiency and cost effectiveness of mass education by using new types of hardware. It was hoped that more people could be educated or trained without having to increase the number of educators—then in short supply— and thus make the system more cost effective. The important outcomes were the development of basic mass education tools like the overhead projector, slide projector and widespread use of film, radio and television broadcasting. Soon it became obvious that the method was not suitable for achieving higher cognitive objectives. It was also passive, denying student involvement. (For further information see Bloom [7,8].) However, mass education techniques such as educational broadcasting and related hardware continued to grow in importance, and are still the most cost-effective teaching method in the modern educational education system. The most common methods that are used for mass education are as follows:

Lectures Although the term 'lecture' is used in the context of tertiary education and training, it also covers any situation in which an educator or an instructor talks to a class of learners or trainees. Telling, explaining or lecturing are the most efficient techniques for communicating facts, generalizations, terms, principles and theories. The face-to-face talk or lecture still holds a central position at many levels of education and will continue to do so for some considerable time to come. A number of research studies aimed at comparing lectures with other teaching methods have been carried out. The results show that lectures are not particularly effective in developing high-level thought among students compared with other methods of learning such as group discussions. The majority of studies which have compared the lecture method with other methods designed for developing lower cognitive skills have not been able to detect any difference that is statistically significant. Another problem of lectures is that student attention tends to diminish fairly rapidly with time. This fall off takes the form of an increasing frequency of attention breaks (microsleeps) in which the student switches off concentration for a short time. The length of time for which a student can maintain full attention to the task of listening and writing (attention span) decreases steadily as the lecture progresses. In a typical 50 min lecture it falls from 12–15 min at the start of the lecture to 3–5 min towards the end of the lecture. Attention breaks usually last for about 2 min. For a straightforward lecture the optimum time for the most effective transfer of knowledge is about 20 min. For long lecture type classes, lectures will be more effective if they are used in conjunction with other suitable teaching methods such as the use of multimedia learning programs. For further details see Johnstone [9]. One aspect of the lecture method which causes some concern is that its effectiveness is dependent on the skills of the individual lecturer. The ability to organize and explain a topic does not come naturally except to small percentage of educators or instructors. Brown [10] gives many useful guidelines on the art of structuring and presenting a lecture. Further hints have been given by Ellington [11].

Film and video presentation Films have been used as a mass educational teaching method for many years. The arrival of the videocassette recorder (VCR) has made the task of showing films and video cassettes easier. In the last four decades a large number of educational films and videocassette programs have been produced. Government agencies, business and industries are a source of many useful video learning materials. Film and video presentations can be used in education and training as an effective lecture substitute. They can be particularly useful if the content has a high visual impact and where other techniques, such as animation, are used. For further details see McInnes [12].

Educational broadcasting A certain degree of learner–educator interaction is possible through printed media. For nearly a century people in all parts of the world have been able to participate in guided independent study through postal correspondence courses. The proliferation of electronic technologies makes it possible to experience place-shifted education. Telecommunication systems embraces a wide variety of media, including telephone, radio and television. 'Distance education' has become the popular term to describe learning via communication. More recently, in Singapore, the government has sponsored a distance education program which emulates the British Open University. In 1971 the British Open university started with an enrolment of 40,000 students and grew to 200,000 by the year 1990. For further details see Dede [13], Gilbert [14] and Mason [15].The advantages and disadvantages of the above types of education in mass education are shown in Table 1.

Individualized learning techniques

Although individualized learning in the form of correspondence has a long tradition in education, it was only recently that it became part of main stream educational technology. The catalyst for this development was behavioural psychology, which was pioneered by Skinner [16, 17], a psychologist at Harvard University during the 1950s.

Skinner was a behaviourist, but with an important difference: he was interested in voluntary behaviour, such as learning new skills, rather than reflexive behaviour as illustrated by Pavlov. Skinner demonstrated that the behaviour of an organism could be shaped by reinforcing or rewarding. Skinner [16, 17] based his learning theory, known as reinforcement theory, on a

Table 1

Technique	Advantages	Disadvantages
Lecturing and expository lesson	1. Cost effective in terms of student/staff ratio 2. Effective in achieving lower cognition and some affective objectives 3. More popular with the students and staff	1. Success depends upon the skill of individual educator 2. Ineffective in achieving higher cognition, affective objectives and psychomotor objectives 3. Student involvement is almost non-existent 4. Pace is fully controlled by instructors 5. Most lectures are too long for the concentration span of students
Film and video presentations	1. Can be an effective substitute for a conventional lecture if the content and level are suitable 2. Can be used to provide basic and realistic pictures and play a supportive role in describing case studies 3. Moving pictures have been shown to be interesting and stimulating for the majority of students	1. Can be a waste of time if level and content are not chosen carefully 2. The control of teaching is in effect transferred to film and video makers 3. Requires special hardware and maintenance team 4. Production of some films or videos can be expensive
Educational broadcasting	1. Can be an effective substitute for a conventional lecture if the content and level are suitable 2. Moving pictures have been shown to be interesting and stimulating for the majority of students 3. Educational broadcasting can be cheaper than films or videos	1. Can be a waste of time if level and content are not chosen carefully 2. The control of teaching is in effect transferred to film and video makers of the broadcasting company 3. Timing of the broadcasts is normally fixed, making them unsuitable to fit into a timetable unless they are recorded. This may require legal permission

series of experiments with pigeons. He reasoned that the same procedures could be used with human beings. The result was the emergence of programmed education which dominated educational thinking during 1960s and led to the development of a wide range of individualized learning techniques such as:

- Computer-based learning programs that are now achieving more widespread use.
- Fully integrated individualized education systems such as the Keller Plan [18] and open learning systems.

Sequential programmed learning In programmed education, at each stage a learner actively participates in performing a set task, after which the learner is supplied with immediate feedback in the form of the correct answer (successive reinforcement). Skinner also argued that each task should be small enough to ensure that the learner is almost always correct in her/his response. The first application of Skinner's research to the classroom situation came in the form of sequential programmed learning. In this type of learning, the subject matter is broken down into a sequence of small steps or frames that logically follow one another. Each of the steps represents only a very small part of the concept or skill to be taught, the division being arranged to guarantee the correctness of the desired response. An immediate feedback on the correctness of the response is designed to provide suitable reinforcement. In this method there is only one possible path that a student can take through the frames. In practice, Skinner's small step requirement has been proved to lead to boredom on the part of the learner. It is now accepted that the optimum step size in any particular learning program is governed by a large number of factors. Thus in modern sequential programmed learning, large and difficult steps are also incorporated in the programs. Furthermore, modern programs have less reinforcement than the early programs developed by Skinner and his followers.

Branching programmed learning In the 1960s an alternative version of programmed learning was developed. This involved the use of several possible paths through the sequence of frames. In addition, a number of remedial loops were also included in order to correct the students' responses to individual frames. Thus, the topic was taught in a number of alternative ways.

Branching programmed learning has been the basis of a large number of self-educational programmes that have been designed for use with computers since 1970s. Use of computers in this substitute tutor role allows students fast and effective access to what is basically a branching programmed learning sequence.

Later developments in individualized learning have involved a much more flexible approach to program design than was used in the relatively strict early programmed learning procedures. Much of the present use of individualized learning has evolved and been adapted in order to meet the specific requirements of particular educational or training establishments or in order to satisfy the special needs of particular students. The characteristics of some of the main individualized learning techniques are summarized in Table II. As in the case of mass education, the individualized learning phase failed to fulfil its early promise. During the 1960s the followers of programmed learning were predicting the early demise of the traditional classroom and instructor, claiming that they would be replaced by teaching machines. These teaching machines turned out to be the biggest non-event in the history of education, for the following reasons:

- The material was far from being user friendly.
- Increasing realization that there is much more to education than teaching facts and principles.

Group learning

There are a number of limitations to individualized learning. The most obvious one is that it prevents students from interacting with one another. They do not develop group skills such as discussion skills and the other skills connected with working as a team. The theoretical basis for modern developments in group learning is the humanistic psychology developed by Rogers [19] during 1960s. Humanistic psychology is concerned with how people interact and learn from one another in small groups ('group dynamics'). Such techniques generally require neither specialized hardware nor software and the emphasis is almost always upon the approach or technique. The use of group learning is now well under way. Its use is evident by the number of group projects, group learning exercises and group use of computer-based learning software. The evolution of emphasis in educational technology from mass education through individualized learning to group learning mirrors the progression from a hardware approach through a software approach to a technology of education approach. An example of evolution in educational technology is the Open University in the United Kingdom. The Open University started by using television and radio. In parallel, there was an extensive period of software development to support students studying on an individualized basis. However, in recent years, there has been much greater concern with providing situations for interaction of students among themselves and with their tutors. Elton's [6] model has been criticized as being incomplete. For example, it makes no reference to the development of other important areas in educational technology such as management of innovation [19], and the development of student study skills [20, 21]. In recent years a number of books have also been written for instructors in order to assist them in devising appropriate activities for students [22].

DEVELOPMENT OF COGNITIVE PSYCHOLOGY

Behaviourists are not concerned with the internal changes when learning takes place. They rely only on the observable behaviour as evidence that learning has taken place. On the other hand, cognitive psychologists construct models about how information is received, processed and manipulated by learners. Moreover, they construct mental models of short-term and long-term memory. According to this model, new information is stored in short-term memory. If the stored information is not rehearsed it fades from short-term memory. Learners combine the information and skills in long-term memory to develop cognitive strategies. One of the most prominent behaviourists, the Swiss psychologist Piaget [23], views the mental processes individuals use in responding to their environment as three key concepts of mental development:

- *Schemata* are the mental structures by which individuals organize their perceived environment. Schemata are used to identify, process and store the incoming information. These structures can be assumed to be the categories individuals use to classify information. Differentiation based on experience leads to the development of schemata.
- *Assimilation* is the process by which the above schemata adapt or change during learning. This is the cognitive process by which a learner integrates new information into existing schemata. During learning, assimilation results from

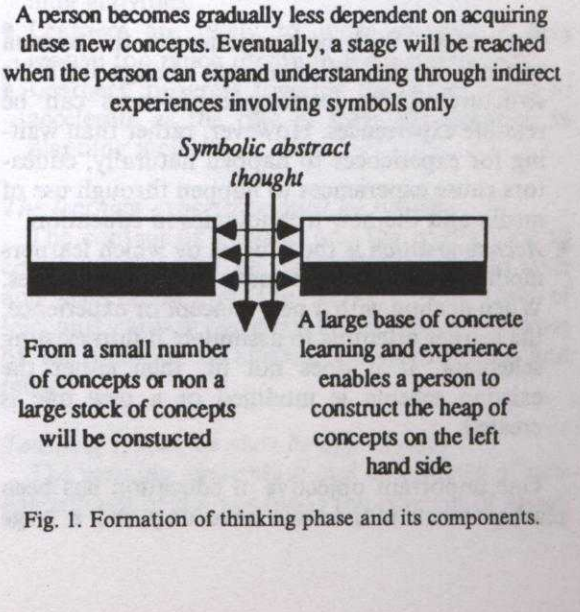

Fig. 1. Formation of thinking phase and its components.

Table 2

Technique	Advantages	Disadvantages
Directed study of material in common textbooks	1. Effective way of teaching basic facts and principles 2. A learner can work at her/his own pace 3. No specialized facilities needed 4. Can be time efficient by reducing the repetition time	1. Dependent on suitable texts being available in sufficient numbers to be used by all students 2. Weak in achieving higher cognitive and affective domain objectives
Study of specially prepared set of notes	1. Can be a more effective way of teaching basic facts and principles if the notes are prepared for a particular group of students 2. A limited interaction can be established between the instructor and learners 3. Searching time for the material will be minimized 4. A learner can work at his/her pace 5. Can be time efficient by reducing the repetition time	1. Preparation and updating of the notes can be a time-consuming task 2. Weak in achieving higher cognitive and affective domain objectives 3. Discourages the searching task which can prove to be a required skill later in students' lives 4. Students will only be acquainted with one way of presentation of the material
Self-education via audiovisual media	1. A learner can work at his/her own pace 2. Can be a more effective way of teaching basic facts and principles because of the increased bandwidth due to audio and video 3. Can be time efficient by reducing the repetition time, especially in teaching certain laboratory skills 4. Students are more enthusiastic in using this type of media	1. The amount of suitable audio-visual material for a particular course is limited 2. Custom-designed material can be both time consuming and expensive 3. Weak in achieving higher cognitive and affective domain objectives 4. Requires suitable hardware and a maintenance team which can be expensive
Computer-based learning (CBL)	1. It enables a wide range of educational objectives to be achieved, especially higher cognitive objectives 2. Allows learners to work at their own pace 3. Allows a high level of interaction between learner and media. It can also adapt to the needs of learners 4. Can be highly stimulating 5. Through computer simulation a learner can achieve special learning objectives	1. The production of CBL material is time consuming 2. The production of CBL material is expensive 3. The number of high-quality programmes is relatively small 4. Production of CBL programs requires knowledge of computing and skills in using special software 5. It requires hardware which is relatively expensive 6. It requires staff to keep the system in operational order

experiences. With new experiences, the schema expands in size but does not change its basic structure. These learning experiences can be real-life experiences. However, rather than waiting for experiences to happen naturally, educators cause experiences to happen through use of media and the new technologies in education.

- *Accommodation* is the process by which learners modify the existing schemata or create new ones. When dealing with a new concept or experience, the learner attempts to assimilate it into existing schemata. If it does not fit, then either the existing schema is modified or a new one is created.

One important objective of education has been reached when individuals have acquired a large number of concepts and large capacity for cognition to be able to think about and solve problems using symbols and without referring continuously to the things for which the symbols stand. Figure 1 shows how the transition from concrete to abstract learning takes place. Bruner [24] proposes that education should proceed from direct experience to iconic representations of experience to symbolic representation. Bruner [24] points out that this applies to all learners. It has already been mentioned that an important step in education is to determine the learner's current level of experience. Educational media that incorporate concrete experiences help students integrate prior experiences and thus facilitate learning of abstract concepts. Historically, improving the balance between concrete and abstract learning experiences was the key reason for using different educational media. A similar model has been constructed by Dale [25] and is known as the 'Cone of experience'. In the first six layers of this cone the learner is a participant in the actual experience. In the next three layers the learner acts an as observer of a mediated event. Finally, in the last two layers the learner observes symbols that represent an event. Hence Bruner's work can easily be superimposed on Dale's cone. Bruner, however, emphasizes the nature of the mental operations of the learner rather than the nature of the stimuli. Figure 1 also shows the way in which operations on symbols produce thought.

A SYSTEMS APPROACH TO A COURSE DESIGN

A systems approach is a sophisticated process for identifying and solving problems. The approach is based on the premise that any organization of human resources, technical resources, financial resources or a combination of all of these is a system made up of elements. Each element has its own function and objectives. However, all the elements are related to each other and all the elements contribute to a common set of objectives. A change in one element may cause a change in other element(s) or in the system itself. The objectives of the total system are attained only when all the elements are integrated in an effective and efficient pattern. In a systems approach, the whole process is always considered more important than the mere sum of its parts. A simple systems approach for designing a course can be summarized as follows:

1. Determine the target population characteristics and topic area.
2. Estimate the existing knowledge and skills that potential learners possess.
3. Formulate objectives or desired learning outcomes of the course.
4. Specify the teaching and learning methods by which the objectives can be achieved. There are far more teaching methods available to choose from than most people realize. Huczynski [26] gives descriptions of nearly 300 different educational and training methods.
5. Construct prototypes. Once the most effective teaching methods and materials for particular purposes—e.g. reading, tapes, films—have been determined, prototype materials must be developed or purchased.
6. Test the prototype. The educational package created in the above stages should be tested with a representative group of students. Data should be collected on what does and does not work, and why.
7. Implement the course. This involves all the logistical arrangements associated with running a course, including structuring, pacing, teaching strategies, selecting appropriate media.
8. The combined result of the above steps is a learning experience provided for the target students. The effectiveness of the pre-planning can be measured by studying student performance, i.e. assessments. Note that the assessment should be closely related to the objectives of the course.

For further details of educational systems development and analysis see Kaufman [27] or Romiszowski [28]. In selecting course material and using media, an educator must take into account some basic learning tenets.

Each learner is unique

Learners' interest, their intelligence, the efficiency of their senses and the way they respond to education make them different from one another. Even if all the students are assumed to start a course with an equal amount of knowledge, variations in intelligence will soon produce variations in progress. Educators can achieve more control over the efficiency of learning experiences by implementing the following ideas:

- Organize learning experiences that take into account individual differences.
- Provide learners with a choice of learning media.
- Encourage individual responses that will reveal learners' ideas about the subject.

Cognition is the foundation of learning

Learners' cognition results in the understanding of perceived events. These cognitions are the materials from which learners build concepts, which in turn are useful in building further concepts and solving problems.

Learning requires involvement

Learners must be aware of their actions and must actively seek information and skill. They must also know what is expected from them. In using educational media, three important factors should be considered:

- Learners usually participate effectively in planning activities.
- Learners are likely to loose interest if they receive too much direction from instructors.
- Learners' progress towards the target tends to accelerate as the rate of their participation in planning increases.

The learning experience must be suitable

The content of a lesson and the media used to communicate must be compatible with the style and background of the learners. The task of selecting learning materials is complicated because of the number of alternatives of methods and media.

Teaching strategies must be appropriate

The growing availability and acceptance of new educational media has made the concept of group sizes redundant. Educators can now alternate between working with large groups (which is the most practical option in most instances), small groups, encouraging peer tutoring and supervising students who work on their own. The current trends in teaching are:

- To communicate the background knowledge to a large group of learners.
- To split the large group into smaller sub-groups that actively use information rather than passively learning it.
- To provide as many opportunities for learners to work on their own.

By using the above strategies, students become involved in learning, regardless of their differences.

Creativity is an objective of learning

Learning for learning's sake is not enough. Instructors who want their learners to acquire maximum benefit from printed and non-printed material should encourage their students to experiment creatively with the material to be learned. This reinforces learning and produces a feeling of accomplishment that encourages further learning. For further information regarding learning tenets see Watson [29].

EDUCATIONAL MEDIA

A 'medium' is a channel of communication. In its most general use the term refers to anything that carries information between a source and a receiver. Examples of media are educators, computers, radio, television, printed materials, etc. The purpose of media is to facilitate communication. An educational medium must be selected on the basis of its potential for implementing a stated set of objectives. An analysis of the educational media spectrum includes a description of:

- the characteristics of each media;
- the ways in which each medium can be presented;
- the ways in which each medium can be used effectively.

When considering educational media, one must distinguish between the materials and the equipment, since both are usually implied when media are discussed. The material itself can exist in several formats. The material and equipment

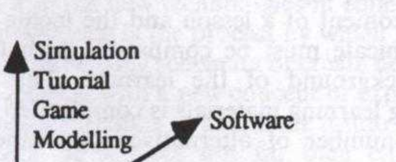

Fig. 2. Relation between hardware, software and techniques.

together constitute the medium. The equipment which stores and transmits the educational material constitutes the hardware, and the contents which are stored and transmitted are the software. A third dimension of the hardware and software concept is the approach chosen, which can be thought of as a technique, as shown in Fig. 2. Techniques are procedures for utilizing hardware to transmit software ideas. Examples of techniques include different types of computer-based learning software. For a detailed classification and examples see Nobar [30].

THE PROPERTIES OF MEDIA

Three properties of media help to show why they are used and what they can accomplish that educators alone cannot. These properties help to determine the ways in which they are used.

The fixative property

This property permits the capture, preservation and reconstitution of an object or event. Photographic film, audio tape and video tape are raw materials for fixing these objects or events. Once a photograph is made or a voice recorded, the information has been saved and is then available for reproduction at any time. This property enables the record of an event to be transported through time.

The manipulative property

This permits the transformation of an object or event in many ways. The event can be speeded up. Conversely, an event may be slowed down by replaying a motion picture film or video tape at a slower speed than that at which it was recorded. Actions can be arrested and then be reversed as in a motion picture which is run backwards.

The distributive property

While the fixative property of the media allows events to be transported through time, the distributive property permits events to be transported through space, simultaneously presenting millions of viewers with a virtually identical experience of an event.

A CATALOGUE OF EDUCATIONAL MEDIA

While the three properties discussed above do not help directly in the selection and use of educational media, they do help to demonstrate the utility of media and the reasons for using a wide range of resources. The physical characteristics of basic media and the ways in which they may be presented are as follows.

Models

A model is a replica or representation of reality. It can either be a miniature, an exact replica or an enlargement. Closely related to the model is the mock-up, which is also a representation of the real thing but is constructed so as to emphasize a particular part or function of the real thing. This type of media may be used for the direct experience (enactive) phase of Bruner's education model.

Simulation

Simulation is the replication of real situations which have been designed to be as near the actual event or process as possible. Examples would be the use of a simulated driver's position in a car with road conditions presented on the screen. Many media, including computers, tape recordings, motion pictures, slides and models, can be used for simulation.

Still pictures

Photographs of any object or event constitute still pictures. A still picture is a record or a copy of a real object or event which may be larger or smaller than the object or event it represents. A still picture may be presented as a textbook illustration, a slide frame, an overhead projection transparency, a computer -generated screen, or an illustration on a television program. This media can be used in the iconic representation phase of experience in Bruner's education model.

Motion pictures

The term 'motion picture' includes both film and video. These media have different origins. Film originated in the chemical process of photography, whereas video is based on electronic technology. The recording of moving images has progressed from film to analogue video tapes to digital recording on disks. Any media that employs a cathode-ray screen or similar device to present the picture portion of a message is referred to as video. Video works by converting light to electronic signals that can be stored on magnetic tape or disk and then reproduced on a television screen. Objects or events may be in normal motion, in slow motion, time-lapse or stop motion. Objects or events may be edited for abbreviating or highlighting. Sound may be synchronous with the visual portion or may be narrated over the action after the event. This media can be used as a powerful tool in the iconic representation phase of experience in Bruner's education model.

Audio

In an analogue sound recording, the pressure waves are picked up by a microphone. A diaphragm inside the microphone responds physically to the changes in the pressure caused by the sound waves and converts them into electrical signals. These signals are an analogue of the original sound. They can be amplified and sent to a loudspeaker where a process opposite to that in the microphone takes place. The electrical signals vibrate a diaphragm to generate audible sound waves in the air. The electrical signals can also be recorded on a magnetic tape and stored for playback later. One of the major problems with an analogue recording system is the element of noise inherent in the system itself. An example of this is tape hiss, a high-pitched hiss on audio tapes that is audible above the sound when the tape is played. Various noise reduction systems are used in order to reduce tape hiss. In the most common type the whole recording is done at a lower set of sound frequencies and so recorded below the tape hiss threshold. When it is replayed through special equipment, the sound signals are converted back to their original frequency with a much lower incidence of tape hiss. However, all such noise reduction systems inevitably distort some of the characteristics of the sound. In a digital sound recording the electrical signals from a microphone are converted into binary representations. There is no noise in this type of recording and sound signals from master recording are easily transferred to compact disk. The digital code is etched into surface of the disk by a laser beam and then read back by another laser beam in the disk player. The recorded binary code is converted back into electrical signals, amplified in the normal way and played back through loudspeakers. An important advantage of the digitized sound is that it can be easily modified once it is encoded. Sound signals are presented in the sequence in which they actually happen unless the recording is edited. Audio recordings may be used by individuals or played directly to an audience or over a central sound system such as radio. This media can be used in the abstract representation phase of experience in Bruner's education model.

Computer-based learning

There are many uses of computers in education and the field is rapidly expanding. One result of this growth has been that the field of computer-based media has evolved with little structure. Many terms in general use lack commonly accepted definitions, and to complicate the matter even further, they are rarely defined by authors. Silberman [31] defines four areas of application of the computer to education: a tool for education, a research and development tool, and a management tool. It is logical to divide the educational function of a computer into two categories:

The computer does the teaching It has become almost common practice to use the terms computer-assisted instruction (CAI) or computer-assisted education, (CAE) for the process in which the computer does the teaching. In 1967 the Association of Computing Machinery gave the following definition for the use of computers in human learning situations:

> A method of education in which a learner and a computer interact with one another, with this two-way communication producing human learning and retention of this learning. Furthermore the computer program with which the

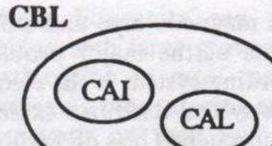

Fig. 3. The union of CAI and CAL.

learner interacts must be developed with specific behavioural objectives in mind.

For further information see Smith [32]. The history of CAI is largely a tale of high investment and low returns. This expensive technology has already consumed vast sums, especially in USA, and there is little to show for it.

The computer assists in teaching The term 'computer-supported education' (CSE) appears to be a good choice to describe all applications in which the computer is used as an educating aid by an educator. CSE would encompass the areas in which the computer is the subject of education or in which the computer is used as an aid in teaching other subjects. The actual teaching, however, is accomplished by a human educator. However, 'computer-assisted learning' (CAL) would be more apt, since it shifts the emphasis to the learner, who in fact is assisted in the learning process by the computer; this would eliminate the imprecision associated with the use of the verb 'assist'. For further details see Gerard [33].

As shown in Fig. 3, the union of CAL and CAI is referred to as computer-based learning (CBL).

MAJOR DIFFICULTIES WITH CBL MATERIALS

The major obstacles to the development of CBL as stated by Luskin [34] and others can be summarized as follows:

1. Higher education in most industrialized countries is organized around the concept of autonomy of institutions and based upon the right of institutions to make their own decisions and the right of the educators to prepare and present course materials in their own way. The procedures for arriving at a consensus vary greatly among institutions. It is therefore highly speculative for business and industry to undertake the risk of producing effective CBL materials.
2. Because of style differences, most CBL materials cannot be easily transferred from one institution to another. Moreover, since education tends to be organized around disciplines, there is a natural slowness for the movement of ideas from one discipline to another. It has been said that education is one of those rare institutions where the whole is less than the sum of the parts.
3. There is little incentive to produce CBL materials. For academic staff in most of the higher education institutions, especially at universities, teaching is a second-order priority—a poor career investment compared with research. Although a combination of an increase in number of students and student/staff ratio has in recent years spurred academic interest in this field, change is still modest and hard won. Of all the institutions which make up the educational system, the university appears to be the most resistant towards the development of CBL material.
4. Inadequate finance or personnel is available to develop and test the CBL materials to assure that they will be educationally effective.
5. The cost of development for a high-quality CBL program is high. Consequently, the quality of the educational programs is generally low and the documentation is usually poor. This often accounts for the natural resistance to the use of programs developed by other people. Some authors find the comparison of developing CBL materials with preparing classroom work unrealistic. For details see Cook [35].
6. The bandwidth of CBL systems is very narrow. That is, all the communication between the computer and the user is restricted to the computer monitor.
7. Lack of adequate intelligence in CBL programs.
8. Lack of simple and powerful authoring systems to enable educators to develop their programs in a relatively short time.

RECENT DEVELOPMENTS IN CBL

Seigel [36] refers to three waves of technology and related know-how:

1. The first wave was related to the computer technology itself, i.e. the design and programming of computers and computer applications. This involved a relatively small proportion of the population, who required highly technical, job-specific training in computing and programming.
2. The second wave came with the advent of the cheap microcomputer and its use by a much greater section of the population. This wave was generated by the hobbyist approach to computing.
3. The third or current wave is characterized by the permeation of all sectors of social and professional activity by computer systems. That is, people will use computers designed for the task they wish to perform; they learn to use it efficiently until it breaks down and then call in a specialist.

Most of the difficulties described by Luskin [34] nearly 25 years ago are still valid. However, the current wave of development has created two major changes in the CBL software environment:

- The development of multimedia systems has increased the delivery bandwidth considerably.
- The development of CBL software through user friendly authoring systems has become feasible from the standpoint of both cost and effectiveness. This has created a cottage industry in education in which costs are high, quality low and duplication commonplace.

There are several interrelated issues that have to be resolved if the use of CBL software is to reach an acceptable level. The resolution of these issues will probably determine the forms by which CBL software will be integrated to the system of education as a whole. For details of a possible solution see Nobar [37].

MULTIMEDIA CBL SYSTEMS

The generic term 'multimedia system' refers to any combination of two or more media that can be integrated to form an informative or educational program. The use of the term 'multimedia' goes back at least to 1950s when it was used to describe early attempts to combine various video and audio media for increasing the effectiveness of conventional teaching. It referred to a methodology which was based on the principle that a combination of audiovisual with other educational materials would increase the effectiveness of teaching. A multimedia system involves more than simply presenting information in multiple formats. That is, it involves integrating different media into a structured program in which each component complements the others, so that the performance of the whole is greater than the sum of its parts. Gayeski [38] defines multimedia as: 'a class of computer driven interactive communication systems which create, store, transmit and retrieve textual, graphics and auditory network of information'. In defining multimedia in education, the lecturing component should also be included among the media as shown in Fig. 4. Educational media play a key role in the design and use of systematic education. A medium, broadly conceived, is any person, material or event that establishes conditions which enable the learner to acquire knowledge, skills and attitudes. In this sense information may be found in books, on computer disks, on audio and video recordings, on films and still pictures, all of which are forms of storage. The retrieval of this information from its storage is a reconstitution of the event or a report of the event.

METHODS OF DEVELOPING MULTIMEDIA PROGRAMS

There are two different philosophies regarding the development of interactive multimedia programs:

Incremental multipass

In this method, the entire course is divided into small sections and each one implemented independently using a multipass approach. In other words, each section is scanned several times, and at each scan one aspect of the multimedia is implemented. The method has been used in most educational establishments. Its popularity is due to the fact that:

- It encourages academic staff to become involved in developing multimedia programs.
- The program can be finished in a relatively short time.

However, it has two major disadvantages:

- In most cases the course as a whole will never be implemented because of the loss of interest or change of direction by the developer.
- Generally, there is no homogeneity in the finished product.
- In most cases the choice and use of multimedia components are inappropriate.

Holistic multipass

In this method, the courseware is implemented as a whole. Namely, the whole course is scanned and at each scan one aspect of the multimedia will be implemented. The main advantages of the method are:

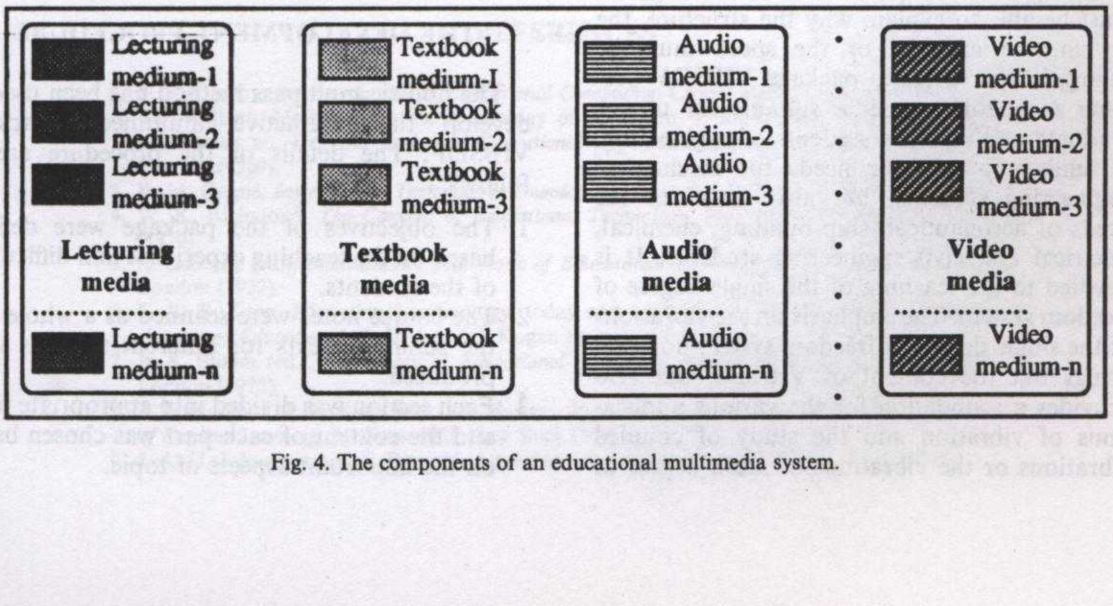

Fig. 4. The components of an educational multimedia system.

- The improvement will be to the whole courseware.
- The final product is more homogenous.
- Even it is unfinished, it can be distributed as an improved product.
- It can be completed in a much shorter time due to its more uniform structure.

However, it has the following disadvantages:

- It requires a completed courseware prior to computer development.
- Only a few academic staff are prepared to take up the development task because of the size of the job.

THE INTERACTIVE MULTIMEDIA PROGRAM VIBSDF

In 1905 S. Timoshenko published his first technical paper in the *Bulletin of the Polytechnical Institute of St Petersburg*. It consisted of the study of shafts using Rayleigh's method. This was the first time that Rayleigh's method had been applied to an engineering problem and marks the beginning of the study of vibration problems in engineering. After working for two companies in the USA, in 1928 he published the first edition of *Vibration Problems in Engineering*. The book represented one of the earliest attempts to present the theory of vibration in an organized manner to mechanical engineering students. Since then, many books have been published and used as supporting material in teaching vibration to engineering students. There are two phases to the study of mechanical vibration:

1. Older mechanical systems are not normally designed to withstand vibration, but vibration is usually a problem that has to be dealt with after it occurs. As a consequence, experience with vibration and learning to solve vibration problems is the first phase.
2. The literature is full of histories of disaster, diagnosis and success. The question that always arises is 'why?' The vibration engineer must be able to explain why the structure, the system, the material or the speed must be changed. The software package VIBSDF presents a supporting media suitable for undergraduate and diploma students of engineering. It fulfils not only the needs for mechanical engineering students, but also caters to the needs of aeronautical, ship-building, chemical, electrical and civil engineering students. It is devoted to the teaching of the single degree of freedom system. The emphasis on the vibrations of the single degree of freedom system not only brings out the content of VIBSDF but also provides a foundation for the various applications of vibration and the study of coupled vibrations or the vibrations of multi-degree of freedom systems. VIBSDF has been designed to enable students to learn how to solve the basic problems by changing the important variables of the physical system such as mass, stiffness and damping. The package also tries to explain why vibrational phenomena occur.

The package deals with the following subjects:

1. Free vibration which takes place when a system oscillates under the action of forces inherent in the system itself and external impressed forces are absent. The system under free vibration will vibrate at one or more of its natural frequencies, which are properties of the physical system established by its mass and stiffness distribution. The aim of the package is to illustrate the variations in natural frequencies as mass and stiffness changes.
2. Forced vibration which takes place under the excitation of external forces. When the excitation is oscillatory, the system is forced to vibrate at the excitation frequency. If the frequency of the excitation coincides with one of the natural frequencies of the system, then resonance occurs and large oscillations may result. The aim of VIBSDF is to illustrate the variation of the amplitudes as the excitation frequency changes. To emphasize the resonance phenomenon, the failure of a major bridge structure and others have been included as video options.
3. Vibrating systems are all subject to damping to some degree because energy is dissipated by friction and other resistance. If the damping is small it has very little influence on the natural frequencies of the system and hence the calculations for the natural frequencies are generally made on the basis of no damping. On the other hand, damping is of great importance in limiting the amplitude of oscillation at resonance. The aim of the package is to give the students a simulated experience of these important results by letting them vary the values of mass, stiffness and damping factor.

For further technical details see Timoshenko [39].

THE DEVELOPMENT PROCEDURE

The holistic multipass method has been used to develop the interactive multimedia package VIBSDF. The details of the procedure are as follows:

1. The objectives of the package were defined based on the teaching experience and difficulties of the students.
2. The course notes were scanned as a whole and the summary texts for different sections were produced.
3. Each section was divided into appropriate parts and the content of each part was chosen based on the important aspects of topic.

4. The key words were marked and help windows for explaining the terms were developed.
5. The text part of the package was narrated in order to increase the understanding and retention period of the material.
6. The frames for illustrating the behaviour of a spring–mass problem were designed and implemented.
7. A number of video clips were selected in order to demonstrate certain phenomena and applications.

SELECTION OF HARDWARE

The most suitable system on the market in terms of adequate quality of graphics, video and audio is a multimedia PC. It has four extra peripherals added to the conventional PC:

- a CD-ROM drive;
- a sound card;
- Microsoft Windows graphical environment with multimedia extensions for video and audio playback;
- a pair of speakers for audio output.

In order to record video on a PC, an additional set of peripherals will be required:

- a video digitizer or card to convert the analogue video signals to digital information;
- a source of video input such as a video camera;
- a VCR or a laser disk player which can be connected to the video capture card;
- video software such as Video for Windows which includes video capture, compression, playback and basic video editing utilities.

The Educational Development Centre (EDC) at Ngee Ann Polytechnic is equipped with a number of interactive multimedia PC systems. Each system has a large disk capacity of 0.5 Gbytes, a VGA/SVGA graphics card, a CD-ROM drive, a sound card, a pair of speakers and other minor peripherals. The authoring system is Authorware Professional which has been used to develop the interactive multimedia programs on site. For further information regarding the technical details of the system see Nobar [37]. The program VIBSDF has been developed at EDC using Authorware Professional (version 2.0). Since Authorware Professional is relatively slow for animating the spring oscillations, these frames have been written in Turbo C and integrated into the program. For further details about Authorware Professional see [40]. Some typical frames from the program are given in the Appendix.

STATISTICAL RESULTS

At present there are no extensive statistical results regarding the use of the package. However, it has been tested by a limited number of students at Ngee Ann Polytechnic. The program will be integrated into the mechanical engineering curriculum in the coming year. A full statistical analysis of the software will be published later.

CONCLUSION

It has been shown that CBL media have an important role in educational technology and can be used effectively in individual and group learning environments. The outstanding problems in assimilation of CBL in education systems have been discussed, and it has been shown that using interactive multimedia system one can remove the problem related to the limited bandwidth. Further progress in interactive multimedia teaching will increasingly take advantage of the pervasive role of higher bandwidths in education.

Acknowledgements—The authors would like to express their deep gratitude to two of their students from the Mechanical Engineering Department of Ngee Ann Polytechnic, Yeo Heng Chai and Tan Cheng Guan, and Kannappan from National University of Singapore who helped to implement the whole program. They spent many hours of their time completing the program and without their efforts this paper would have never been finished.

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APPENDIX

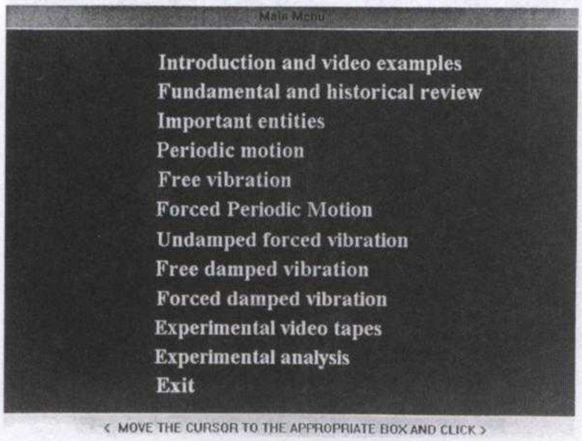

Fig. A1. Main menu for the package.

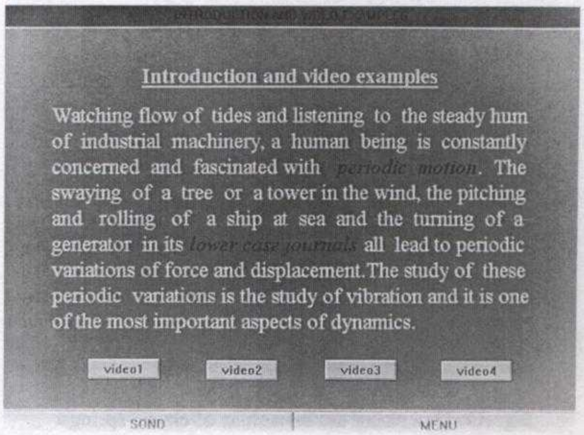

Fig. A2. Introduction to the package and videos.

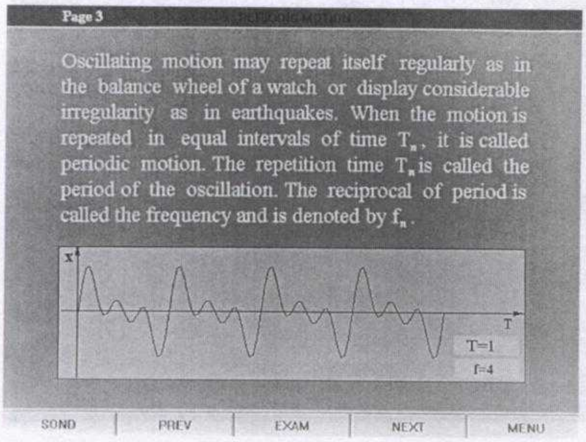

Fig. A3. The frame describing the period.

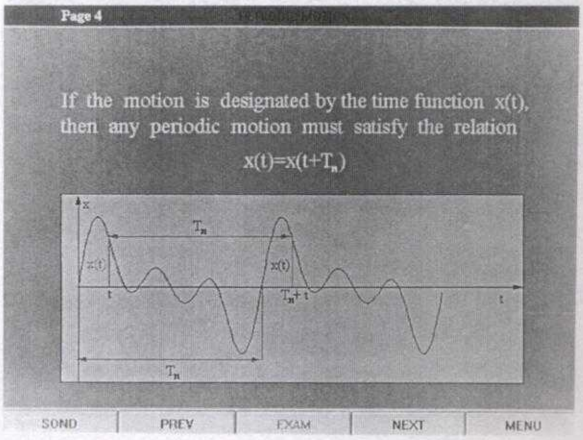

Fig. A4. The frame describing periodic motion.

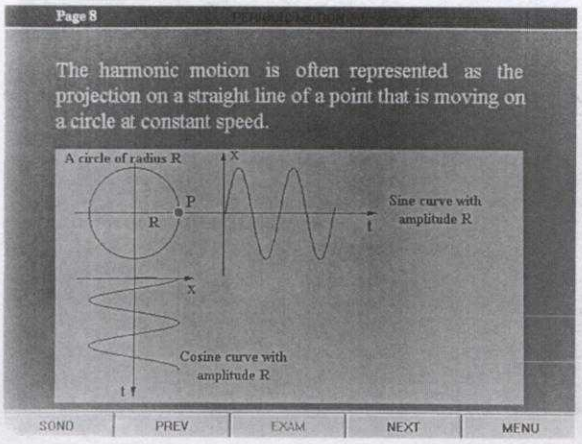

Fig. A5. The frame describing sine and cosine.

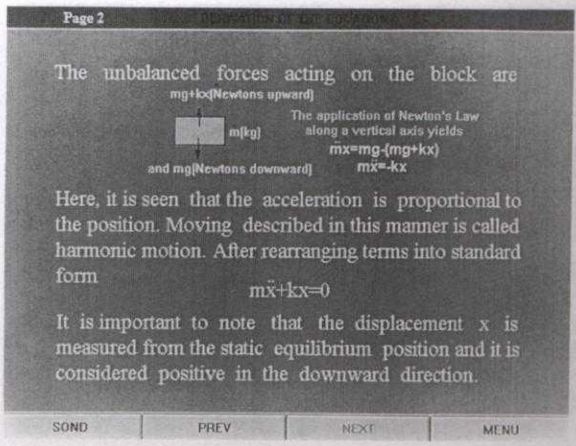

Fig. A6. Derivation of the equation of the motion.

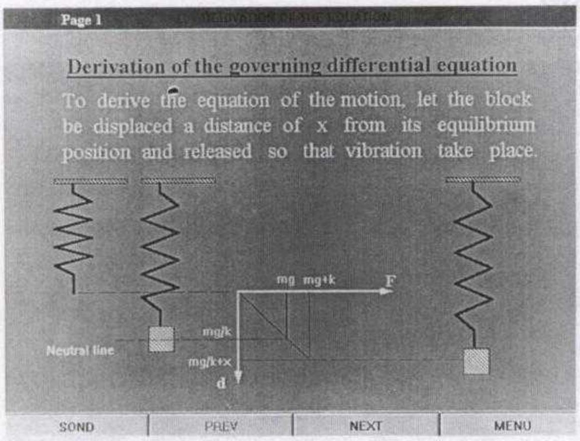

Fig. A7. Describing the behaviour of elastic springs.

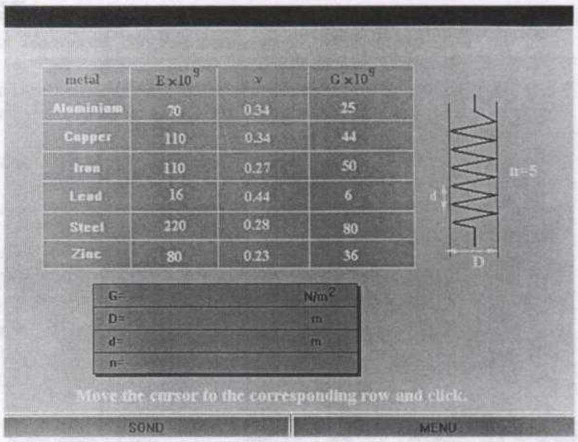

Fig. A8. Sample of the table for calculating *K*.

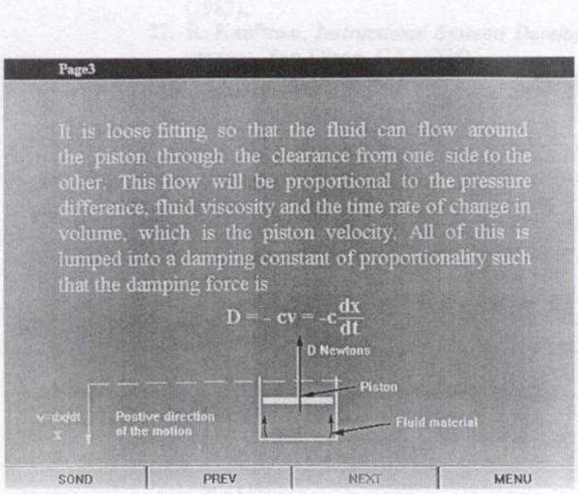

Fig. A9. Describing the nature of the damping force.

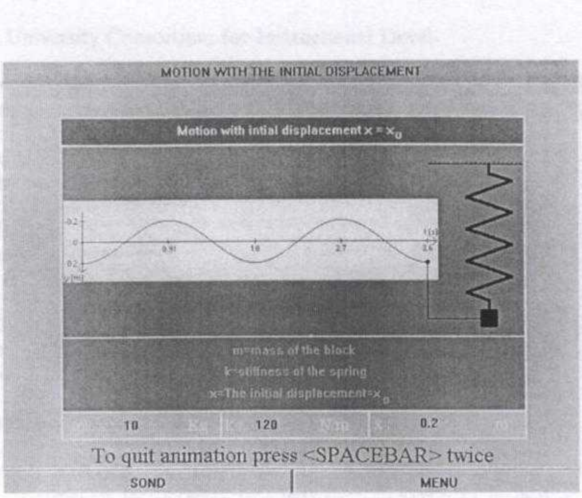

Fig. A10. Free vibration with x_0.

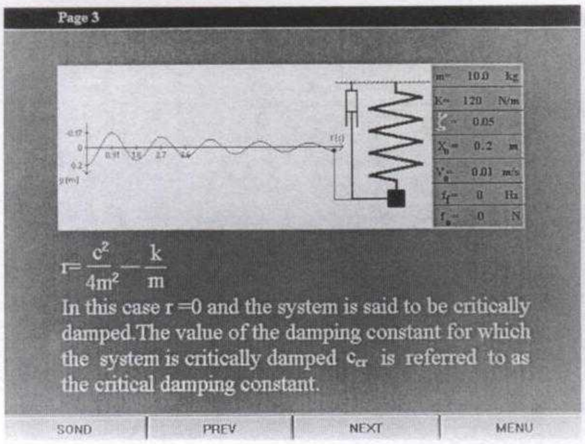

Fig. A11. Illustration of the free damped vibration.

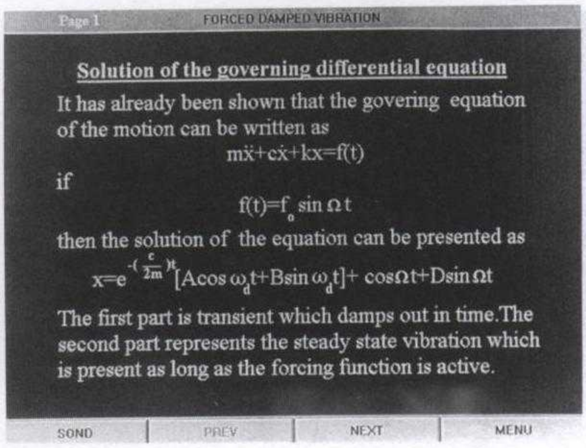

Fig. A12. Illustration of the forced damped vibration.

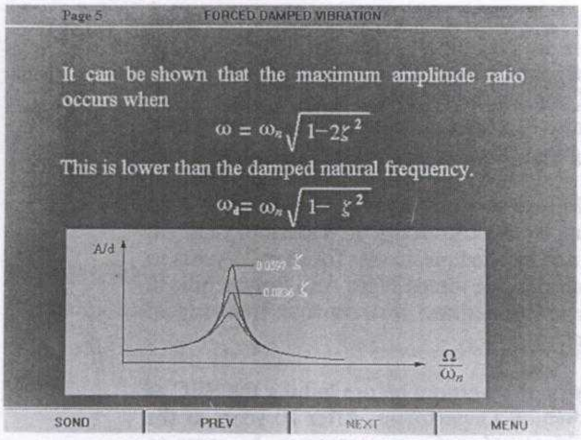

Fig. A13. Variation of *A*/*d* vs. frequency ratio.

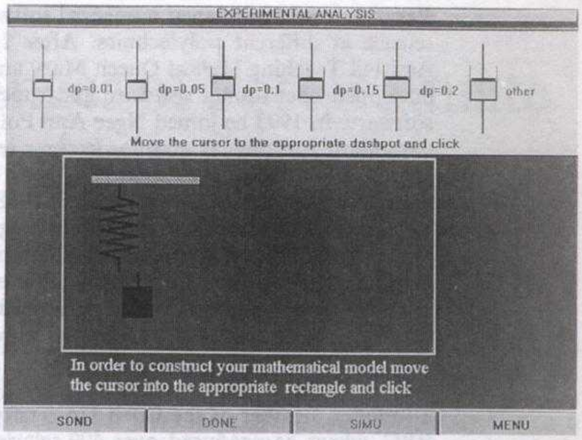

Fig. A14. Construction process for experimentation.

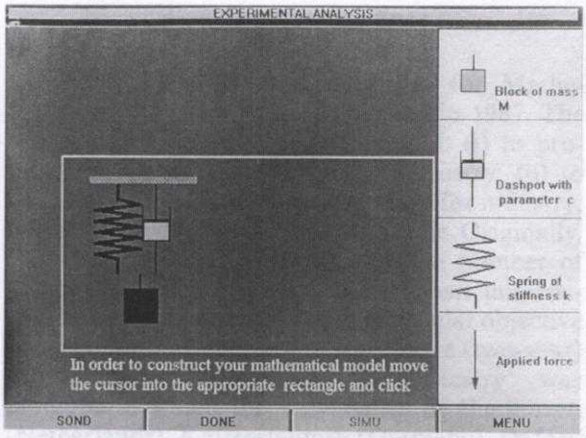

Fig. A15. Construction process for experimentation.

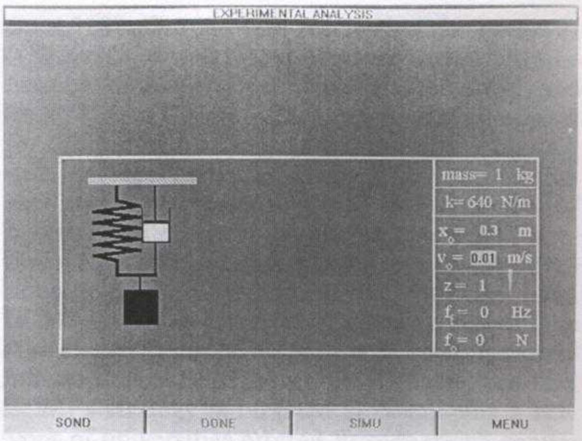

Fig. A16. Construction process for experimentation.

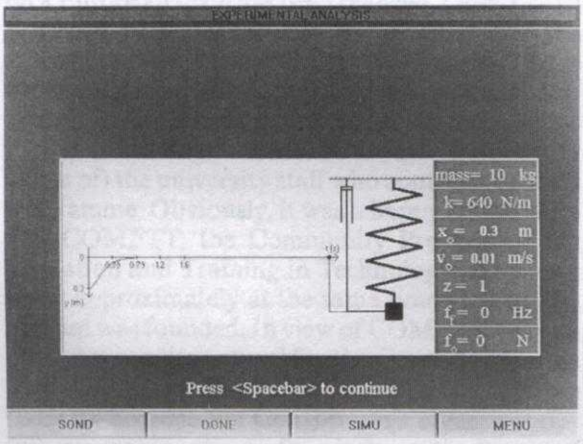

Fig. A17. Displaying a typical response.

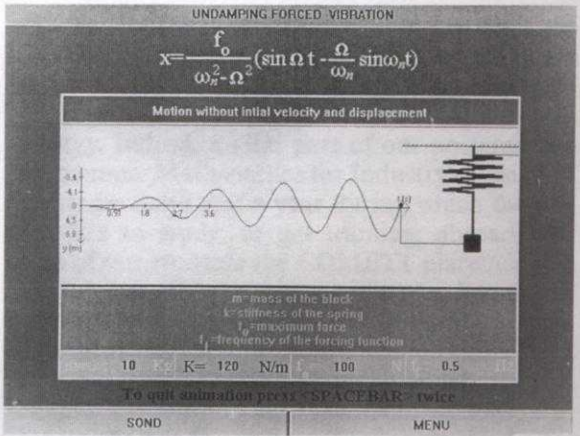

Fig. A18. Displaying a typical response.

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