Int. J. Engng Ed. Vol. 12, No. 6, p. 444–456, 1996
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Lecturing with Multimedia Tools*

M. J. DAVIDSON
Department of Civil and Structural Engineering, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

This paper describes the enhancement of a lecturing environment through the development of a set of multimedia software tools. The course to which this approach is being applied is a first course in fluid mechanics for Civil Engineering students. The motivation for introducing multimedia into the lecture theatre was driven by a set of educational initiatives, which are the result of an ongoing reflective process aimed at continuously improving the quality of the course. The key components of the resulting multimedia software are described, as is the system employed to monitor the impact of changes made to the course. Student responses and performance in the course indicate that the implementation of these educational initiatives, through the multimedia enhanced lecturing environment, has been effective. The future plans for the development of these software tools and corresponding changes to the way the course will be implemented are outlined. Finally, the role that small-scale developments of this nature will play in bringing about the more widespread application of multimedia in the tertiary education sector education is discussed.

INTRODUCTION

THE APPLICATION of multimedia technology in engineering education in Hong Kong is relatively rare. To take my own institution as an example, the Hong Kong University of Science and Technology (HKUST) was founded in 1991 and it was designed to provide a technologically advanced environment for academics and students alike. However, to date there has been a general reluctance of faculty to make use of available multimedia technology to enhance the learning experiences of their students. This is not surprising given the considerable investment of time required to put together multimedia tools and the lack of professional rewards associated with this activity.

However, the addition of multimedia components to a traditional teaching or learning environment has obvious advantages. Animations, for example, can be employed to help explain difficult concepts. Video segments bring real world scenarios and laboratory demonstrations to the students at essential points in the learning process. Simulations enable students to explore the concepts they are learning and to develop an intuition for them. Multimedia software provides a system in which these additional tools can be integrated into a single teaching/learning environment. There are also advantages in terms of the ease in which the multimedia tools can be modified and upgraded as the need arises. This in turn encourages faculty to make modifications that they feel will improve the learning environment for their students.

If multimedia is to be considered then it should be as part of an ongoing improvement process in an academic's teaching activities. It cannot be seen as a one-off solution to all of his or her teaching woes. The academic should have a well-established process of teaching improvement before consideration is given to multimedia technology. In many cases there is much that can be done to improve teaching before the introduction of such technology is considered. An improvement process would normally involve monitoring and reflection to determine where improvements can be made. Actions are then taken to improve the teaching/learning environment and the responses of students are monitored to determine how effective those changes have been. The process then begins again with further reflection. This is referred to as an 'action research' approach to teaching improvement (for example [1]). The monitoring phase will normally consist of some formal (surveys for example) and informal (discussions with students and personal reflections) components.

It is often stated that a team of experts are required to development effective multimedia tools (for example [2]). The experts include instructional designers, graphic designers, software programmers, animators and video experts. The academic is then relegated to the role of content expert. For certain activities the team of experts model is appropriate, for example, in the development of sophisticated self-access systems. The development of such systems is beyond the resources of most academics.

However, there is no need for a team of experts to enhance an existing set of lecture notes, laboratories and tutorials with multimedia tools. To achieve this type of technically enhanced teaching (TET) with currently available software and hardware tools is not a formidable task. In the future there will be an increasing tendency for academics to pick up a good multimedia authoring system,

* Accepted 22 November 1996.

after planning the content and layout of a lecture, rather than pen and paper or overhead transparencies.

Discouragement abounds for faculty involved in such activities, with it often being suggested that faculty developing their own multimedia teaching/learning environments is a waste of time. In the context of TET, this is equivalent to suggesting that faculty are unable to develop lectures, laboratories and tutorials by themselves and that they require a team of experts to do so. If this is indeed the case then our whole approach to the preparation of teaching materials needs to be changed.

In this paper I describe a relatively small-scale approach to the introduction of multimedia tools for teaching purposes. The approach involves taking the educational systems that have served us well in the past and enhancing them through the use of multimedia tools. There is no attempt to completely overhaul or replace existing systems, but the aim is to improve them with the incorporation of multimedia components. With this approach faculty are able to develop their own effective multimedia tools with a limited investment of time. Another important characteristic of such tools is that the faculty retains complete control over the software tools. The tools have been developed to suit the individual's teaching style and changes and modifications can be made with ease. If a team of experts is required every time the academic wishes to modify the software, it is of limited value and in fact it discourages an 'action research' approach to teaching improvement.

As an example of this approach I will discuss the enhancement of a set of lecture notes for an introductory course in fluid mechanics for Civil Engineering students. The major reference for this course is [3]. The course covers the topics of fluid properties, statics, kinematics and an introduction to dynamics. The course is taught over a period of 14 weeks. In each week there are three hours of lectures, taught in two 1.5-hour time slots. In addition each student is required to complete five, 2-hour laboratory sessions during the semester. The course was taught in its present form for the first time in the spring semester of 1995, without the multimedia, and in the spring of 1996 the same course was taught with the multimedia lectures notes.

In enhancing lecture notes the multimedia components of primary concern are text, graphics, animations/simulations, still photographs and video. Sound is of secondary importance, because the lecturer provides the voice for the images presented in the software.

MOTIVATION

The introduction of multimedia tools into the lecture notes of the introductory fluid mechanics course was part of an ongoing process of improvements to the course, which began the first time it was taught in 1992. The course was originally part of a larger course, but in order to allow students more time to absorb the material the original course was split in two and spread over two semesters. In addition I have placed an increasing emphasis on situations which strongly encourage students to directly communicate with the lecturer. This is particularly important when teaching students for whom English is a second language, because they are often reluctant to practice this language with a teacher whose first language is English. This involved placing a greater emphasis on tutorials and designing these tutorials and the laboratories to encourage communication with all of the students. These changes have seen a steady improvement in the students perceptions of the course as gauged by the University's standard evaluations.

One of the major reasons for encouraging the students to communicate directly with the lecturer is that modifications and adjustments can be made to lectures as the course progresses, based on the feedback received. Another important reason is that effectiveness of changes can be monitored and further changes can be determined based on the students' own perceptions of the course.

In the past I had noted three issues which I felt needed to be dealt with in the course:

Reorganisation

Students taking the course have a tendency to try to memorise all of the notes given to them. This in turn made them feel that the course was extremely difficult and the workload very high. Although the course is difficult for Civil Engineering students (largely because of the significant mathematical component), if the students are able to isolate the key ideas (or concepts) in each section and then view the remaining material as an application of those concepts, the course is more manageable. It is important that they commit to memory the key ideas, the assumptions behind them and their application. The derivations however should be understood, but not necessarily memorised. Although I had attempted to isolate these concepts within my overhead lecture notes by highlighting them, the students were still finding it difficult to isolate essential ideas in the notes. It is important therefore that I provide more guidance for them in this area. This would involve reorganising my lecture notes, so that each section was divided into subsections which isolate the key concepts, derivations and applications. In fluid statics for example the basic laws governing the spatial variation of pressure in a stagnant fluid become the key concepts, the derivations of these ideas are placed in a separate section. In the applications section topics such as manometry, buoyancy and forces on submerged surfaces are covered. This in effect provides an ongoing study guide for students. It enables them to review the key ideas in each section as we move through the course. This is important because the lectures rapidly build on understanding gained in earlier parts of the course. In addition students were finding it difficult to keep track of the location of a particular lecture in the overall structure of the course. In this situation students rapidly lose interest, because they have little idea of how the material being taught fits into the topic as a whole. A more effective overview structure was required which reminds students in a visual way where the current piece of material stands in the overall structure of the course and in effect gives them a constant course location reference.

Localisation
A second problem was a general lack of interest in the area of Water Resources Engineering for which the course being discussed is the introductory course. Students generally felt that the best career opportunities are in the Structural and Geotechnical Engineering areas. This is largely because of the extent of construction that is constantly taking place in Hong Kong and the high frequency of life threatening landslides during the wet season, which receives considerable media coverage. This lack of interest results in poorly motivated students. In reality Water Resources Engineering is of major importance to Hong Kong and China and clearly a greater emphasis should be placed on portraying this to the students during the course. Perhaps the most effective way to do this is through the introduction of more local examples. These include general local examples with the aim of explaining how the material fits into the world around them and detailed examples in which the principles are applied to solve or better understand a local phenomenon. It is hoped that this approach will generate more interest in the area and enable students to better understand the important role that Water Resources Engineering will play in China's and Hong Kong's futures. Some of these examples are engineering related, but others are not. The important factor is that they are local examples to which the principles can be applied. In developing a deeper understanding of the topic, the students should apply the principles to the world around them. Unfortunately, they have a tendency to isolate education from real life.

Dynamic demonstrations
Another important weakness in the students was their inability to intuitively imagine the dynamics of examples and problems. My lectures in the past have been largely based on static diagrams. In viewing these diagrams I automatically add considerable value to them in terms of the motion of the fluid. However the value added is based on more than 10 years of experience in the area. The students have no such experience and in most cases have never seen (or noticed) the phenomena being discussed before. Extensive verbal descriptions of the dynamics of the problem being discussed (which are only effective for those with good language skills) can be augmented by making these static diagrams dynamic through the use of animations and videos. This enables me to show the students the value that I add to the static diagrams. Therefore, the students learn how to imagine and generate mental models of problems based on the concepts they have learnt. Developing this type of physical intuition is very important, because it is often needed to begin solving problems and it provides a realism check on computed solutions.

Although it would be possible to achieve the first goal using traditional delivery systems, the frequent use of video and slides is impractical because of the time involved and animated dynamic demonstrations are really only feasible using a computer-aided system. The use of multimedia allows for the incorporation of each of these changes into a single integrated set of lecture notes. In these notes videos, photographs, animations and other multimedia components are available at the click of a button.

KEY ELEMENTS OF THE SOFTWARE

The hardware platform for the development of the software was provided by a Pentium 90 MHz computer with 16 MBytes RAM, a 1 GByte hard disk, a Sound Blaster Card (Creative SB-16) and a Video Blaster Card (Creative RT300). In addition a still camera and video camera where used for gathering images. A scanning facility must also be available for the digitisation of still images. The software platform utilised was Multimedia Toolbook 3.0. This was chosen because of the ease in which sophisticated standalone applications can be developed.

Overall my approach in developing the multimedia lecture notes was to keep the pages as simple as possible and to avoid using gimmicks. The multimedia tools are employed where they have educational value. The lecture notes contain several key elements which were designed to address in a direct or an indirect manner the issues raised above. These key elements are described below.

Software structure
A colour-referenced layered structure has been developed which provides the students with a persistent reminder of their present location in the overall course structure. There are in general three layers and a schematic diagram of the structure is shown in Fig. 1. The entry layer has a green background and it provides an overview of the whole course indicating the five sections that will be dealt with, that is, introduction, fluid properties, fluid statics, fluid kinematics and fluid dynamics. From this page the lecturer moves down to the second layer which has a blue background

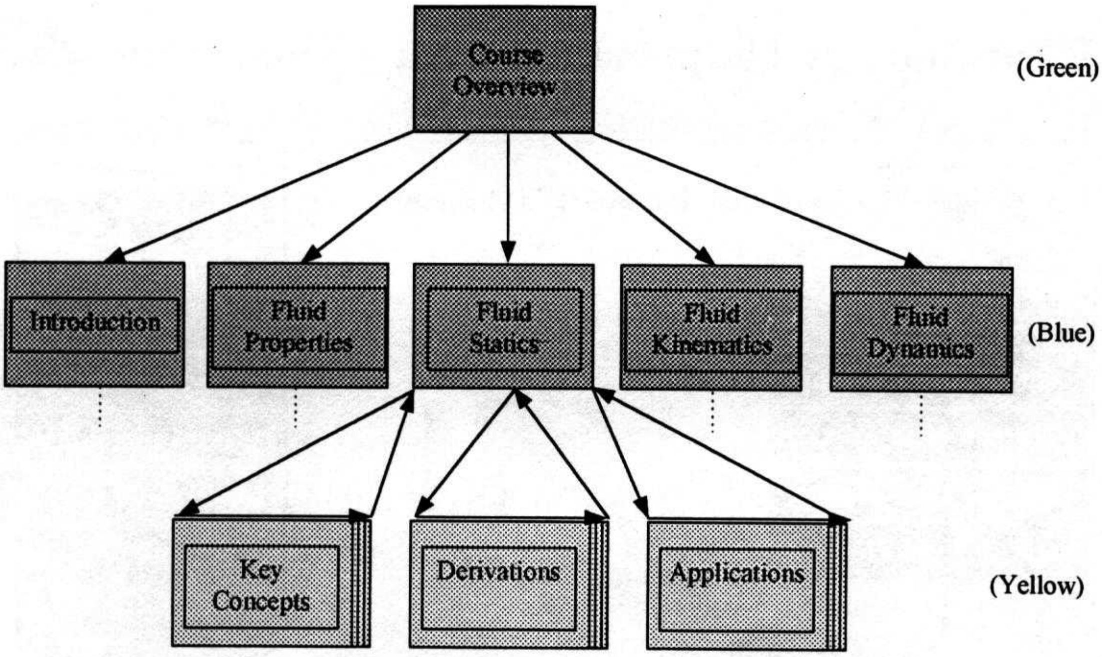

Fig. 1. A schematic diagram of the general structure of the multimedia-enhanced lecture notes.

and provides more information about the topics in each of the five major sections. At this level where possible the material is grouped into key concepts, derivations and applications. Below this level rests the lowest level (with a yellow background) which provides what could best be described as a set of multimedia-enhanced 'overheads'. These pages are stepped through sequentially and they provide the basis for the lectures. It is possible to move up from any page in this layer to the blue level.

My lectures always begin at the entry level layer and I move down and up through the layers as the lectures progress, reminding the students of where they stand in terms of the overall structure of the course. The background colours reinforce the structure of the course and the present location

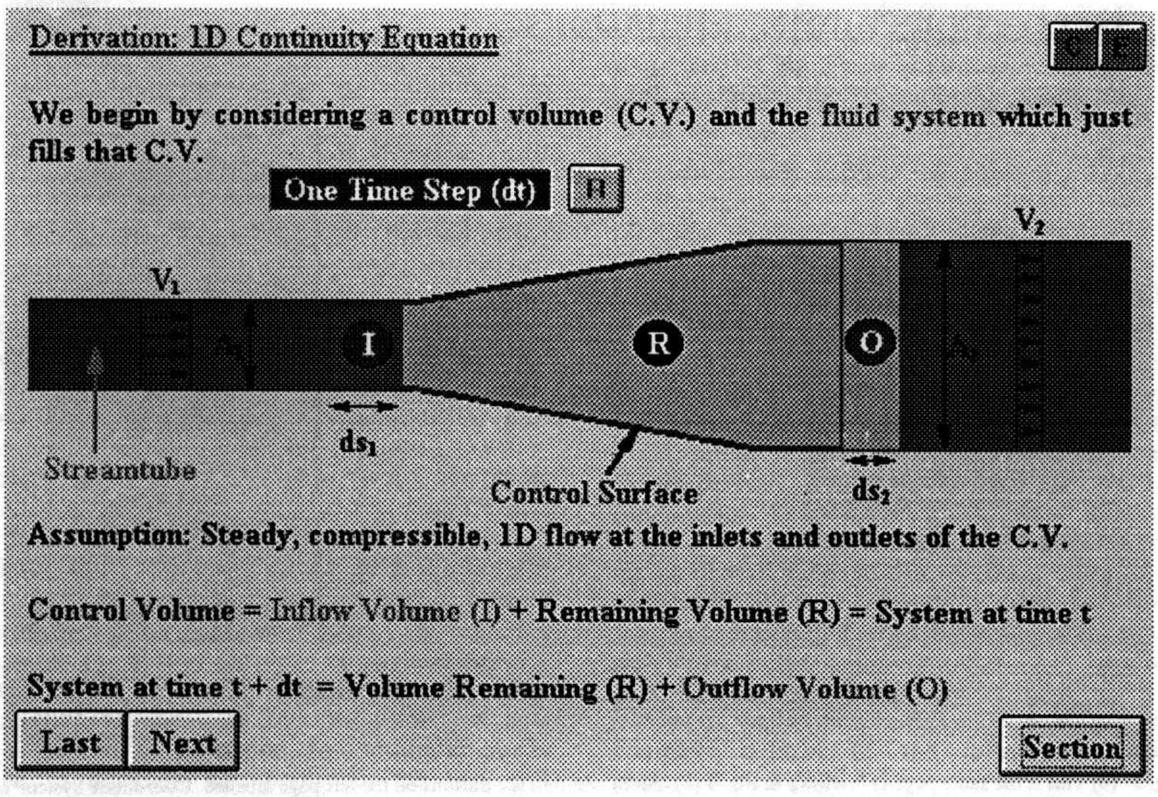

Fig. 2. An example of colour coding between text and animated objects which helps to reinforce the links between the diagram and text.

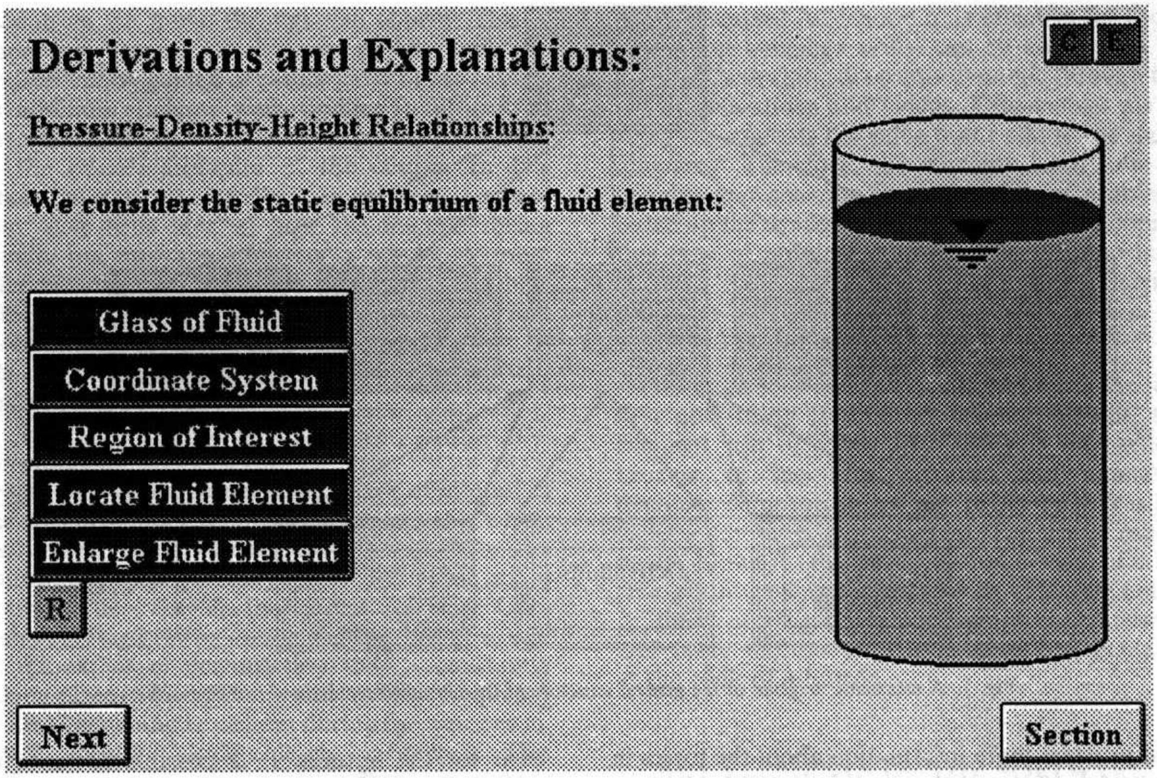

Fig. 3. (a) A page showing the initial stage of the development of a figure which forms the basis for the derivation of the fundamental principles of fluid statics. Clicking the 'Glass of Fluid' button on the left of the page has produced a glass of fluid on the right hand side of the page. The reason for starting with a glass of fluid, as opposed to the more typical general mass of fluid, is that the students can relate more easily to a glass of fluid. In fact I encourage them to give the issue some thought the next time they are drinking a glass of water.

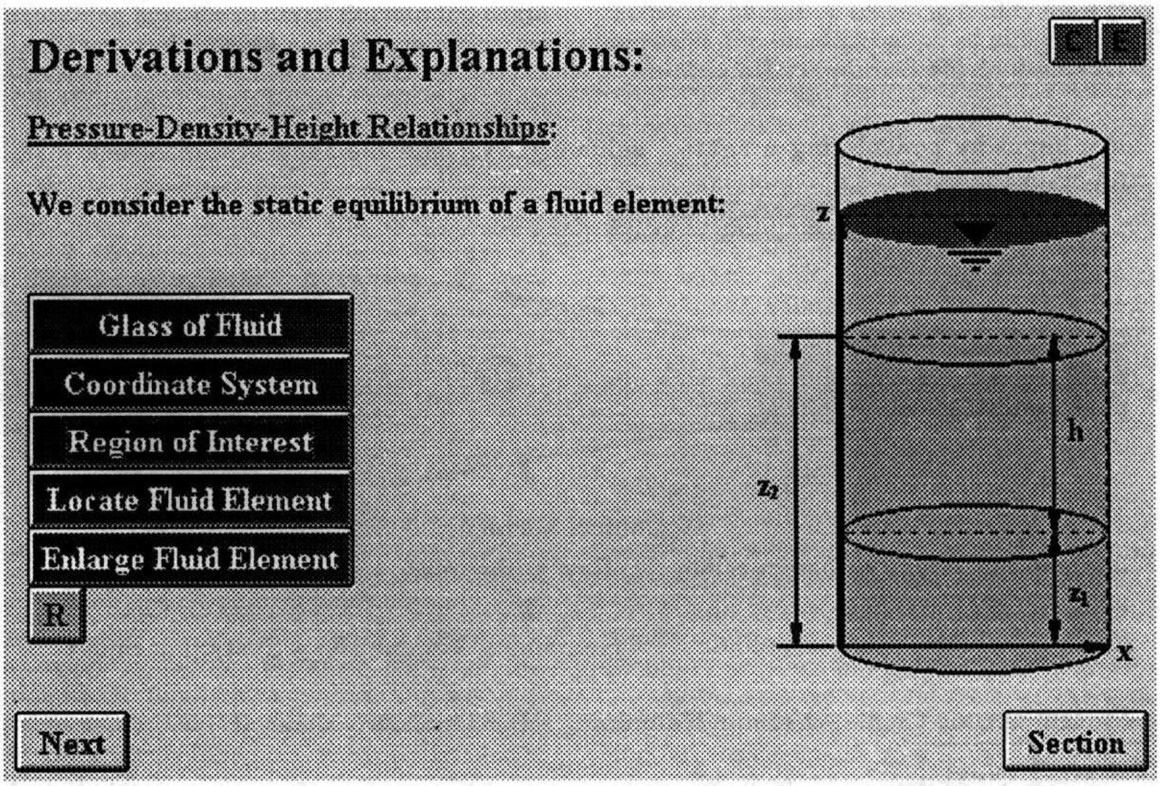

Fig. 3. (b) This is the same page as is shown in Fig. 3 (a), but in addition the buttons on the left page labelled 'Coordinate System' and 'Region of Interest' have now been clicked adding more details to the figure on the right of the page.

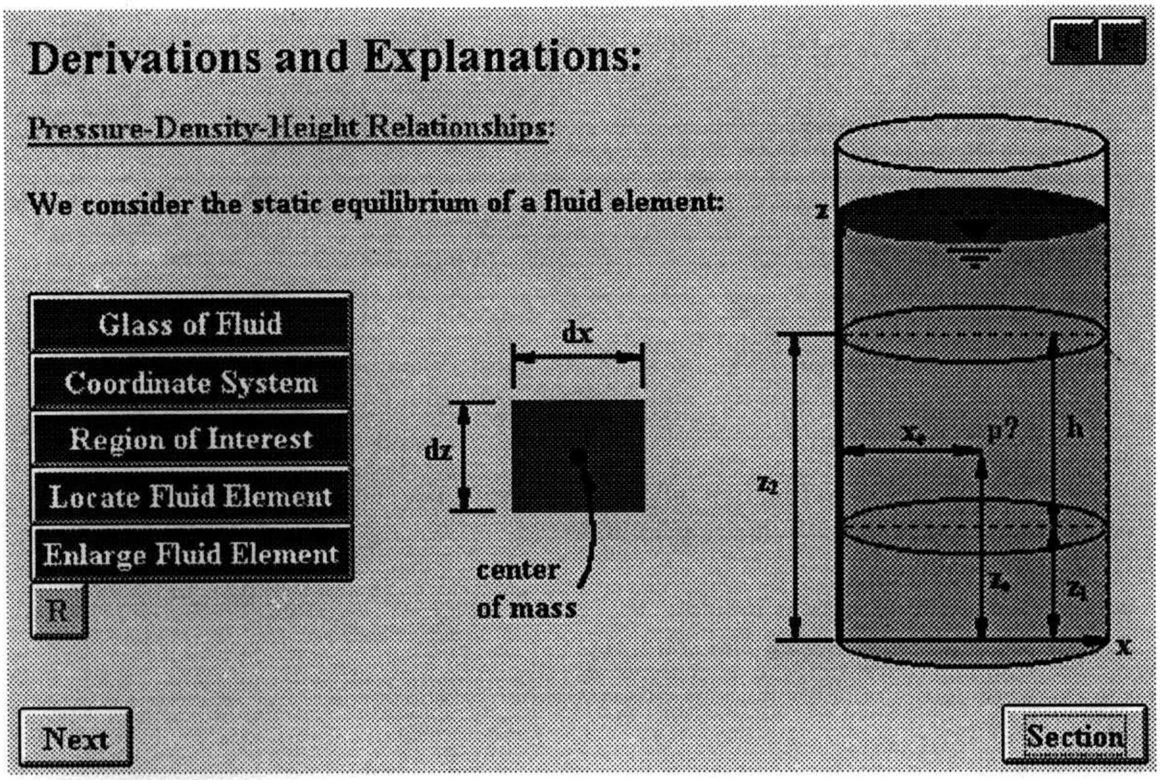

Fig. 3. (c) The diagram on the right of the page, which began forming in Fig. 3(a), is now complete. Many students find it difficult to understand the details of such a diagram without the staged construction demonstrated here.

within it. This is important particularly when students are dealing with several different courses on the same days that the lectures are given and when the material being presented is building on concepts developed earlier in the course.

Colour coding

Colour coding (or referencing) is also used on individual pages to highlight key ideas and to link text and objects. An example of this is given in Fig. 2. Here an animation shows the motion over a single time step of a fluid system, which initially fills the control volume shown. At the end of the animation a set of labels appear which are colour-linked to the text at the bottom of the page. Although difficult to see in this black and white copy of the original page, the label 'I' is the same colour as the text 'Inflow Volume (I)' and similarly the labels for 'R' and 'O' are colour-linked to the text 'Volume Remaining (R)' and 'Outflow Volume (O)'. This colour referencing reinforces the links between the text and the diagram and provides visual guidance for the students as to the relevance of the text. Visual guidance is also provided by using a consistent colour scheme throughout the software. Force vectors, for example, are always purple in colour and velocity vectors blue. This makes it easier for students to immediately identify the force and velocity vectors in a diagram or animation. In addition colour is used to highlight key points in the text and important mathematical expressions. In keeping with the concept of a consistent colour scheme these are always coloured red.

Computer-aided graphics

Computer-aided graphics refers to the structured development of complex diagrams. A complex diagram is constructed in much the same way as a lecturer would on a whiteboard. However, there are three major advantages in using a computer-aided system:

(1) the time required to construct the diagram during the lecture is significantly reduced;
(2) the diagram is always of high quality;
(3) the diagram is repeatable, that is, one can easily erase the diagram and reconstruct it for the students without any significant delays.

An example of computer-aided graphics is shown in Figs 3 (a), (b) and (c). These figures represent the same page at different stages in the development of a diagram, which forms the basis for the derivation of the fundamental principles of fluid statics. When the set of buttons on the left of the page are clicked the diagram gradually appears on the right of the page. The button labelled 'R' (at the bottom of the set of buttons) resets the figure, that is, it erases it. A reset button appears alongside all animations and computer-aided graphics, so that these can be repeated as many times as needed by the lecturer. In this way the lecturer is in complete control of the information being presented on a page.

Another form of computer-aided graphics is to

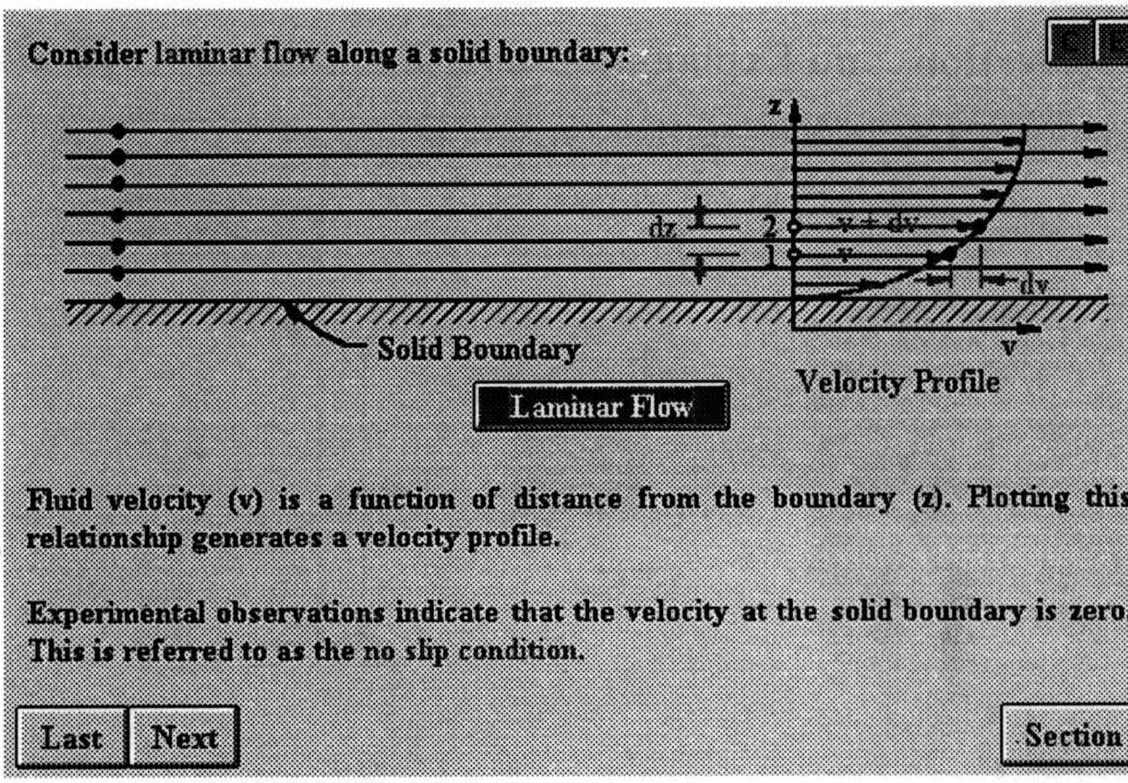

Fig. 4. A page from the software in which an animation is employed to assist the students in visualising laminar flow near a solid boundary.

copy the same basic diagram onto a series of pages and to modify the diagram on the subsequent pages as the students' understanding of the ideas being presented develops. This approach is particularly useful when solving problems, because the development of the student's understanding of the problem is represented graphically. The repeated use of a basic diagram is relatively easy in a computer-generated set of lecture notes, because the figure can easily be copied from one page to another. Therefore it is possible to make more extensive use of graphics in this system, than would be practical in more traditional delivery systems.

Computer-aided animations

Animations play an important role in demonstrating the dynamics of the fluid behaviour being discussed in a lecture. This is particularly important in situations where the students have had no previous exposure to the situation being presented. A relatively simple example is shown in Fig. 4. On this page laminar flow of a fluid across a solid boundary is being discussed. Here the concepts of a velocity profile and the no-slip condition at the boundary are introduced. In order to reinforce these concepts the static diagram can be brought to life by clicking the laminar flow button at the bottom of the diagram. The particles on the left of the diagram then move with different velocities which are indicative of the velocity profile.

This type of animation shows the students how to run a mental model of the fluid motion, based on the information they are given in a static diagram. Mental models are important because they enable the student to picture the fluid flow in their own mind and this can provide valuable insight into the problems being dealt with. They also allow the students to compare their mathematical solutions with their own physical intuition, which provides an important check on these solutions and may lead to improved intuition for the problem.

Laboratory videos

Although the students are required to complete five laboratory sessions as part of the course, during this time they are only able to conduct a small number of experiments. There are many demonstrations and experiments, which if introduced at the appropriate time, can be invaluable in helping students to grasp the ideas being presented during the lectures. Numerous laboratory demonstrations have been recorded on video, digitized and included into the multimedia lecture notes at appropriate locations. These videos are available at the touch of a button and they generally last for less than a minute. An example of two such videos is shown in Fig. 5. Here the students are being introduced to laminar and turbulent flow. The videos provide a visual comparison of the orderly motion of laminar flow, with the random and chaotic turbulent motion in a jet. The video of turbulent motion also helps the students to link turbulent flow to many situations that they observe in real life, for example, the diesel exhausts

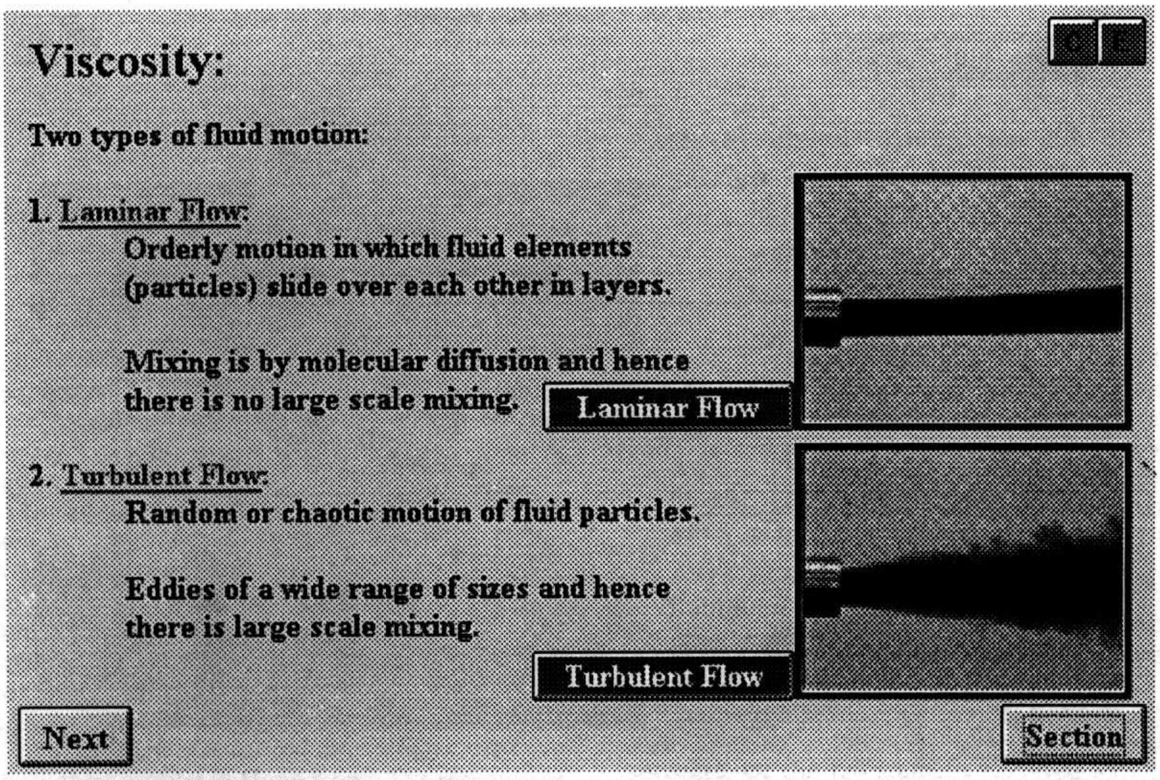

Fig. 5. On the page shown, video sequences of laboratory experiments provide visual confirmation of the differences between laminar and turbulent motion.

from taxis and buses in Hong Kong. These then act as a reminder of the material they are learning in the course and provide motivation for the students to learn more about the phenomena.

In addition video sequences and still photographs of the experiments that the students conduct in their laboratories are also integrated into the lecture notes. In this way the students have a clear indication of the relevance of each experiment to the material being taught in the lecture theatre.

Field videos

Field videos are employed to bring real-life local scenarios into the course at appropriate places. These can take the form of recorded news items or personal recordings with a camcorder. The quality of the latter, although not professional, is sufficient for the students to make the necessary connections and hence provide the motivation to understand the material being taught. At times the non-professional nature of the videos has the advantage of making the course more personal for the students. The use of video in this way enables us to visit many different locations and events in Hong Kong without leaving the lecture theatre. Where appropriate international video items are also made use of. Figure 6 shows how a video sequence can be added to bring realism to the material being taught. Initially an animation is used to show how a pontoon with a poorly distributed load of containers can become unstable and turn over, dropping the containers into the surrounding sea. A click on the reality button then overlays a video on the top of this animation. The video sequence shows a news clip of a similar scenario in which a container ship in Hong Kong's Harbour turned over.

IMPLEMENTATION

The multimedia lecture notes were implemented for the first time in spring semester of 1996. A copy of the original handwritten notes was given to the students at the beginning of the semester. A hardcopy of the multimedia notes will be provided in future, but at the time of the first implementation these were not available. The pages of the software are projected onto a large screen in the lecture theatre and the lectures are conducted in a similar way to those given with overhead transparencies.

The multimedia enhanced lecture notes are an important lecturing tool, but other more traditional methods are still required to emphasize key points and provide additional explanations. For example, I frequently break from the multimedia lecturing system and use the whiteboard to work through and discuss points with the students. Without this the students become restless after looking at a computer-generated screen for extended periods of time. These changes in the delivery system during a lecture, help the students to remain attentive.

It is interesting to note that I am yet to find a well-designed lecture theatre for multmedia

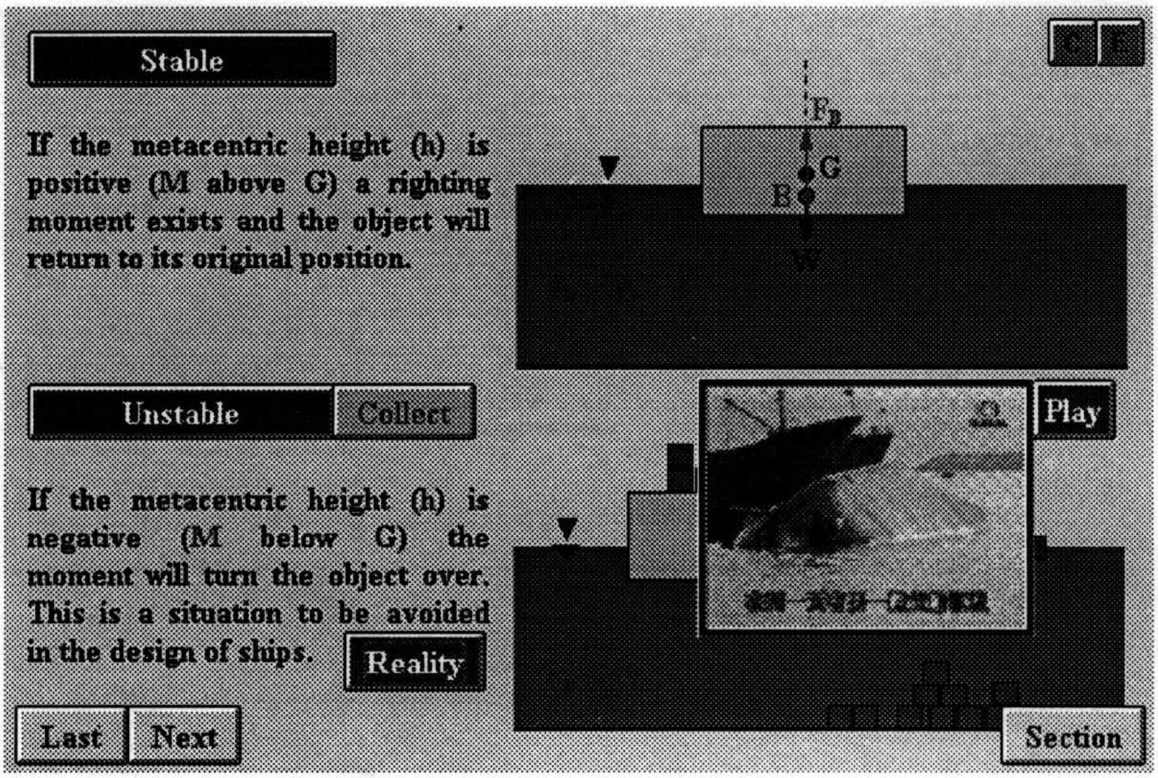

Fig. 6. An overlay of a video sequence of a news clip provides a realistic setting for a discussion of the stability of floating bodies.

lectures. Those at UST and those I have visited at other institutions assume that if one is making a multimedia presentation, there is no need to use a whiteboard, thus the projection screens inevitably hide the whiteboards. It is in fact very useful to have a display on the screen and to work from this on the whiteboard, in a side-by-side fashion. In addition these theatres require that you dim the lights to effectively utilise the projection system. This creates problems with dual use of the whiteboard and projection system, and students complain that the low light levels make it difficult for them to concentrate and make their own notes.

Towards the end of the semester after frequent requests from the students the software was provided on a self-access basis for them. Although the software was not designed for self-access purposes, the students found it easy to use because of their exposure to it during the lectures. The software was provided for them on a small number of computers in the Water Resources Teaching laboratory.

STUDENT RESPONSES

In the past I have monitored the impact of changes made to courses through informal discussions with the students, my own perceptions of the impact and the standard university course survey. This survey covers topics such as course organisation, difficulty, workload and instructor preparation, enthusiasm, interest generation, attitudes towards the students and so on. The questions in this survey are very general, but they do give an overall impression of the students' response to the course and the instructor.

In making a major change such as introducing multimedia lecture notes I felt it was necessary to gather additional more specific information about the impact of these changes. Bearing in mind that the students have a significant workload and that only a small portion of the contact time could be dedicated to this activity (because of the need to cover the course material), two relatively simple, but informative, data gathering techniques were selected. These involved conducting two additional surveys and a conceptual quiz. The additional surveys and quiz were first conducted when the course was taught in the spring of 1995 without the multimedia lecturing tools to 93 students. These were then repeated again in the spring of 1996 after the introduction of multimedia, when the course was taught to 132 students. The increase in enrolment is due to the fact that the university is still in the startup phase of its development.

Surveys

A diagnostic survey was created for the course and it was based on the Study Process Questionnaire (SPQ) which was developed [4] to evaluate student study approaches. However, in the diagnostic survey the questions were designed to be specific to the fluid mechanics course. Questions focused on a number of issues ranging from

Table 1. Student responses with respect to the major software components in terms of generating interest.

Component	Ineffective (%)	Average (%)	Effective (%)
Structure	6	37	57
Colour coding	8	22	70
Computer-aided graphics	1	9	90
Computer-aided animations	2	13	85
Laboratory videos	11	25	64
Field videos	9	26	65

learning habits, to the perceived role of fluid mechanics in their future careers. In the spring of 1996 additional questions where added to this survey which focused on the multimedia lecturing tools.

The survey confirmed concerns I had about the students' approach to the course. The responses from both groups indicated that students recognised the importance of fluid mechanics to their future careers, but they are motivated to learn the material by necessity rather than interest. This is consistent with the fact that most students in the programme select Civil Engineering because of the Geotechnical and Structural disciplines which have the highest profiles in Hong Kong. The response of the students also indicated considerable concern about grades and a tendency to study material by rote. More positively, they recognised the importance of isolating essential concepts in the course.

Students were also asked to rank the importance of lectures, lecture notes, tutorials, lecturer help, peer help, textbooks and laboratories to their learning. Both groups of students indicated that the lectures and lecture notes were the most important tools in aiding their learning. Although this is positive in the sense that it shows the effectiveness of these tools, it also indicates a high degree of dependency on the lectures in their learning. This type of information provides useful background when considering further changes to the course and these are discussed later.

Direct feedback on the multimedia lectures was obtained through a set of questions added to the survey conducted in the spring of 1996. Of the 124 students surveyed, 75% of the students considered the multimedia lectures to be effective in enhancing the lecturing environment, whereas 20% felt they made little difference and 5% thought the multimedia lectures were ineffective in this regard.

Students were also asked about the effectiveness of the different key components of the software in making the presentations more interesting and in making the concepts clearer when compared to traditional lecturing techniques. The responses to these questions are given in Tables 1 and 2. The students obviously feel that all the tools help to enhance the lectures, but interestingly it is the computer-aided graphics and animations that they feel have the most impact in terms of interest generation and clarification of the concepts.

Finally, students were given the opportunity to make written comments about the multimedia software. Of the 124 students surveyed 85% took the opportunity to comment on the software and the course. The tone of these comments was in most cases positive and examples of such comments include:

> 'It is very effective and useful media to lecture this subject since we often have to visualise the real case in fluid. Moreover, by using multimedia, it is more interesting and make the subject more lively. I strongly agree to use multimedia to lecture courses. I wonder if I can run this program from other computers.'

> 'Traditionally lecturers use transparency to present teaching materials. I feel that it is not tidy and it is not systematic enough when we want to look at something taught previously. On the contrary, multimedia can show the structure of the course clearly. The video is good at showing the concept clearly. On the whole it is good for teaching.'

> 'It is useful to use multimedia for lecture. The computer-aided animations help me to understand the fluid motion.'

> 'The field videos help us to relates the theories we learn with daily lives experiences; that's a good tool.'

These comments indicate that the educational

Table 2. Student responses with respect to the major software components in terms of explanation of concepts.

Component	Ineffective (%)	Average (%)	Effective (%)
Structure	9	26	65
Colour coding	5	32	63
Computer-aided graphics	2	11	87
Computer-aided animations	2	19	79
Laboratory videos	8	33	59
Field videos	10	31	59

initiatives built into the software are effective. Unfavourable comments generally focused on problems with the projection system and lecture theatre environment. These included problems with the focus and colour definition of the projected image (13%). In addition some concern was expressed about the dim lighting required for the projection system, which made it more difficult for the students to concentrate (10%).

The second survey conducted was the standard SPQ survey. This was done to provide general information about student study habits. The most reliable indicator, from the survey, of student approaches to learning is the deep approach value [5], [6]. The survey was conducted in the 10th week of the semester in spring 1995 and the deep approach value was 42. It was conducted again in the 10th week of the spring semester in 1996 and the deep approach value was 44. These figures are consistent with those published for students studying for degrees at other institutions in Hong Kong [1].

General information about students' responses to the course and the instructor were obtained from the standard university survey. The summary results were basically unchanged from the spring of 1995 to the spring of 1996, this is despite a 45% increase in the course enrolment and a time-table shift which moved the course to a less desirable time slot from the students perspective (late afternoon as opposed to mid-morning).

Conceptual quiz

The conceptual quiz was designed to explore misunderstandings of the material taught at the beginning of the course (fluid properties and fluid statics). The quiz was given without warning several weeks after the material had been taught and it therefore gives an indication of the retention of the material. The questions are relatively simple focusing on drawing diagrams and simple mathematical formulations which demonstrate the fundamental principles.

At this stage a comment on the academic performance of the two groups of student is appropriate. The intake statistics of the two groups of students, indicate that academically they are similar. The average performance of each group is almost identical, although the distribution of the group taught in 1995 is more skewed towards weaker academic performance.

When the quiz was conducted in the spring of 1995 several significant problems were noted. Although most of the students demonstrated a reasonable understanding of the principles of fluid statics, their ability to draw free body diagrams was very poor. This knowledge should have been retained from a previous course in the curriculum. In addition they had difficulty in isolating the key ideas that were being utilised in solving the problems. This is despite the fact that the diagnostic survey results indicate that they recognise the importance of isolating such key concepts. These issues were dealt with in the software, through more extensive graphics showing the detailed construction of free body diagrams and the revision of the course structure as discussed. In the spring 1996 the performance in the quiz was generally better than in the spring of 1995. There were significant improvements in the quality and accuracy of the free body diagrams and in the ability of the students to recognise the key ideas that were being utilised in solving the problems.

However, it is important to note that this is not a direct result of the multimedia software. It is a result of the initiatives built into the multimedia software. The multimedia is the medium I have chosen for expressing those initiatives. The same improvements could have been achieved through a different set of initiatives designed for other media. However, multimedia does provide a convenient environment for making such changes.

PERSONAL REFLECTIONS

In the previous two semesters I had taught classes of 90 students in fluid mechanics and hydraulics. I found it more enjoyable teaching 132 students with the multimedia lecture notes than teaching 90 students without them. One reason for this is that students have a better appreciation of where they are in the overall structure of the course and hence the relevance of any given lecture to the course as a whole.

Another reason is that students appear to find the lectures more interesting and this is largely because of the graphics, animations and videos. Therefore, it is not necessary to spend as much time and effort on actions designed to keep the students' attention. However, it is important to combine different delivery techniques during the lectures. This has been discussed.

In addition, fewer explanations of the difficult concepts are required and this is because of the animations and computer-aided graphics. With these tools I am able to demonstrate fluid flow situations which are difficult to explain to students (particularly in their second language). Concepts such as the relationship between a control volume and a fluid system have in the past given students some difficulty. With the animated diagrams they are able to grasp the basic idea quickly and then move on to ask more challenging questions; for example, many attempt to extend the ideas presented to them in a plane to three-dimensional space. In general the students seemed to have a better understanding of the material during the lectures and they ask more intelligent questions more frequently.

CONCLUSIONS AND FUTURE DIRECTIONS

The development of a set of multimedia-enhanced lecture notes has been described. The motivation for introducing multimedia into the lectures is based on three educational initiatives. These involve:

(1) changing the course structure to further highlight essential ideas in the course and to provide a simplified structure for the course material;
(2) placing a greater emphasis on local examples with the aim of improving student motivation;
(3) introducing dynamic demonstrations with the aim of helping students to develop physical intuition for the fluid motion.

A multimedia delivery system was selected because it provides an environment into which all three initiatives can be incorporated. In the software these initiatives take the form of a three-layered lecture note structure with colour referencing, computer-aided graphics and animations, laboratory and field videos.

The software has been implemented successfully. Survey results indicate that 75% of the students felt that the multimedia tools enhanced the lecturing environment. The survey results also show that the students feel that the computer aided graphics and computer aided animations are most beneficial to them in terms of making the course more interesting and in clarifying the concepts.

Comparisons of results from the standard University survey indicate that the overall quality of the course (taught with the multimedia lecture notes) was similar to that taught in the previous year, from the students perspective, despite an increase of 45% in class size and a less desirable timetable for the lectures. In addition I observed that it was more enjoyable teaching a class of 132 students with the multimedia lecture notes, than it was teaching a class of 90 students without the enhanced lecturing environment. I also observed that the students were reaching a basic level of understanding more quickly and focusing on adding complexity to these basic ideas.

Similar comparisons of student performance in a conceptual quiz revealed improvements in the students' ability to draw free body diagrams and to isolate the key ideas that they were utilizing in solving problems. These were two issues specifically targeted in the multimedia lecture notes. They are therefore a result of the educational initiatives built into the lecture notes and not the multimedia format itself. However, the two tools employed to bring about these improvements (an extensive use of computer-aided graphics and a colour-referenced layered system) would be difficult to achieve using other delivery systems.

The introduction of multimedia-enhanced lecture notes into the first course in the Water Resources area is part of an ongoing process, which has the objective of continuously improving the quality of the course. The enhanced lecture notes now form the basis for further improvements and these can be made with relative ease. In the immediate future these improvements will involve developing a bilingual self-access version of the notes. This will enable the students to replay the lectures in a language of their choice (either Cantonese or English). Modules are also being developed to provide multimedia support for the laboratories associated with the course. In the long term the multimedia-enhanced lecture notes will provide coverage of much of the basic material on a self-access basis. The lectures, which will be conducted with smaller groups less often, will then focus on discussions of difficult concepts and problems. Two advantages of this approach are that it will encourage students to learn more independently and it will also help them to develop more effective technical communication skills.

A multimedia-enhanced lecturing environment has obvious advantages and these have been described in this paper. This project is faculty driven and the software has been developed to suit the author's teaching style. The past, present and future development and implementation of the software remains firmly in the control of the faculty. A multimedia delivery system has been chosen for the implementation of educational initiatives, because of the integrative nature of the system and the fact that changes can be made to the resulting lecture notes with relative ease. With currently available software, the development of multimedia lecture notes is not difficult, but it still requires a considerable investment of time. The most time-consuming activities are the preparation and development of graphics, animations, photographs and videos. When course-specific databases containing these materials become widely available, the time required to put together an effective multimedia set of course notes will be comparable to that for traditional delivery systems. At this point multimedia will have come of age within the traditional university environment.

Despite the hype, however, it is unlikely that the traditional approaches to higher education will change dramatically, because of the importance of human interactions in education and in the professional careers of our graduates. However, these new tools can be employed to enhance traditional teaching and learning environments and through these enhancements there will be a shift in emphasis away from large-scale one-way lecturing scenarios.

Acknowledgments—the author acknowledges the financial support of the University Grants Committee of Hong Kong through the Action Learning Project and the Teaching Development Grant. Two research assistants, Mr K. L. Chan and Mr K. W. Lai, have provided assistance in developing the software.

REFERENCES

1. D. Kember, D. and M. Kelly, *Improving the Quality of Teaching through Action Learning*, Education Development Unit, Hong Kong Polytechnic (1994).
2. M. S. Wald, *Trends in Multimedia Production and Delivery Systems,* keynote lecture, Second International Conference on Multi-Media Engineering Education, Melbourne, Australia, July (1996).
3. R. L. Street, G. Z. Watters and J. K. Vennard, *Elementary Fluid Mechanics* (7^{th} Edition), John Wiley & Sons, Inc (1996).
4. J. Biggs, *The Study Process Questionnaire (SPQ): Manual*, Australian Council for Educational Research, Hawthorn, Vic. (1987).
5. J. Biggs, *Student Approaches to Learning and Study,* Australian Council for Educational Research, Melbourne (1987).
6. D. Kember and L. Gow, Cultural specificity of approaches to study, *British Journal of Education Psychology,* **60**, 356–364 (1990).