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Computer Assisted Learning for Fluid Mechanics

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CALF

CAL – Fluid Dynamics

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START / RESUME / *full index* / *how to use the course* / *website*/ *presentation*

Computer Assisted Learning for Fluid Dynamics

K.J.Badcock and A.H.Littlejohn [1]

1 Introduction

A final year student studying engineering was heard to say

> I just want to pass the final exam.....my real learning will begin when I start work.

The general impression gained during an informal survey of other students from the same group was that this is a widely held view. This report describes the development of a computer based course designed to promote the development of high level learning.

The project Computer Assisted Learning for Fluid Dynamics (CALF)[2] was originally motivated by an observation that students often find the mathematical analysis associated with fluid dynamics difficult and demotivating. This leads to courses in fluids becoming a struggle to remember enough of the mathematical techniques to pass the final exam, meaning that higher level learning, such as developing an overall picture of the subject or gaining physical intuition, is not attained for many students.

Fluid dynamics is a very visual subject and this is not usually exploited in conventional lecture based teaching. Experimentation is a good way to visualise the subject and gain physical insight but the practicalities of catering for large numbers of students means that this is not widely used. Flow simulation is now a mature science in its own right and offers a potential solution to this problem by allowing students to *experiment* via a computer program.

The CALF project's aim was to design and implement an interactive multimedia course to enhance student learning on a lecture course in Fluid Mechanics given at the University of Glasgow for final year Aerospace and Mechanical Engineering students. The first half of the course is given on boundary layer theory and the second half on computational fluid dynamics (CFD). The multimedia course has been designed for use

- before a series of lectures to provide a concept map of the material
- during lectures to reinforce material through active learning
- after lectures by suggesting relevant sources of further information.

In this way it is hoped to improve student learning by providing the students with an overview of the subject before worrying about the details presented in the lectures and by making the learning process more interactive.

The course has been designed to be as interactive, dynamic and motivating. The course is web based to make it platform independent. This was an important consideration given the heterogeneous nature of the local computing facilities. Regular independent student evaluation was carried out and the results of these strongly guided the design of the course. These points will be discussed below.

2 Description of the Course

The subject area of boundary layer theory is particularly appropriate for this pilot project since it is largely self-contained and has a mix of modelling, physics and numerics. The CALF course is written in four discrete sections, each of which can be selected via a menu. These sections are:

- introduction to the boundary layer concept
- derivation of the boundary layer equations
- numerical solution of the boundary layer equations
- validation using a commercial package

In order to access the course, the student has to login using a password. When s/he accesses the course for the first time s/he is immediately directed to the section on *how to use the course* including a brief explanation of the navigation aids.

Navigation through the course was refined using feedback from the initial student survey. Although the philosophy is that the student should be able to jump in and out of the course at any point, there is a *recommended route* via the forward and backward arrows. These are located within the icon bar at the top of each page giving a consistent look to the screen design. Other navigation facilities include:

- an icon which returns the student to the main menu allowing quick access to the whole course
- a facility to email the tutor for assistance
- access to supplementary learning resources, such as references, historical notes and case studies.

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[2] course team: KB, AL and Alan Baldwin (Aerospace Engineering, University of Glasgow) and Robert Watt and Malcolm Robb (Department of Mechanical and Manufacturing Engineering, University of Paisley)

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These facilities mimimise the need to use the browser navigation aids.

The course is designed so that the student can cognitively build upon concepts which are already familiar. There is a strong attempt to link *real* situations with the more *abstract* ideas under investigation. Flow modelling using commercial CFD software and experiments illustrating boundary layers around bodies are two examples of the more *real* and *visual* aspects of the CALF course.

There is also an attempt to cater for different learning styles. This cannot be done easily in a lecture. Students have experienced difficulty with the mathematical analysis. Now they can choose from - and switch between - different teaching methods built into the course. One method uses a traditional abstract approach, the other uses illustrations, animated cartoons, video clips and analogies to get the message across. This approach makes the maths more accessible to the *visual thinkers*.

Each section is concluded with Self Assessment Questions based on the original aims and objectives. These SAQs are assessed by the Clyde Virtual University Assessment Engine based at Strathclyde University.

The course can accessed from a web server through a browser from any computing platform. In particular, the course has been tested on SGI and Mac clusters at Glasgow, a Hewlett Packard cluster at Paisley and various machines around the country. The course has been developed to be compatible with Netscape version 2.0 and later. Earlier versions of Netscape are not Java enabled and are unable to format all of the text properly since they cannot interpret all of the HTML features used. There are around 8 hours of course material, including pictures, illustrations, animations, video of experiments, *talking head* video and Java applets which enable students to experiment with numerical parameters. These are all woven together by a creative pedagogical design.

3 Course Design

3.1 Pedagogy

There are four broad aims underpinning the pedagogical design. These are:

- students should learn by investigation
- the course should accomodate individual learning styles
- the course should seem more relevant to the 'real world'
- the course should be stimulating and enjoyable

In order to try to engage the student in thinking about the subject a question and answer system was designed. It works like this: the student is given some information, then asked a question. The student should not worry about answering the question incorrectly, but rather should try to reason out an appropriate answer. The student then selects an answer, from a choice of three or four and is given some feedback, according to this answer. There are often opportunities to test out the validity of this answer via video, animations or interactive Java applets which allow experimentation with numerical parameters and observation of results. A similar pedagogical model of question and experimentation was developed by Jones and Smith in the 80s and has been used very successfully [2] [1].

3.2 Student Attitude Survey and Observations in Lectures (January 96)

Using the philosophy that course design should *start with the student*, a student attitude survey was undertaken to determine the preconceptions students would bring to CAL and to raise issues for the course design. A questionnaire was distributed to 4th year students after a lecture on the numerical solution of the boundary layer equations. The main information gained from this survey was

- the students had most difficulty during the lecture with the maths although there was a spread of opinion as to whether the maths was explained clearly, probably reflecting the varying abilities in the class
- the students liked the visualisation used in the lecture
- the pace of the lecture was thought to be too fast
- most students thought their computer skills were moderate
- a small number of responses (20 %) indicated strong reservations about using CAL, a similar proportion were very enthusiastic about the idea and the rest were cautiously positive
- the main reservation was the potential lack of a human element within the learning
- the ability to work at your own pace was identified as a potential advantage.

Personal interviews with students revealed that the major motivating factor for many students was the final exam. The consequence of this was that students favoured *techniques* to improve their exam performance rather than striving for meaningful learning. Students even expressed the notion that real learning would begin during the training for their first job! This highlights the urgent need for assessment procedures to be addressed to promote effective learning.

Based on the survey it was clear that some care is required to set the CAL element to a course in a proper context and to provide human back-up. However, in general the majority of students surveyed were enthusiastic about the use of CAL. It was also clear that the presentation of the maths is an important area. This exercise was of a limited scope but provided useful information for the design of the CAL package.

3.3 Course Implementation

A system for course development was established to optimise the communication between the subject authors and the developer. This involved the use of screen design sheets to describe the layout and links for each screen prior to implementation. Initially several drafts of each screen were required as the housestyle was established. The material was then implemented (see next section). The style of presentation has the following features

- the language used is informal
- text only screens are avoided with one or two pictures incorporated per screen
- a question is generally posed after a minimum of three screens.

Two main options were considered for implementing the course. The first option was commercial authoring software such as Authorware. The advantage of this approach is the ease of authoring. The disadvantage is that the course is tied to IBM compatible or Mac platforms and this was felt to be a particular problem since university computing facilities are heterogeneous. The second option is to use the World Wide Web (WWW) and this makes the course platform independent at the cost of slightly increasing the difficulty of course development.

The rate of course development is an important issue - a preconception about CAL is that a large amount of effort is required to produce a small amount of material. This has not been the experience of the current project. Significant effort was required to develop a suitable style for the course and to establish the necessary background skills. This stage took about two months. Two hours of teaching material was then developed in two weeks prior to the April student evaluation (see below). Therefore, once the methodology had been established, the production of material proceeded fairly rapidly.

Various tools are available to help with authoring in HTML (eg WebMagic from Silicon Graphics) but it has been found that writing pages directly in HTML is faster. Video and graphics can be incorporated easily but interaction (i.e. taking some user input and responding to it) requires the use of Java or the common gateway interface (CGI) which allows applications to be run on the web server. These applications (eg production of information in a graphical format based on a user specified parameter) can be called by the HTML, thus increasing the possibility of student experimentation. HTML, Java and CGI was learned from scratch in a short time and any of these can be picked-up easily by someone with programming experience.

3.4 First Student Evaluation

The first evaluation was carried out on 1st April 96 (three months after the start of the project) when about one-third of the course had been developed. In order to make the evaluation as objective and unbiased as possible, it was run independently by Sue Tickner from the TILT group at the University of Glasgow. There were three sessions with 3rd and 4th year students in Aerospace and Mechanical Engineering at Glasgow. Each session took the form:

- an introduction from the evaluator
- students had 1.5 hours to try out the course for themselves on Silicon Graphics workstations
- the students were observed throughout this period and any problems noted
- students were interviewed in a focus group session to highlight particular points
- students were asked to complete a questionnaire

To summarise, problems which were highlighted include:

1. none of the students had read how to use the course, resulting in avoidable confusion.
2. security warnings in Netscape also caused confusion when data was submitted to CGI scripts. This could easily be avoided by resetting the 'preferences' in Netscape.
3. some of the animations were too fast and students experienced difficulty in using the movieplayer software
4. although students liked the question and answer style, they wanted more varied feedback. They also wanted clearer indication of whether or not their answer had been right or wrong - a point which had been avoided by the developers in order that the students wouldn't feel as if they had to get all the questions *correct*!
5. better continuity was required between sections
6. students experienced difficulty with the mathematical section. Some said they found screens of equations demotivating, even though the maths wasn't considered (by them) to be difficult.

Despite this, the general feedback was positive. The visual aspect of the course was particularly appreciated as was the way in which theory was related to real applications and the use of commercial sofware. Some made copious notes whilst the final year students said they would use the uncompleted course as revision for their final exam.

3.5 Improvements to the Course Design

The valuable feedback gained from the first student evaluation was used as a basis for improving and further developing the CALF course. The problems highlighted in the evaluation were tackled head-on in the following way:

1. When the student enters the course for the first time s/he is directed towards the section on *how to use the course*.
2. Netscape preferences are preset in an alias when the course is started up
3. Greater attention was given to the design of animations. Subsequent animations were split into a series of pictures called from a menu using a Java applet
4. Questions were worded more carefully so that the student wouldn't feel as if s/he was being tested An anomoly is that a *tick* or *cross* was given, depending on the answer. The feedback was varied according to the student's answer.
5. Special attention was given to improve continuity between screens. This often involves having a hyperlinked word leading to the next screen.
6. A major strength of a CAL course is that it can be designed to cater for individual learning styles. More than half of the students using the course are likely to be *visual thinkers*[3]

[3] personal communication from Prof Alex Johnstone of Teaching and Learning Service, University of Glasgow

so it is not surprising that the students had most difficulty with the section which treated the maths in an abstract way. This section was redesigned, so the student would be given a choice of two different styles of teaching. While one route presents the Maths in a more analytical manner, the other uses an analogy based on calculating the position of a car travelling along a road. This is illustrated with a series of illustrations, animations and talking head video clips. Since the student is probably aware of his/her own learning style, then s/he has the ultimate choice over which route to take. The student can switch between each of these two *learning routes* at any point.

These improvements to the course had been implemented by the beginning of June. A second evaluation was required to find out if these changes were real improvements.

3.6 Second Student Evaluation

A second student evaluation was carried out independently by Sue Tickner. This took place at Paisley University involving undergraduate and postgraduate engineering students. A report of this evaluation study is included in Appendix B.

Despite the fact that some technical problems hampered the evaluation, the students still gave a positive response to the CALF course. In general, it was believed to increase interest in the subject. They felt that the explanations were clear and the graphics helpful.

The students gave an enthusiastic response to the redesigned Maths section, with 80 % of them deciding to choose the *visual* route. However, many returned to the *analytical* route and commented that it seemed much less intimidating, because they had first encountered the material in the *visual* teaching style. Therefore, on this limited evidence the choice of learning styles appears promising.

Students also liked the question and answer style to the course. They seemed satisfied with the varied feedback and liked the *ticks* and *crosses*!

Confidence logs, recorded immediately before and after going through the course, illustrated a marked increase the students' confidence over a range of subject areas. In other words, the students feel as if they are positively learning fluid dynamics.

However, there were also some negative comments, mainly regarding the navigation through the course, which 67 % of students felt needed improvement. The students seemed confused by hyperlinked words leading to the next page, especially when there was also a *forward arrow*. Screen numbering was suggested and there was a general anxiety that they may have missed out part of the course. They seemed to want a completely linear route. Perhaps this is more of a reflection on the present education system which doesn't encourage exploration and overloads students with *material to be covered*.

The download times for some of the animations was also fairly lengthy, though this was partly due to technical problems experienced in downloading from Glasgow University.

These are problems which still have to be tackled, but generally it seems that the course is converging upon an improved design.

4 Conclusions and Future Work

4.1 Course Use

The conclusions and future work arising from this project cover technical and educational areas. The philosophy adopted for the development of the course has been to try to produce something which will help to improve student learning. This inevitably lead to an (informal in this case) examination of the methods currently used and the following problem areas were identified:

- poor student motivation due to an apparent lack of relevance
- an emphasis on low level learning driven by the assessment process
- lack of dynamic presentation
- failure to cater for students as individuals.

CALF aims to overcome some of these problems by using the approaches described in this report. However, the problems created by the current assessment procedures cannot be overcome for a single course which still retains those procedures. The student attitude to CAL from surveys and informal interviews can typically be summed up as

> CALF helps us to understand fluid mechanics....but all we really want is to pass the final exam.

This was reflected by the widely expressed preference for a linear route through the course to ensure that no material (which might feature in the exam) is missed. This negative attitude can partly be overcome by making the course as relevant to real applications as possible to improve motivation, but only assessing higher level learning can fully encourage the development of high level skills such as creative or critical thinking. CALF can help to improve the situation by improving student motivation for lectures by

- making the subject area interesting and relevant
- removing the mathematical obstacle to understanding by improving visualisation of the subject and catering for different ways of learning
- creating an overview of the area unobstructed by details, thus allowing the student to gain more from the lecture course.

The planned use of the course at the University of Glasgow will feature timetabled sessions for students to access sections of CALF before encountering the material in the lecture course. A demonstrator will be on-hand to provide assistance with using the course and to discuss the technicalities of the subject. Students will also be able to use the course at all times limited only by their access to the web. The uneasy relationship between the CALF aim to foster high level learning and the ruthless student focus on the final exam will make the incorporation of CALF into the existing course a delicate exercise and there remain many open questions in this area. A formal evaluation of the effectiveness of the different learning routes is planned in collaboration with the Teaching and Learning Service (TLS) at the University of Glasgow.

A possibility opened-up by using a computer based course is to use the internet for distance learning. It is intended to test the use of remote tutoring by email and video conferencing by using the local Metropolitan Area Network Clydenet. This could be extended in the future to give students access to workers in industry and to specialist courses for which there is too little interest at their own institution.

4.2 Development Issues

The major outstanding problem with the development involves the use of videos and animations. First, the size of the images used is too large leading to a long download time over the network. This problem is likely to be ameliorated by advances in networking technology. It is planned to investigate the provision of the course from compact disc by using a program which simulates the use of a web server. Finally, no study of video compression and file formats was made due to time constraints and this should be done in the future.

Student comment on the animations was generally positive but this was qualified by criticisms of the lack of control, particularly over speed. A new method of allowing access to frames from a menu, using a Java applet, was tried and this appears to improve the situation at the cost of making the *animation* a set of static images. Using a Java applet to play an animation as a set of images being displayed in sequence was unsuccessful since the size of the files mitigated against the rapid loading required. Using an applet to generate all or part of the images appears to be a promising alternative which would improve the downloading problem. This would also allow the embedding of the animation window into the browser although spawning animation windows can be useful for the student as it allows continued access to the material in the browser window. The automatic loading and playing of animations could be valuable because some students found some of the animations disappointing, probably arising from rising anticipation whilst waiting for the sequence to download.

Minimal use has been made of sound throughout the course. This was a decision taken with regard to the practicalities of using sound in a laboratory which with hindsight was wrong. Examples of possible uses of sound in the course are for the *how to use the course* section, to replace the commentary given using text within the animations and to provide a form of dialogue for the question-and-answer style. The *talking head* video clips are the weakest feature of the course and highlight the need for careful scripting, some acting skill and a bigger playback window so that visual clues are visable. A result of the informal assessment of lecture based teaching was that the combination of visual and aural clues is powerful and this should be exploited in computer based courses.

The interactive quality of the course was enhanced by the replacement of simulations using CGI with Java written applets incorporating a graphical user interface. The Java programming language was found to be convenient and it was found straightforward to create these applications. An applet is also used to log student progress although this information is not currently exploited in the course. Dynamic reconfiguration of paths and automatic calls for tutor help are possible uses for this information. The student is asked to login on entering the course but this is simply to allow identification for logging purposes and would not stop *unauthorised* access.

The main conclusions about implementation are that

- once a style is in place material generation can be rapid
- development requires creative input from both the subject expert and the multimedia expert and hence a constructive working relationship is required in which both are equals (i.e. a development method which involves a (non-multimedia proficient) subject expert and a (non-multimedia proficient) typist is unlikely to produce good results)
- the use of the web for delivery to allow platform independence has been successful and implementation has been straightforward
- it is difficult to anticipate student reaction and hence regular independent evaluation is a crucial part of the development process, even if this is informal

4.3 Future Development

There are several possibilities to build on the success of this project. These involve the use of computer based courses to improve high level student learning and as a vehicle for research into understanding student learning. The key features of future work will be

- maximum interaction - heading towards as close to 100 % interaction as the technology will allow
- making use of as wide a variety of resources as possible including simulation, experiment, real design examples, video, sound, animation, text, lectures, tutoring, group learning..... with the guiding principles being
  - to use the most appropriate means of making a point
  - to make resources accessible (as opposed to available) to students by placing them in context
  - to make the inherent beauty and interest of the subject apparent to the student
  - to cater for students as individuals by allowing for individual learning styles
  - to encourage high level learning such as critical and creative thinking by giving the student scope to explore

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- Jim Kavanagh (G-Geology) and Richard Green (G-AE) for help with digitising video
- Brian Gribben (G-AE) and other members of the CFD research group for their help with material preparation

REFERENCES

[1] L.L.Jones and S.G.Smith, *Teaching in Higher Education*, (3), 78, (1989).

[2] L.L.Jones and S.G.Smith, 'Can multimedia instruction meet our expectations', *EDUCOM Review*, (1), 38, (1992).

A Project Presentations and Publicity

- *Computer Assisted Learning for Fluid Dynamics* - paper accepted for ALT-C conference, University of Strathclyde, September, 1996
- *Interactive Learning Software on the Web* - invited presentation by Ken Badcock and Allison Littlejohn to Glasgow Multimedia Developers Group, University of Glasgow, 11th July, 1996
- demonstration at ClydeNet awareness day, University of Glasgow, 26th June, 1996
- demonstrations to representitives of British Aerospace (Military Aircraft Division, Brough), Defence Research Agency (Farnborough and Bedford) and Westland Helicopters at University of Glasgow, June, 1996
- *A Computer-Assisted Learning Package for Fluid Mechanics* - presentation by Robert Watt at Scottish Fluid Mechanics meeting, Paisley University, 21st June, 1996
- invited presentation on *computers for visualisation* to Department of Geology and Teaching and Learning Service, University of Glasgow, 12th June, 1996
- *Concept maps in the Virtual University* - University of Glasgow press release, 26th July, 1996

B Second Student Evaluation Report

C Sample Screen Shots

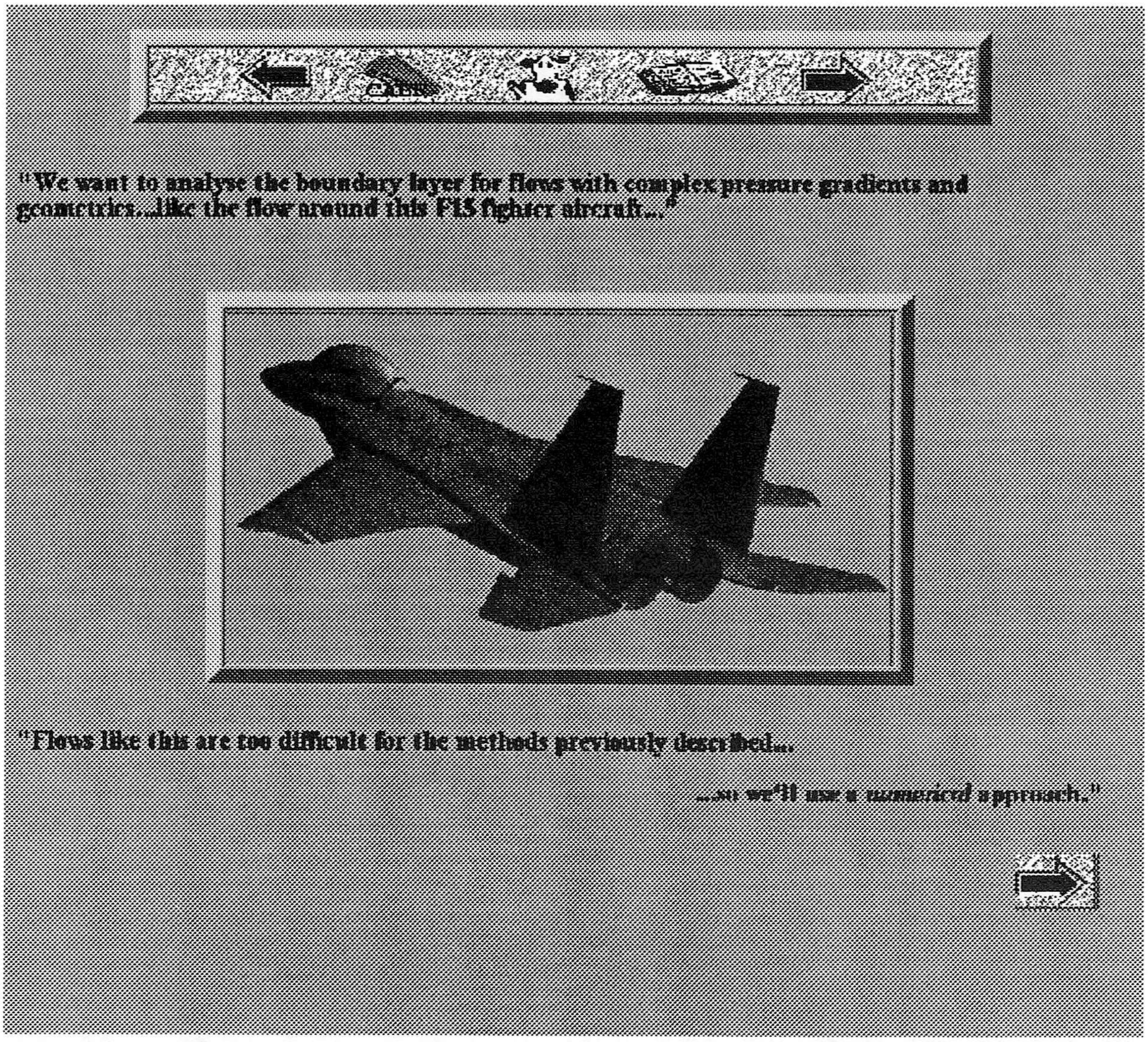

Figure 1. Introductory screen for numerical section motivating subject via a real world situation.

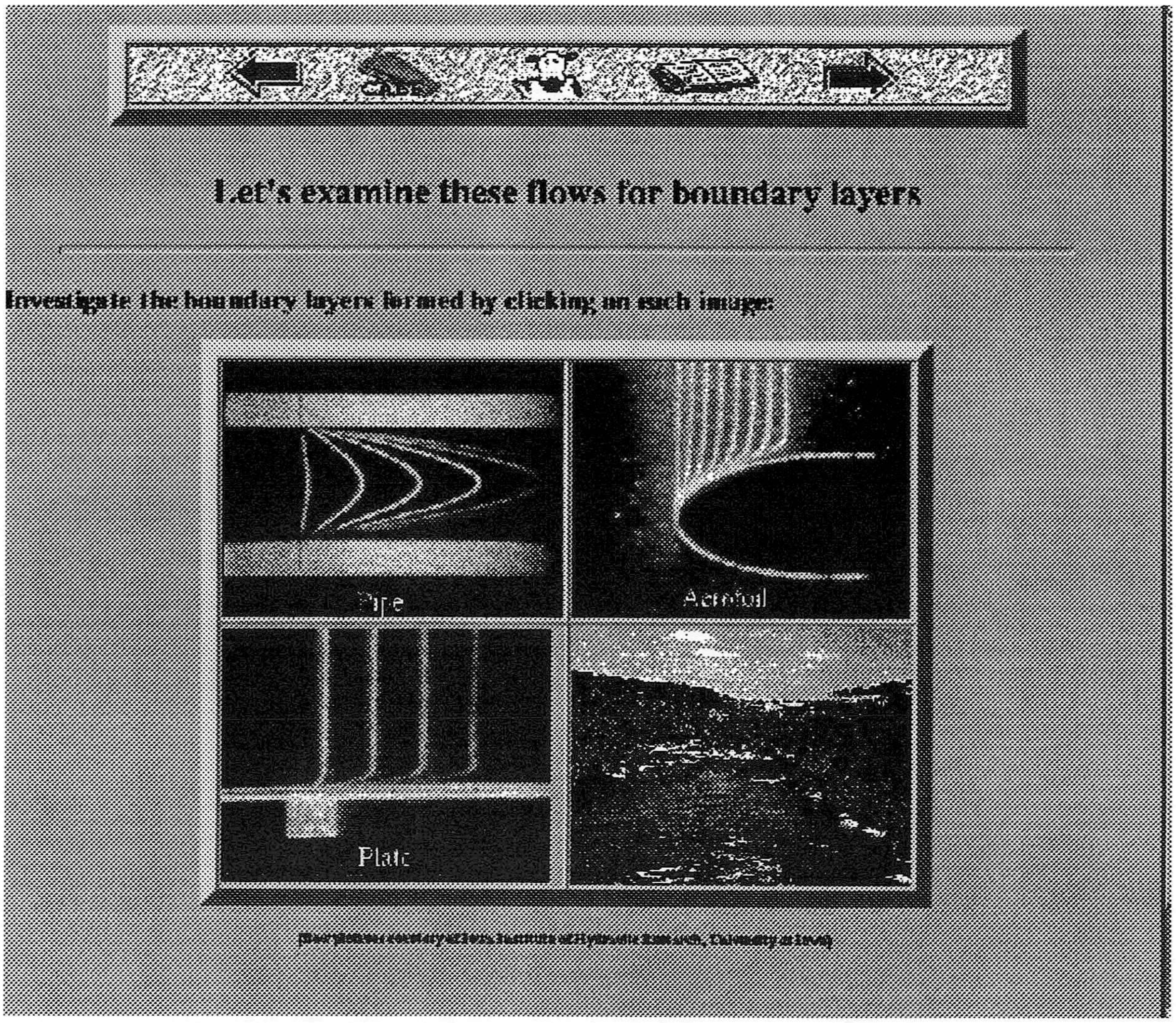

Figure 2. Screen featuring video clips of flow visualisation.

D Screen Design Sheet

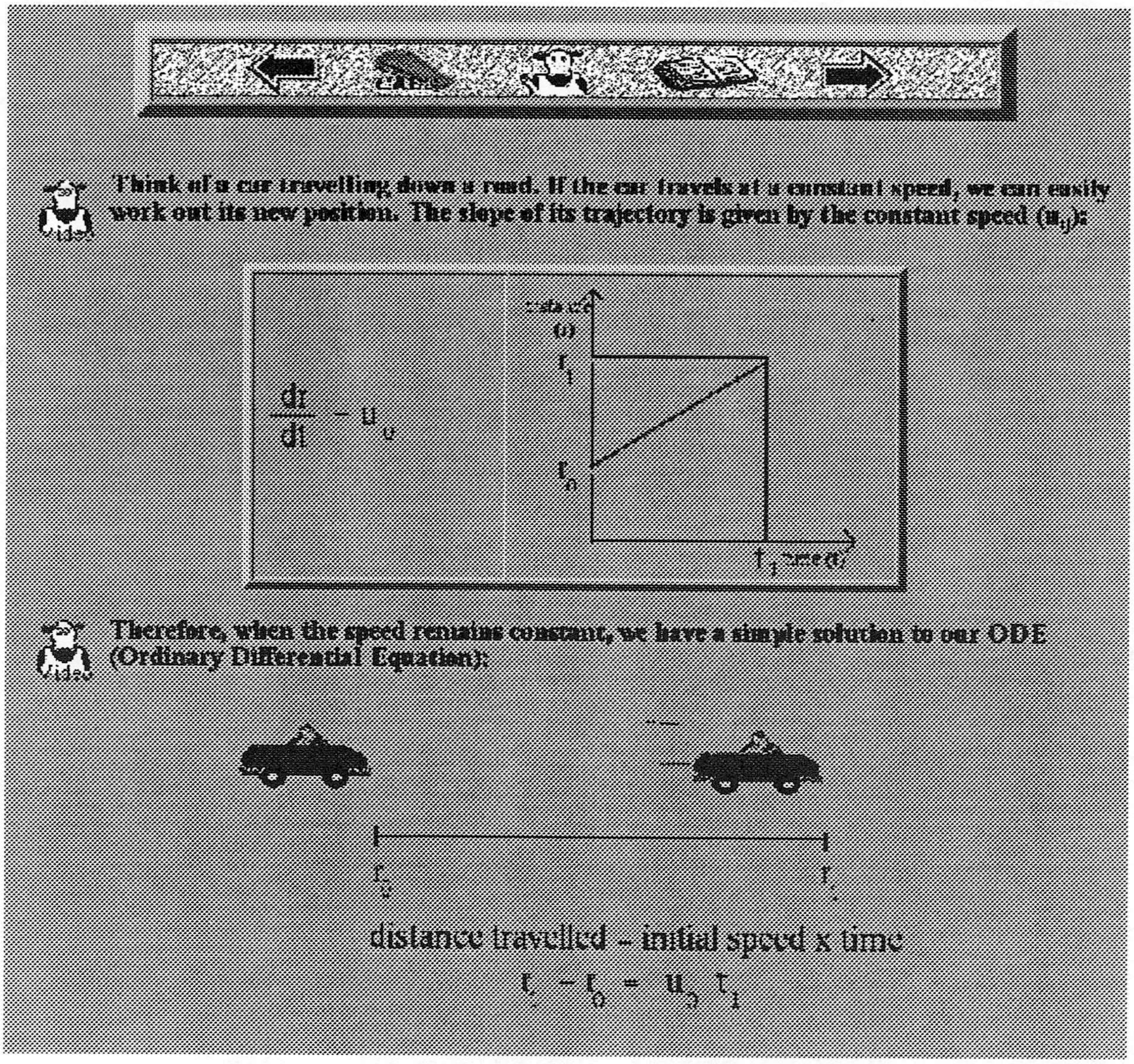

Figure 3. Sample screen from the pictorial route.

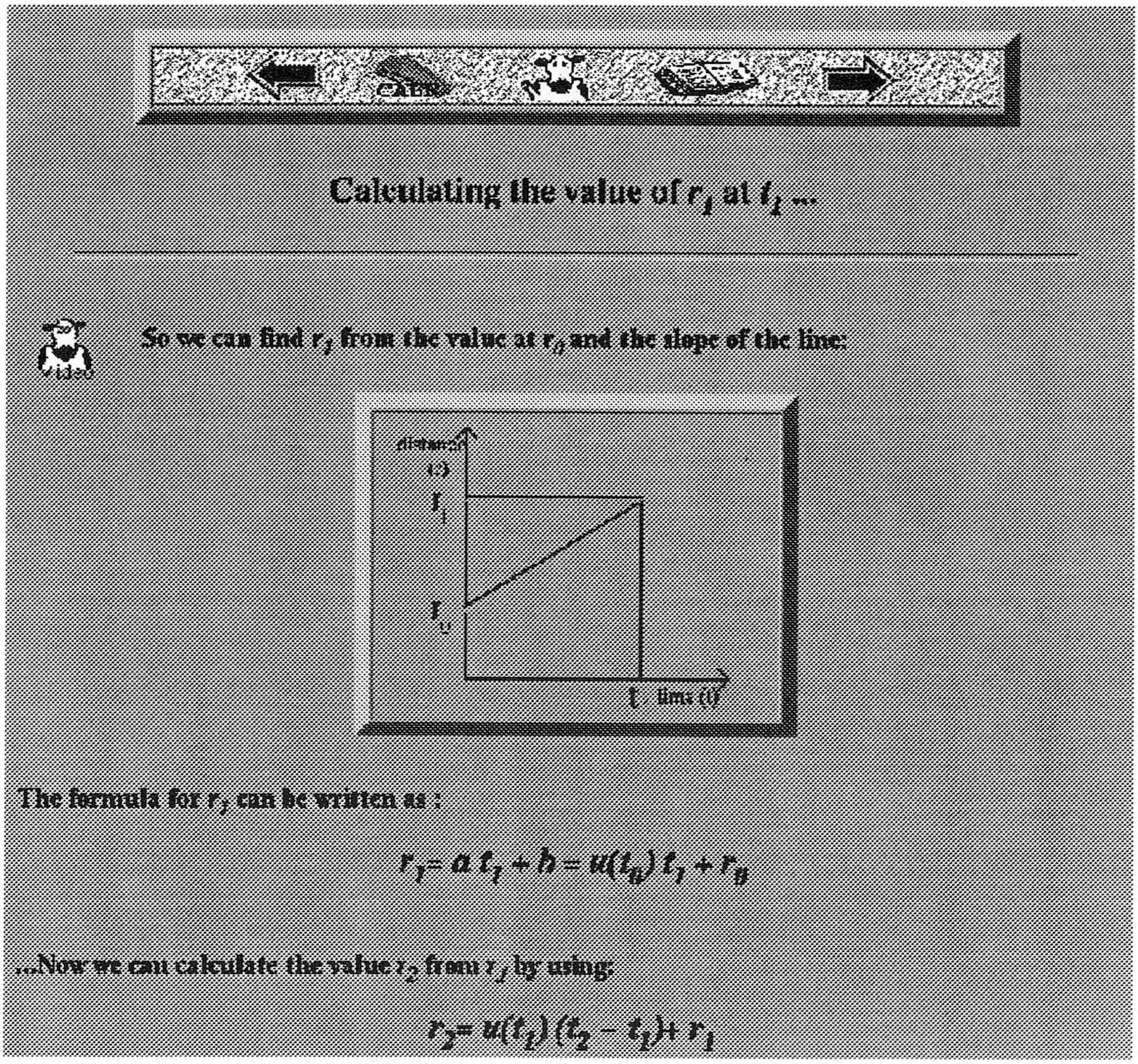

Figure 4. Screen from the traditional maths route.