Int. J. Engng Ed. Vol. 17, No. 2, pp. 176–188, 2001
Printed in Great Britain.

0949-149X/91 $3.00+0.00

A WWW-based Course Structure for Teaching a Thermodynamics and Heat Transfer Course*

M. RIDWAN, C. YAP and M. A. MANNAN
Department of Mechanical & Production Engineering, National University of Singapore, 10 Kent Ridge Crescent, Singapore 119260. E-mail: mpemma@nus.edu.sg

This paper sets out to present a comprehensive and integrated approach to teaching a Thermodynamics and Heat Transfer course using the World Wide Web. Existing WWW-based teaching structures and their shortcomings are first discussed. Then the concept and contents of a course portal following the comprehensive and integrated approach are presented. Different aspects of the portal, namely, the Main Page, the Multimedia Page, the Courseware Page, the Contact Page and the Search Page, are described. Future directions to improve the portal are discussed.

INTRODUCTION

THE ADVENT of the Internet or the World Wide Web (WWW) and the proliferation of PCs in most homes besides those in the corporate world, have signalled a new era of communications and information which transcends almost all barriers. Bits of news and other kinds of information, in forms that include videos, images and sounds, have become readily portable.

Platform-independent languages such as JAVA and numerous other add-ons to the WWW that made online interactive programs a possibility have widened the usage of the WWW as more than just an information provider. It has also become possible for services to be provided on the Web. One such beneficiary is the education industry. Numerous education websites have been developed and are now online.

However, it is important to note that most of these sites are underutilising the power of the technologies that can work with the WWW. They may be classified into two broad categories:

- Sites with typewritten or scanned notes about the topics featured on the Web, without providing any interactivity,
- Sites with JAVA applets or other interactive program types (CGI, API's or scriptable-server side programs) that enable certain concepts to be tested or shown. This may come in the form of quizzes or animation programs to show simulations.

There are even some sites that combine interactive and comprehensive notes on the subject matter and also interactive programs such as JAVA applets to test concepts and to show simulations to aid in understanding. Two such examples can be found at www.thermofluids.net [1] and at http://137.132.148.60/vibration/OneDOF/ [2–5]. The former is a hyperlink to a site in the US that offers excellent applets to test thermodynamics concepts along with notes on key areas. The latter refers to a site developed at the National University of Singapore in collaboration with a visiting professor from the University of Western Australia, Professor Brian Stone. The site includes comprehensive notes on Vibrations, JAVA applets that test students and also parameter-changeable applets to depict the vibrations of different systems.

These two sites are in the minority, in offering more comprehensive usage of the technologies available for the WWW. There is great potential for more on the web to assist and complement teaching using the traditional lectures and tutorials at the tertiary level. This is especially so in NUS, where the whole campus has already been wired up with T1 broadband connections in anticipation of utilisation of such IT technology.

It is the intent of this paper to introduce a generic concept on creating a totally integrated and complete template for teaching on the WWW or a particular module at institutions of higher learning. A portal currently under development for a first-year Thermodynamics and Heat Transfer module in NUS will be discussed here to illustrate this concept. (It is to be noted that several aspects of the portal especially in terms of its aesthetics are not final.)

A glimpse of how the main page of the portal might look like is given in Fig. 1.

* Accepted 20 August 2000.

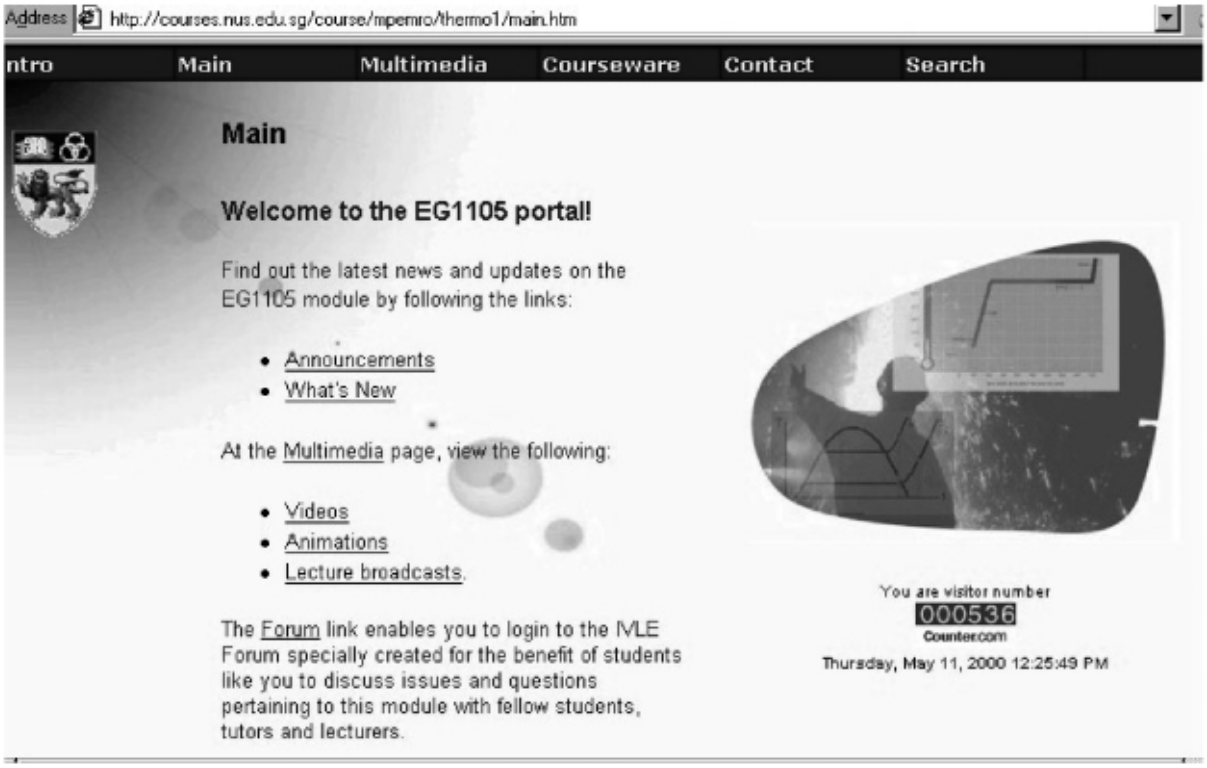

Fig. 1.

CONCEPT AND CONTENT

The main page

This is the first page the visitor to the portal would see upon entering. As such, a good explanation of what the portal entails would be described here. A concise description of the contents of the main links would be described and shortcuts provided for easy access to the relevant web pages. The portal would be customised to 800×600 resolution to cater to the majority of users with normal 15-inch monitors. This is an important aspect of the design of this portal. In most of the style and quality of the multimedia, care is taken not to alienate users who do not have high specification computers, whether 17 or 21-inch monitors or the latest 7th Generation processors such as Athlon from AMD.

Under the main page menu are two sub-level menus entitled, 'What's New' and 'Announcements'. As evident from the title, the former lists anything new that has been added to the portal since the last update whether thermodynamics-related or heat transfer-related. These additions can be in the form of new streaming videos, new lecture notes, broadcasts or other contents that would be highlighted in later sections.

The latter updates students on the latest about the course itself rather than the contents of the portal. Students can find out conveniently the latest tests, quizzes and changes in syllabus. These updates are far more efficient than the conventional notice boards. The updates are easily updated and provide a very rapid author/reader channel of communication.

The dichotomization into these two sections (Thermodynamics and Heat Transfer) is needed both in 'What's New' and 'Announcements' to separate the issues that are pertaining to either sections within the EG1105 module. This is important since early in the term, only news of the thermodynamics part would be constantly updated rather than the heat transfer part and vice-versa in the later part of the term. Other sections in the portal might need the same separation, as will be explained in the appropriate sections later. A picture of the Announcements page is shown in Fig. 2a.

Multimedia page

One of the two important sections of the portal (the other being the courseware page), the multimedia page is where full utilisation of various Internet Technologies can help students understand much better through the usage of multimedia, the subject that they are currently pursuing. This use of multimedia had been too expensive and not easily accessible until the advent of the Internet. As is well documented, information is absorbed much more effectively when received through action and sound rather than just by sight especially in highly conceptual subjects such as Thermodynamics and Heat Transfer. Certain concepts and ideas are more easily understood through the use of dynamic multimedia content. The multimedia content here is

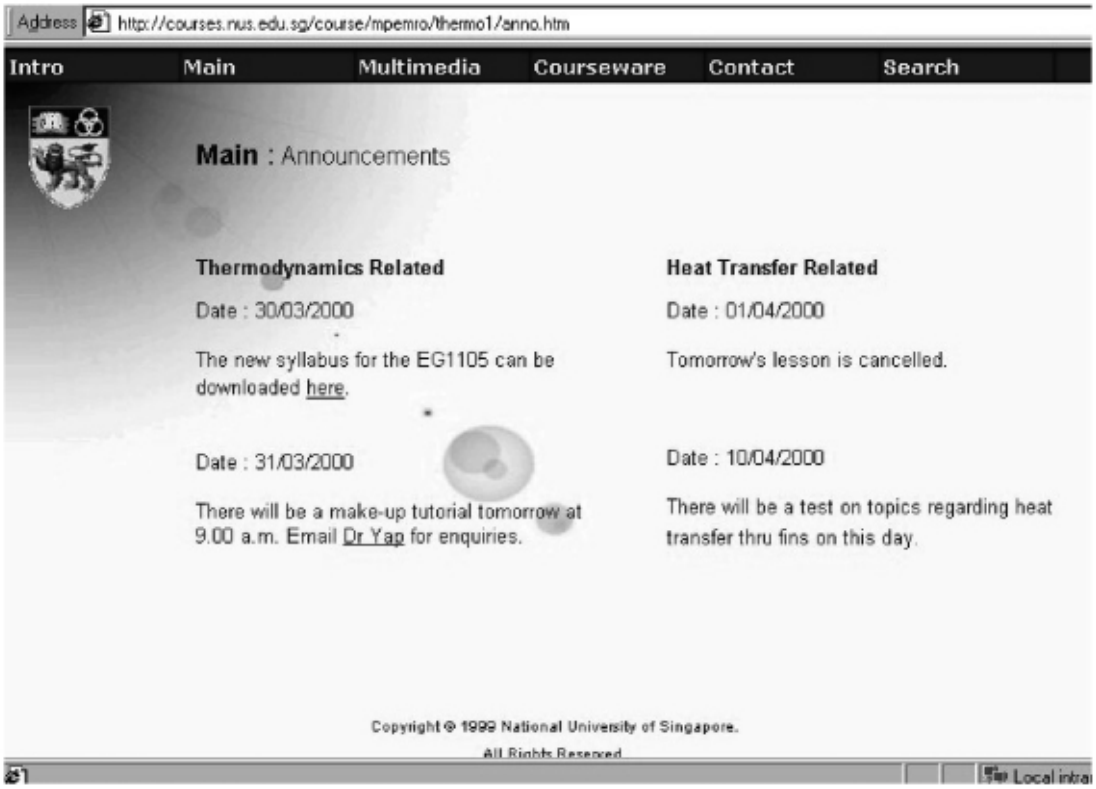
Address http://courses.nus.edu.sg/course/mpemro/thermo1/anno.htm
Intro
Main
Multimedia
Courseware
Contact
Search
Main : Announcements
Thermodynamics Related
Date : 30/03/2000
The new syllabus for the EG1105 can be downloaded here.
Date : 31/03/2000
There will be a make-up tutorial tomorrow at 9.00 a.m. Email Dr Yap for enquiries.
Heat Transfer Related
Date : 01/04/2000
Tomorrow's lesson is cancelled.
Date : 10/04/2000
There will be a test on topics regarding heat transfer thru fins on this day.
Copyright © 1999 National University of Singapore.
All Rights Reserved.

Fig. 2a.

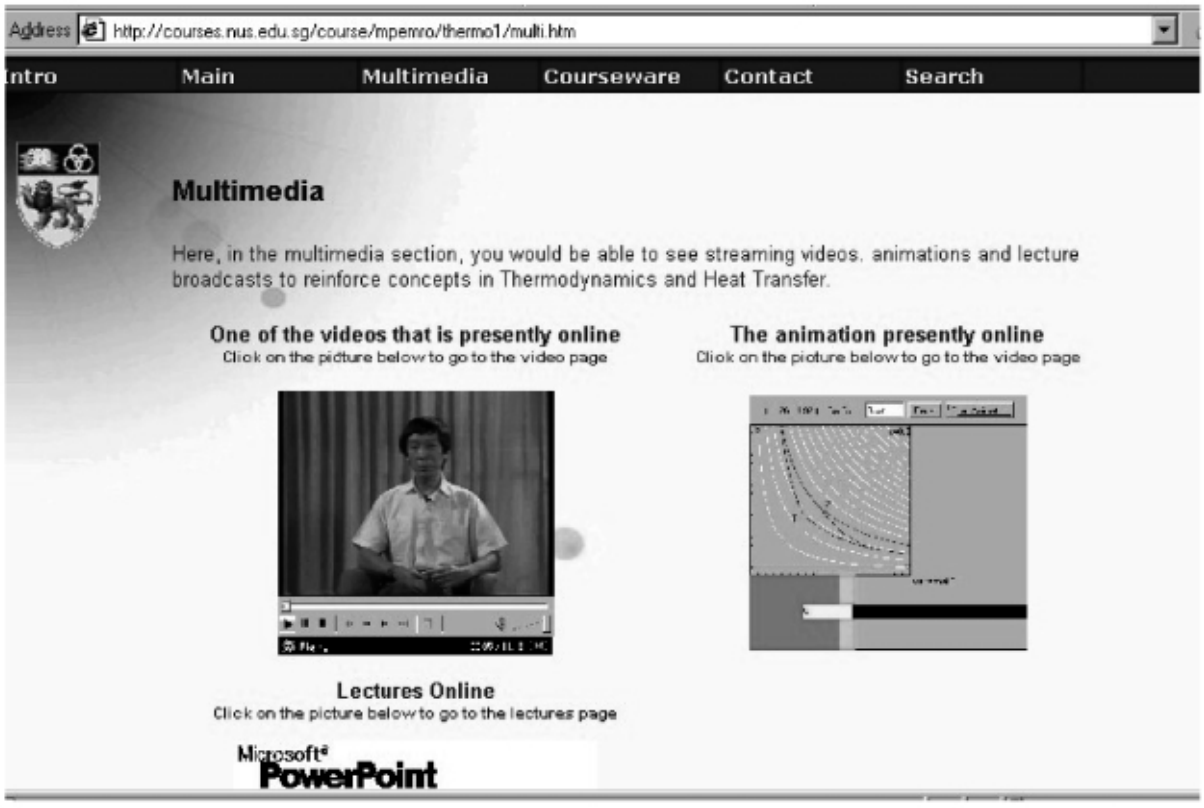
Address http://courses.nus.edu.sg/course/mpemro/thermo1/multi.htm
Intro
Main
Multimedia
Courseware
Contact
Search
Multimedia
Here, in the multimedia section, you would be able to see streaming videos, animations and lecture broadcasts to reinforce concepts in Thermodynamics and Heat Transfer.
One of the videos that is presently online
Click on the picture below to go to the video page
The animation presently online
Click on the picture below to go to the video page
Lectures Online
Click on the picture below to go to the lectures page
Microsoft PowerPoint

Fig. 2b.

divided into three sub-levels, viz. digital video streaming, animations and lectures online.

All these can be accessed through the multimedia cover page or through the navigation bar at the top. Clicking on specific pictures on the cover page brings the user to the sub-levels. A screen shot of the multimedia cover page is shown in Fig. 2b.

Video sub-level

In the 'videos' sub-level, existing videos related to thermodynamics and heat transfer at the first-year level are digitally streamed online using the Windows media technology and proprietary advanced streaming format (ASF) files. Two videos that have been encoded and embedded are presently online. The first is a digitization of the Air-conditioning Lab Experiment Introduction video that is normally shown at the start of the aforesaid experiment. This is an example of how Internet technology could benefit both students and educators. Although students might still be required to view the 20–minute video as an introduction to the experiment, they could be encouraged to view the digitized video online beforehand providing them additional time to absorb the related principles and concepts and hence more greatly appreciate the experiment. They would also be able to rewind or replay the entire clip whenever necessary, before or after the experiment and hence, gain good understanding of the subject. Questions and doubts can be cleared during the lab session itself, again allowing the educator to focus on clearing difficulties in understanding which students have identified from their prior and on-site viewing. The screen capture of the video is shown in Fig. 2c.

Figure 2c gives a clear indication of advantages of having similar videos made for other experiments. The other digitized and encoded video shows a simulation of evaporation and condensation through the use of a 'drinking-bird' toy the motion of which depends on the state of the liquid inside its body. Besides the better clear demonstration of engineering principles that such a simulation gives students, educators have the flexibility of including well-made videos on the subject matter without needing to show them during lectures in which there may be time constraints. The video of the simulation is shown in fig. 2d.

The videos were digitized using the Windows Media Encoder software from Microsoft Corporation version 4.0.0.3485 and along with a video capture card hardware. The reasons for choosing the ASF format over others like MPEG, Real Video, AVI and VIVO are as follows:

- Good quality-to-size ratio—an acceptable 20 Mb was needed to digitize the 11 mins of the Airconditioning Lab Intro.
- Availability of hardware to encode videos.
- Availability of software (downloadable free from the Web)
- Plugin that can be automatically loaded on the two main web browsers (Internet Explorer and Netscape Navigator) ensuring videos can be viewed by majority of users. There is a way to code the html to ensure all-browser compatibility

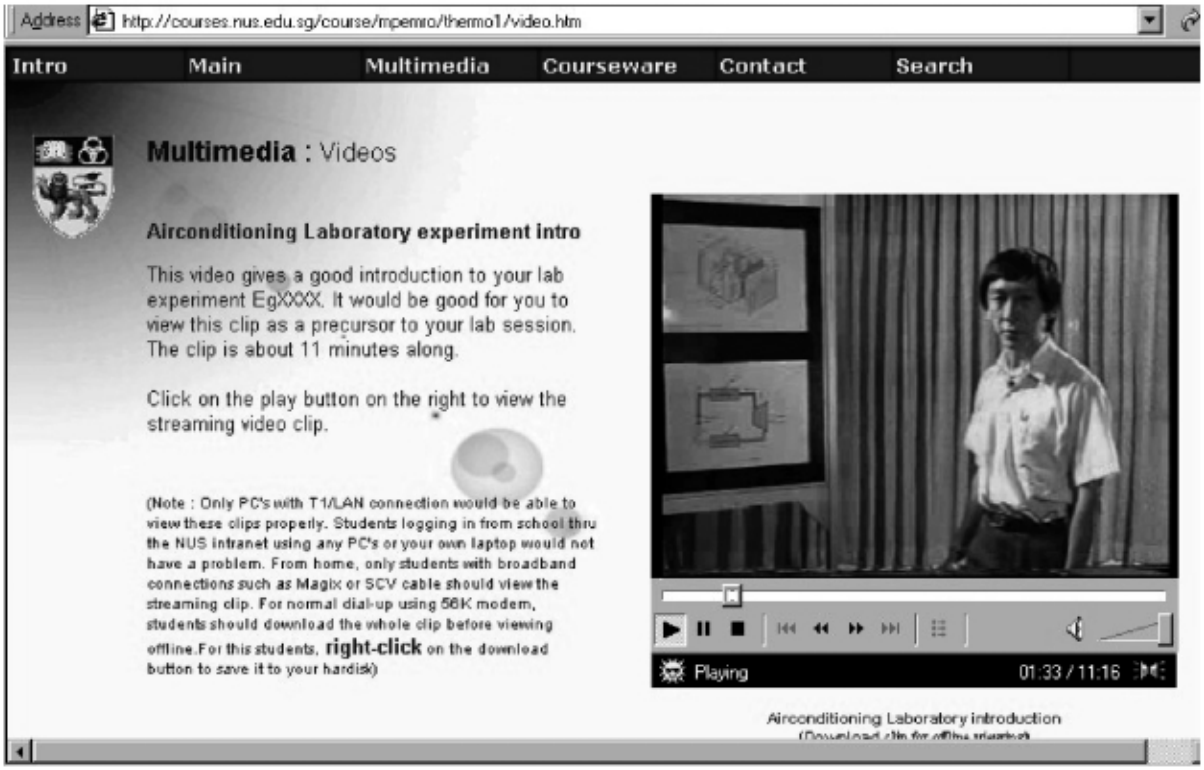

Fig. 2c.

Fig. 2d.

(see the Fig. 2e). The important tags to note are the ⟨Object⟩ tag and ⟨Embed⟩ tag which are the different ways in which Microsoft's Internet Explorer and Netscape Communicator would invoke the plugin necessary to run the ASF files online, if in the first place, they are not installed in the browsers. By putting these tags in the html of the web page, browser compatibility issues would not be a bother anymore. This is again important so as not to alienate any users.

- Ability for video streaming to be configured so that different quality can be produced for different connection speeds. (i.e. 56K modem or T1/LAN connection) without alienating users, again the main motivation behind such configurations. But it must be added that for the streaming video on the air-conditioning introduction, it can only be viewed correctly with T1/LAN connection. This means they can only be viewed properly if students log in from school through the NUSNET-III network or if they do so from home via broadband connections such as Magix or Cable. The lower configuration is not included since the lower quality configuration would have defeated the purpose of showing the clip as the viewable quality would depreciate to such an extent that certain aspects of the video may not be clear or decipherable. For the other video clip however, a lower quality video was made and would be added to the page soon for those accessing from home using a normal 56k modem. The quality drop for the second clip does not make the video indecipherable and hence the encoding of the lower quality video was still viable.

As to the issue of not alienating users, an alternative may be provided for users who use much lower-speed 56K modems to view the air-conditioning video clip from home. These users will be allowed to download the video and view them offline where necessary. However, with the cabling up of Singapore with broadband connectivity, within a few years, most students are likely

File Edit Search Help

```
<object id="MMPlayer1" width=340 height=320 classid="CLSID:22d6f312-b0f6-11d0-94ab-0080c74c7e95"
codebase="http://activex.microsoft.com/activex/controls/mplayer/en/
nsmp2inf.cab#Version=5,1,52,701" standby="Loading Microsoft Windows Media Player components..."
type="application/x-oleobject" align="middle">

                <param name="Name" value="values">
                <other parameters here>

<embed type="application/x-mplayer2" pluginspage="http://www.microsoft.com/Windows/
MediaPlayer/download/default.asp" src="mms://mod.nus.edu.sg/feng/airconindexed20000309.asf"
autostart="0" showcontrols="1" showdisplay="0" showstatusbar="1"
defaultframe="Slide" width="340" height="320" align="middle">
</embed>
</object>
```

Fig. 2e.

to be accessing this or similar portals through broadband connections, eliminating the problem of poor access speed.

Animation sub-level

Another sub-level within the multimedia page is the animation page. Again, these animations, similar to the videos, can illustrate concepts better. The animations here are still under development. The technologies that would be used to create this animation have been narrowed down to two, JAVA and Macromedia Flash. The latter is the most likely technology employed due to the ease of programming, smaller size files, compatibility with all browsers through html coding (like the one shown for ASF files) and time constraints. Two topics suitable for the use of animation are heat engine cycles and the heat transfer mechanisms (conduction, convection and radiation). Time permitting, at least two applets (either JAVA or Macromedia) are expected to be used on the animation sub-level page of the portal.

Lectures sub-level

The last sub-level within the multimedia page is the lectures page. Here, there will be three different formats of lecture presentation on the Web. They are as follows:

- Online PowerPoint slide presentation.
- Downloadable PDF files of lecture notes.
- Online lecture broadcast.

This page is also dichotomised to thermodynamics-related and heat transfer-related sections for the same reasons mentioned in the section on the main page above. The presence of the three different formats owes much to the concept of not alienating users as much as it serves different types of objectives in presenting lectures on the Web. The first format serves the purpose of transferring any PowerPoint slides already created for actual lectures to be put on the Web without fuss and without frills. This is done using the new features of PowerPoint 2000, which enables any PowerPoint presentation to be saved as an HTML file. This is considered a 'no frills' format since only preset animations and no sounds can be added although the original presentation may have them. But it can easily be viewed with any standard browsers and students logging in from home using a normal 56K modem would not have any problem viewing it. An example of how the HTML files would look like is shown in Fig. 2f.

By either clicking on the slide topics in the left border or by clicking on the arrows at the bottom of the page, students can go to any particular slides

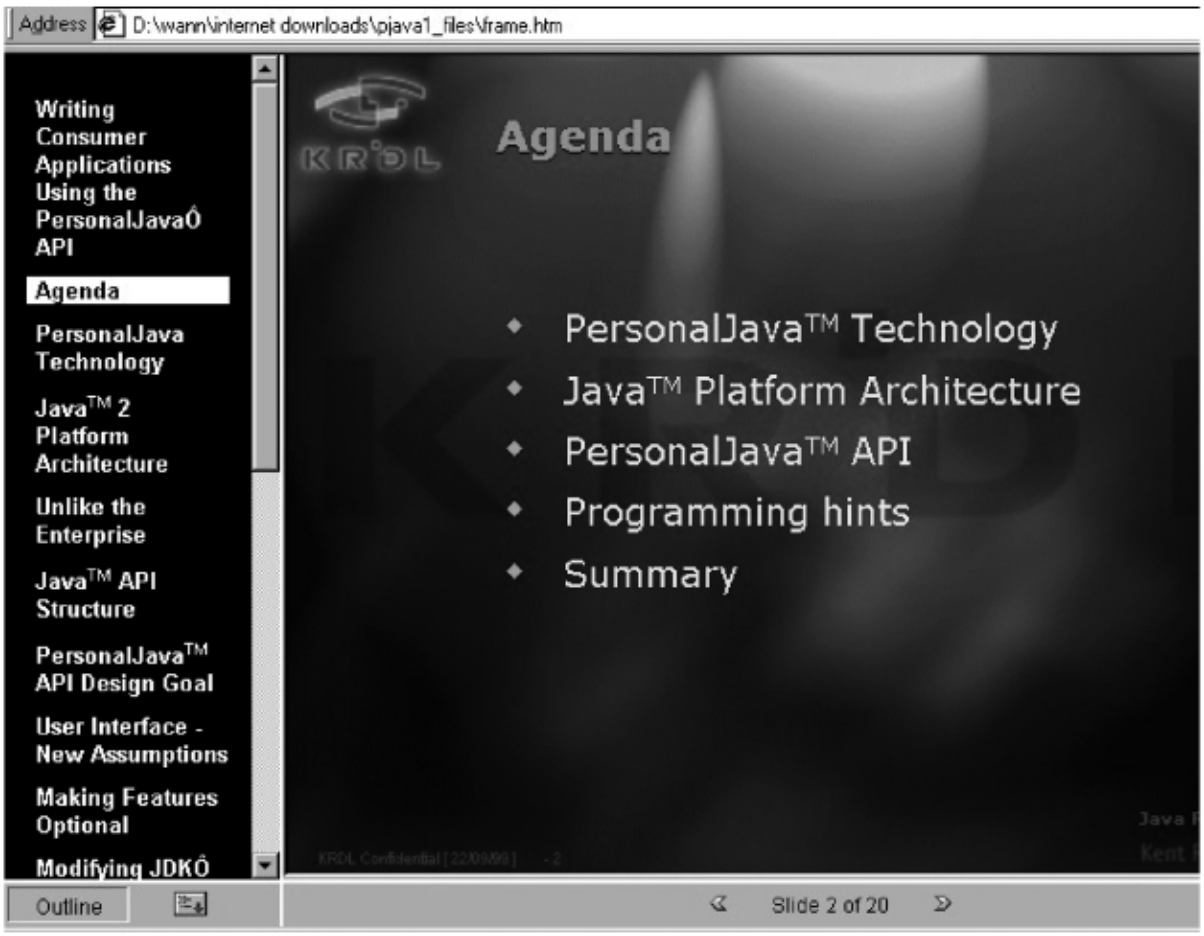

Fig. 2f.

they want to view. They are in control of the pace of their learning. This is one of the biggest advantages of putting lectures online in this way or in the other two ways. There is a need to understand that different students have different abilities at understanding and deciphering concepts. Actual lectures do not have the ability to cater to these differing needs especially in very big classes, which are the norm here at NUS. Hence, having lectures online through this form or others would be a boon to students who want to study at their own pace. The notes for this module are currently being converted to the PowerPoint format, after which the web version would be put online.

The second format is especially useful when certain parts of the notes that educators wish to put on the web are not presently in PowerPoint presentation or are not easily changed to that format. Putting it online as downloadable Adobe PDF format allows educators to show exactly what they want the students to see and at the same time protects it from being modified. This has numerous advantages over alternatives such as converting it to HTML files (which are easily edited) or scanning actual notes (which can take a much longer time to prepare). This format also allows students without broadband access to view the lecture notes offline. The PDF files for the EG1105 would only be added online after the actual lecture has taken place.

The last format which is also created from a new feature in PowerPoint 2000, adds interactivity, sound and the 'feeling' of an actual lecture taking place right on the students' PC. Any animations or sound effects created on the actual PowerPoint presentation can be transmitted to the web format. A video of the lecturer giving his lecture can be synchronised with the presentation to reflect 'real-time' lectures. This online broadcast though, can only be viewed properly with broadband access. The actual taping and conversion to broadcast files online would be done when the actual lectures takes place from July 2000. An example of how the web broadcast would look like is shown in Fig. 2g.

The PowerPoint slide on the left would change accordingly with the embedded ASF video on the right. As mentioned above, these three different formats exist to cater to all bandwidth users. Low-bandwidth users can just download the PDF files or view the static PowerPoint files while high bandwidth can view the online streaming broadcast. This concept of viewability to all users is very important so as not to alienate any students without broadband connection at home. Without alternatives, they can only view them in the LAN network at school, and hence eliminating advantage of also looking at lectures from home.

It is also important to note that these notes do not replace but rather reinforce or complement the actual lectures. Engineering students at NUS sit through lectures at stretches of two to three hours almost every day. It is very taxing for them to fully concentrate throughout the lectures. Some

Fig. 2g.

important issues in the lectures may be easily missed. Viewing online lectures as many times as necessary help to eliminate that. Of course, as mentioned above, the biggest advantage lies in the ability of the students to study at their own pace.

Courseware page

This is the other important section of the portal. The courseware link brings student to the Flying Fish environment [6, 7] and other links on the Web that has relevant and even extra educational information to help them in the above mentioned module. The cover page for the courseware section might look like Fig. 2h.

Flying fish environment sub-level

The Flying Fish tutorial environment is an integrated web-based teaching system that allows educators to create diagnosis enabled questions using JAVA and scripts and to be able to monitor the whole class performance through its server program. Creating these questions and being able to monitor students' performances doing them is important and would be discussed later. About fourteen different problem sets have been created specifically for the Eg1105 module. Students can easily try these questions by clicking on the Flying Fish link. All the problems so far are from Tutorial 7 and Tutorial 8 questions from the 1998–1999 academic year. More questions would be added later.

The ability for students to practice online is something that must be regarded as very important and useful for any teaching portal. After all, knowing all the theories and concepts online without actually practicing on any questions to test those understanding would be of little use in the exams where finally, questions have to be answered anyway. Application of those concepts is very important and only questions can help do that. Actual tutorials can help too but with the ability to practice online, tutorials would be more efficiently used for clarification on wrong answers or techniques rather than the drudgery of going through every question one by one in class. Before the tutorials, students can actually do similar questions (such as past year questions) online and if they have trouble with getting answers correct on certain topics, they can easily clarify them during tutorial. Similar to the laboratory time saved if video streaming is available online, tutorial time would not be wasted too if tutorial questions can be done online.

The ability to monitor students' weaknesses is also important. Flying Fish through their diagnosis and JAVA implementation allows that. The screen shots and discussion of the monitoring window of the software describes how tutors and lecturers can identify weak areas and concentrate on this during lecture or tutorials.

As can be seen in Fig. 2i, the Flying Fish allows the staff to see a snapshot of all the students in his class at any given time. It would allow him or her to see which questions students are having trouble with, just by looking at the progress display. The different colours of the progress bar tells which questions any particular student has problem

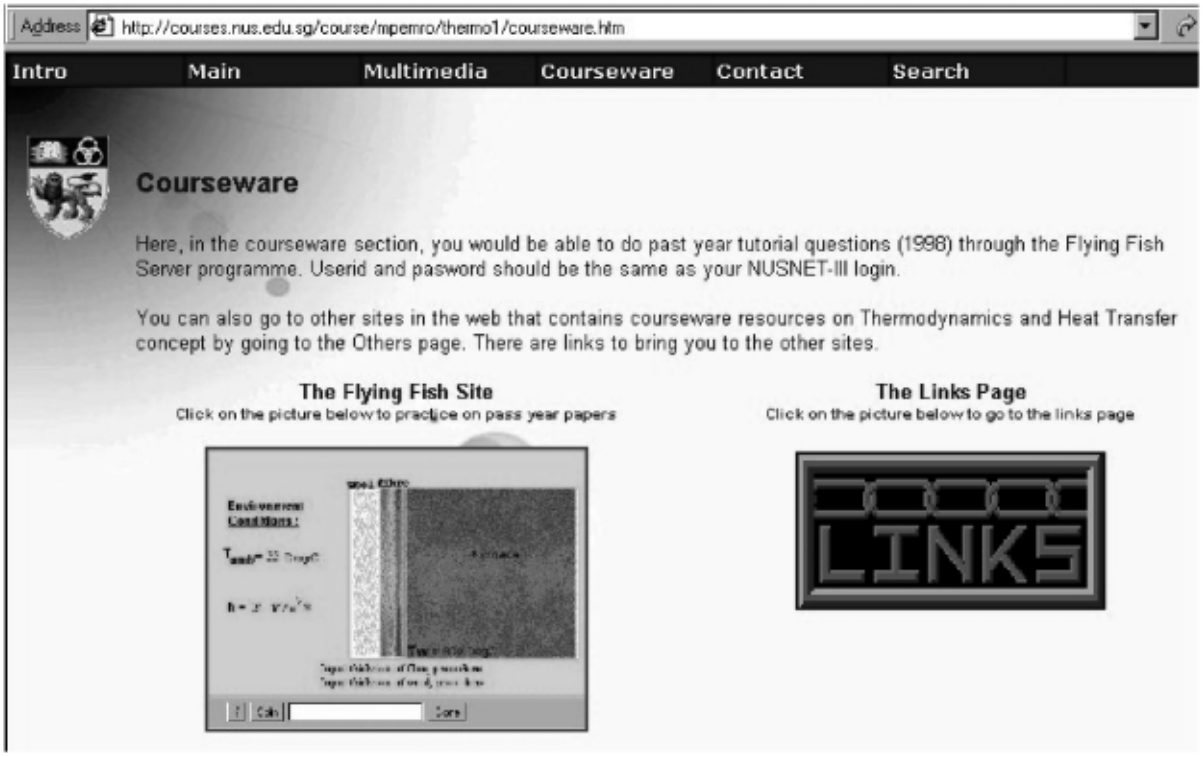

Fig. 2h.

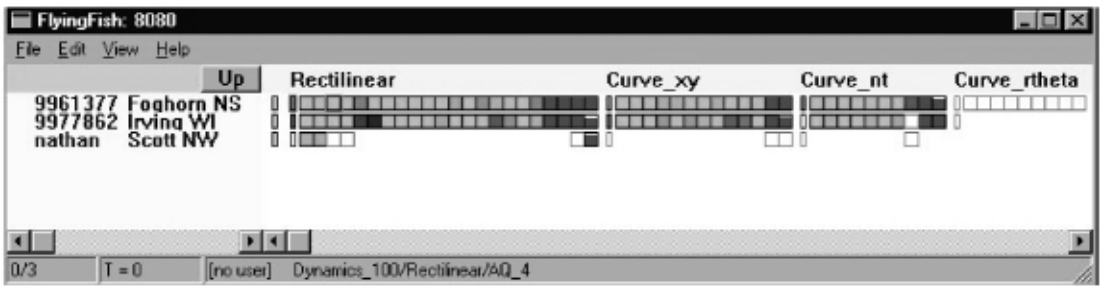

Fig. 2i.

with or problems where he has attempted the question a number of times without getting the answer correct. This would enable educators to teach more effectively in lecture and tutorial since students' errors in attempting questions are known beforehand. Sorting the students by progress, educators can also find out which students have fallen behind by looking at the bottom of the list. This would also allow educators to focus on students who have more problems than others.

Another important aspect of this questions is that it is able to give diagnostics to students answers beyond just a 'yes' or 'no' for correct and wrong answers respectively. Educators are also able to create questions where the sum of the variable values can be randomly generated for different students. This would immensely help in eliminating the behaviour of students in copying from each other. The questions are also able to 'remember' the values of variables given to particular student if he tried the question again. Let's look at one of the fourteen questions created for the Eg1105 portal to illustrate the above points. This is question 2b from tutorial 7 from the 1998–1999 academic year (Fig. 2j).

First, look at the variable, h and T. The value there would change accordingly if another person logs in to the same question. Different students would have different variable values to work with, even from the same question. And if the above particular student logs in again to try the same question, the system 'remembers' his variable values and shows the same value of h and T above. When he types in the answer field and presses done, a pop-up window would show up giving a diagnostic that corresponds to his answers. For example if he had neglected the units, the pop-up in Fig. 2k would be seen.

Figure 2k is a standard response to a standard error common for a student to make. The system,

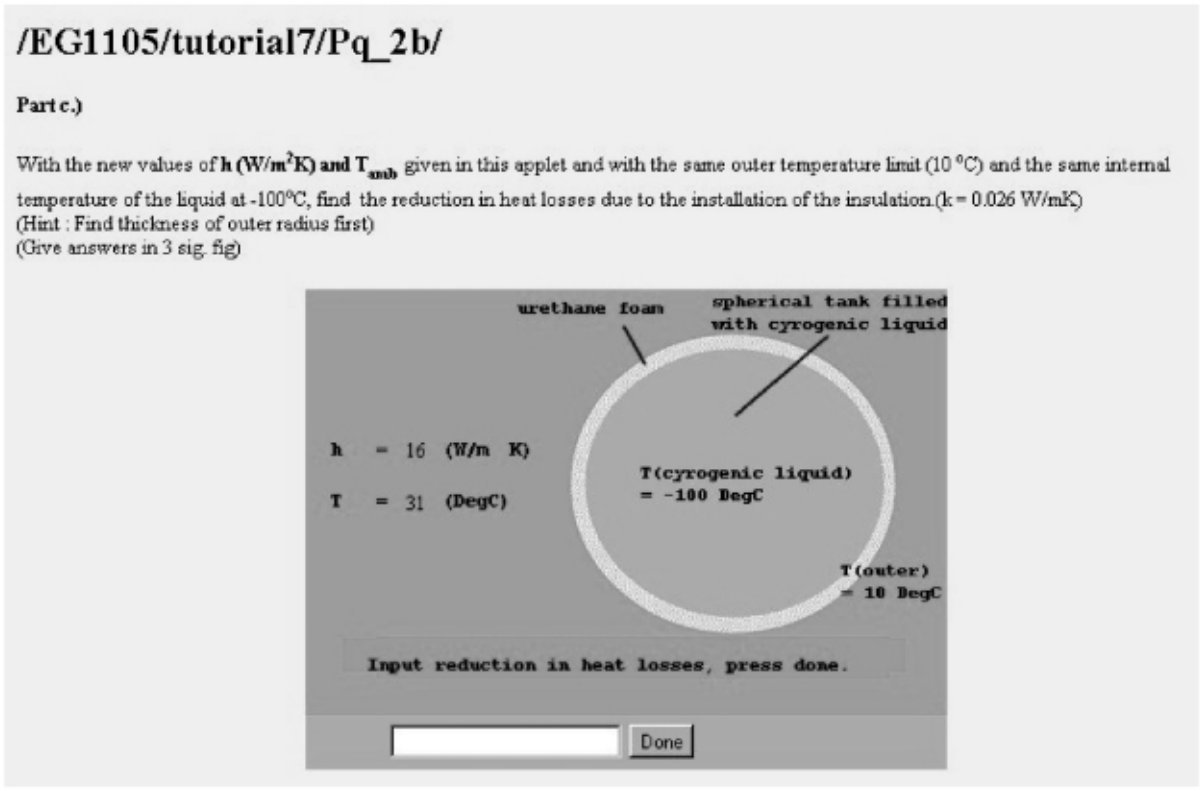

Fig. 2j.

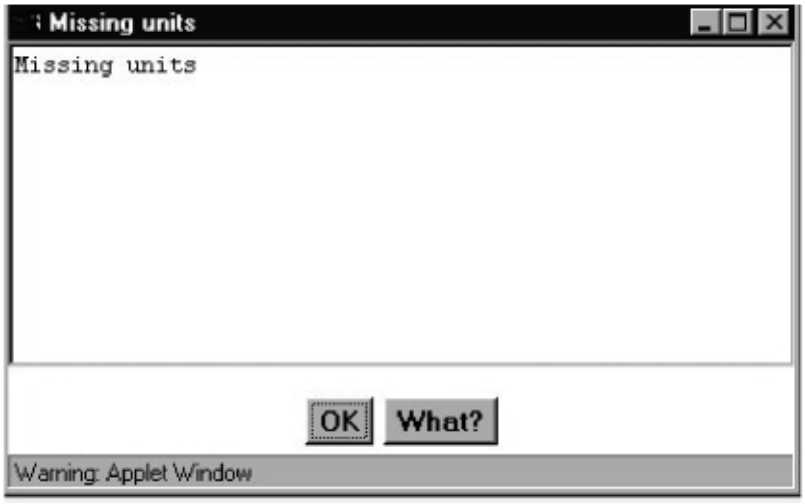

Fig. 2k.

```
ClearErrorList();
                // remember that the first "error" is the correct answer.
                LoadError(redloss, "W", "", "", 0, 1, 0, 0);
                // ans, units, title, message, severity, c0, c1, c2 [competence classes]
                LoadError(15497, "W", "own2.html", "Remember you have your own numbers for
                every problem; do not use the numbers from the paper tutorial.", 3, 2, 0, 0);
        }
```

Fig. 2l.

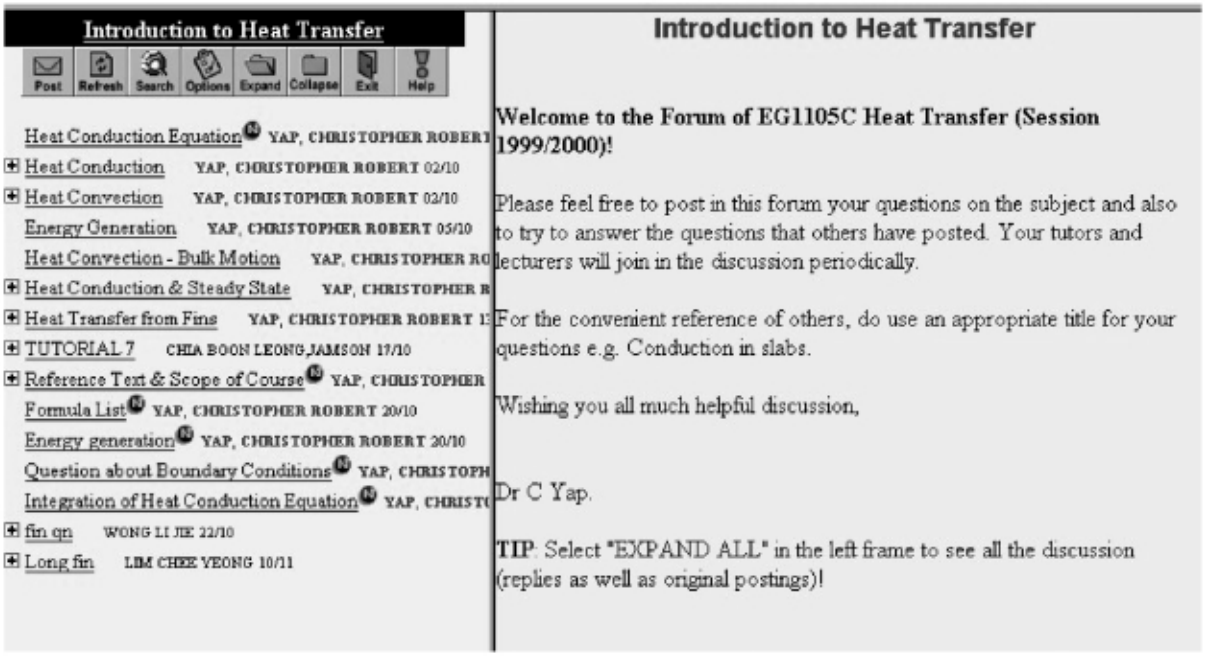

Fig. 2m.

though, allows for educators to customise the diagnosis to trap errors that they anticipate in any question. They can do this by changing some line of code in the source JAVA code for the questions. A portion of the above source code pertaining to error diagnosis is shown in Fig. 2l.

In this method, `ClearErrorList()` values in each error list may be provided to anticipate student's errors. In the above example, we have 'trapped' students who have merely copied the answers from the paper tutorial that they might have obtained. The answer in the paper tutorial was 15497 W (based on a different set of variables) instead of the correct answer. A message '`Remember . . .`' (full text shown in Fig. 2l) would then appear in a pop-up window. The

errors that educators can trap are endless and are only limited by the educators' knowledge and experience. With such detailed diagnosis available, students can actually learn from their mistakes. It adds to the total advantage of putting questions online in the education portal.

Other links sub-level

As for the other links page, these external websites would give students a world-view of the topics they are studying, through the examples in those websites. One such link would be the TEST educator website that contains excellent applets on thermodynamics. Other excellent links that may contain articles, applets and applications that may help them in understanding thermodynamics concept better are also presently online with more links to come whenever anything relevant has been found.

The contact page

Here in the contact page, there exists links for students to e-mail the relevant professors and the web administrator for any problems regarding the module and portal respectively. Another response channel is the forum that allows discussion between students and between students and educators. This would be beneficial as students can answer or post questions at their own free time and educators can answer them, also at their own free time. Besides the obvious benefit of not having to answer the same query repeatedly, educators also get to receive first-hand feedback from students who would normally not even speak out during lecture or tutorial since this way is much less intimidating. Only when further clarification is needed, students can meet face to face with educators. A wider reach and coverage is achieved.

Since there exists a good forum infrastructure from the IVLE (integrated virtual learning environment) in NUS, we have created a direct link there instead of creating a totally new forum. Here's how the forum cover page looks like if students clicked on the forum link (Fig. 2m).

A forum such as the above would promote teamwork, understanding and ability to see other peoples point of view especially when students help each other.

Search link

The search links up to search engines all over the Web. This is added as a matter of completeness so that students can go directly to search engines to find out further data and information that is related to the module but have not been included. The links are also consistent with the concept of providing a complete and integrated solution to an education portal.

FUTURE DIRECTIONS

A chat program where a certain time and date can be fixed for 'live' questions and answers session can be added under the contact page. This can be especially useful near exam periods. Educators need not be in the office the whole day to entertain students at different times but instead, can answer questions at one particular time within the comforts of his home even, in front of a PC.

Video conferencing can be added under the contact page to allow students and educators to talk and see foreign students and educators. Collaborations with other universities and educational institutions or even players who are industries which are related to the subjects can be called upon to give some kind of talk to add 'spice' to the teaching and learning experience.

VRML technology can be used to add 3-D animations to the multimedia section so as to enhance understanding by offering better 3-D conceptualisation rather than just 2-D applets. Virtual Lab technology developed by NUS can be added in the portal for specific experiments that comes under this module.

CONCLUSION

A prototype portal for teaching a Thermodynamics and Heat Transfer module (EG1105) has been described in this paper to illustrate the concept of an online integrated teaching approach using existing and new technologies. Detailed explanation of each technology has been given and reasons given for the usage of such technologies and how they offer certain advantages over and above existing methods of teaching, offline and online, has also been given. The successfulness of this concept can only be observed after the next semester is over (July to Dec 2000)

But regardless of success or not, it is important to note that this portal is created not to replace existing methods of teaching, online or offline, but rather to complement and reinforce them. The advent of the Internet and its widespread use necessitates such an approach to be developed so that a more streamline and comprehensive tool can be used in conjunction with existing teaching methods to benefit students and educators alike.

REFERENCES

1. The Expert System for Thermodynamics (TEST) Home Page: www.thermofluids.net
2. Brian J. Stone, A computer-assisted learning package for two-degree of freedom vibration, *ASEE Annual Conf. Proc.*, Session 2234, Canada (1994) pp. 1262–1266.
3. S. Hiranniah, M. A. Mannan and B. J. Stone, A web-based teaching approach for mechanical vibrations, *3rd Baltic State Conference*, Sweden, (1999) pp. 68–72.

4. N. W. Scott, S. Hiranniah, M. A. Mannan and B. J. Stone, Teaching one degree-of-freedom vibration on the WWW, to be presented for ASEE 2000, St.Louis, USA (2000).
5. M. A. Mannan and Sunil Hiranniah, Web-based systems for teaching, tutoring and assessment: current status and future directions, *Proc. ASEE IL/IN Sectional Conference*, Illinois, USA, (1999) pp. 143–148.
6. N. W. Scott and B. J. Stone, A flexible Web-based tutorial system for engineering, maths and science subjects, *Global J. Eng. Educ.*, **2** (1) (1998) pp. 7–16.
7. N. Scott and B. J. Stone, Continuous monitoring and class performance, *ASEE Annual Conf. Proc., 222002* (1998) pp. 1–7.
8. The World Wide Web in Education: A Closer Loo:. http://edweb.gsn.org/web.intro.html
9. IT in Teaching and Learning: Next big thing or next best thing: http://www.lgu.ac.uk/deliberations/seda-sem/it_teach.html
10. Sunil Hiranniah and M. A. Mannan, Using Java for developing engineering education software, *Sofware for Eng. Educ. J.*, **15** (1999) pp. 9–11.
11. P. J. Hicks, E. L. Dagless, P. L. Jones, D. J. Kinniment, F. J. Lidgey, R. E. Massara, D. Taylor and L. T. Walczowski, A computer-based teaching system for electronic design education, *Int. J. Eng. Educ.*, **13** (1) 1997, pp. 64–71.
12. Shelli Kay Starrett, A beginner's approach to teaching with the Internet*, ASEE Annual Conf. Proc.*, Session 2632, 1996
13. Anup Kumar, Julius P. Wong, Yung-Nien Yang, Herman R Leep, Hamid R. Parsaei, William G. Sullivan and Gerald J. Thuesen, A virtual learning environment for an engineering design course, Session 1639, *1996 ASEE Annual Conf. Proc.*
14. Randall Guensler, Paul Chinowsky and Christopher Conklin, Development of a web-based environmental impact monitoring and assessment course, Session 1658, *1997 ASEE Annual Conf. Proc.*
15. D. G. Devenish, R. D. Entwistle, N. Scott and B. J. Stone, An assessment package with diagnostic facilities, *Proc. Int. Conf. Computers in Education, Selected Applications Track Papers*, Singapore, December 1995, pp. 101–107.
16. N. W. Scott and B. J. Stone, The design of Java applets for vibration teaching on the WWW, 2000 ASEE Annual Conference.
17. B. J. Stone, A Review of some CAL initiatives in the UK (with particular reference to assessment), *Teaching and Learning Forum: A focus on learning*, Edith Cowan University, Australia, (1995) pp. 245–249.
18. Colin McCormack and David Jones, *Building a Web-Based Education System*, New York, Wiley Computer Publishing (1998) pp. 19–52.

Mohamad Ridwan is now an Analyst Programmer at the Center for IT & Applications, Faculty of Engineering, The National University of Singapore. He received his B.Eng. in Mechanical Engineering from the same University. Together with a team of programmers, he seeks to enhance the teaching and learning in the Engineering Faculty through the innovative use of Information Technology. His main area of work is in the development of Multimedia courseware, which are both interactive and dynamic. He is currently working on creating modular multimedia courseware and also taking charge of the live Web-casting for the faculty. When working on this paper, he was a Research Engineer in the Mechanical Engineering Department and was part of the department's project entitled, "Application of IT in Teaching, Tutoring and Assessment". Ridwan is also a recipient of the Best Technical Report Award in 1997 while undergoing his undergraduate course.

Christopher Yap is an Associate Professor in the Department of Mechanical Engineering, National University of Singapore (NUS). As a Colombo Plan scholar, Dr Yap obtained the degree of BESc with Dean's honors in 1975 from the University of Western Ontario, Canada. After completing his military service in 1977, he worked as a mechanical engineer in the Container Terminal Engineering Department of the Port of Singapore Authority (PSA). In 1980, he left PSA to join NUS as a Senior Tutor. He obtained the M.Eng. degree from NUS in 1982. Proceeding to the UK under a NUS post-graduate scholarship, he graduated from the University of Manchester Institute of Science and Technology with a Ph.D. in 1987. He then joined the Department of Mechanical Engineering at NUS as a faculty member. His main areas of interest, research and expertise are pertaining to turbulent heat transfer, numerical thermofluids and energy efficiency. He has also a keen interest in the teaching of subjects in Engineering. As a member of the Faculty, he has served in many committees including as Vice-Chairman of Teaching Methodology, Evaluation & Examination Committee, Faculty of Engineering (1993–95) and Chairman, E-Newsletter Editorial Committee, Department of Mechanical & Production Engineering (1999–present).

M. A. Mannan is an Associate Professor in the Department of Mechanical Engineering, National University of Singapore (NUS). He obtained his M.Sc. (Hons) in machine tools and manufacturing engineering in 1975 from PFU, Moscow on a Government of India scholarship. He joined the Royal Institute of Technology (KTH), Stockholm in 1975 and

has been affiliated with the same until 1994, where he held different positions such as research engineer, research associate, research scientist and associate professor. In 1987, the academic title of docent was conferred on him by KTH. He joined NUS in 1994 as a senior visiting fellow and was appointed as a senior lecturer in 1995. His research interests include metal cutting, metal forming, non-conventional machining, machine tools and fixtures, dynamics of machines, engineering acoustics, control and monitoring of processes and engineering education.