

# Increasing Student Involvement in Materials Engineering Service Subjects for Mechanical Engineers\*

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*The design and preparation of a series of interactive computer-based tutorials for first year mechanical engineering students allowed them to become actively involved in their learning as a means of overcoming the problems with large tutorial groups. The students were taking an introductory subject in materials engineering, and the tutorials led the students through a number of modules providing information, simulations and examples. The student response to these tutorials was overwhelmingly positive, although some negative responses suggested that some tutorials were too long. Some revision of these courses resulted in their length being reduced as a consequence.*

## INTRODUCTION

THIS PAPER DESCRIBES the development of a suite of computer-based tutorials as part of the teaching of an introductory subject, MATS9520 Engineering Materials, to first year mechanical engineering students. The School of Materials Science and Engineering provide this as a 'service' subject as well as similar subjects for students studying other engineering courses. Each year the class typically consists of approximately 250 students. The students receive two hours of lectures a week, plus six, two-hour tutorial/laboratory classes at fortnightly intervals throughout the fourteen week session. Tutorial/laboratory classes for this subject before 1999 consisted of approximately ten classes for groups of about twenty-five students. The class size inhibited student participation; the students were mostly inactive, while some were unable to see the laboratory demonstration clearly. Because students might see the service subjects as peripheral it is particularly important that they engage the students and involve active participation. In such an environment, where students are passive and uninvolved in their learning, they often adopt attitudes consistent with 'surface' learning [1]. Achieving engagement and participation is more difficult because of the large class sizes that occur during these courses.

There was a review of the laboratory and tutorial classes to improve the learning experience of the students. The review revealed a need for the

students' active involvement in their learning and that achievement of this was possible with the use of both smaller groups and interactive computer-based tutorials.

Financial considerations inhibit sub-division of laboratory classes into very small groups (typically less than six), where students would perform extensive hands-on laboratory work. Such small groups would increase the demonstrator cost four-fold and make running the subject economically unsustainable.

An alternative method, dividing the original group of twenty-five into two groups of about twelve, increased student activity during the two-hour period. Each sub-group would then perform a one-hour computer-based tutorial and a one-hour laboratory activity. While one sub-group was doing the tutorial the other would do the laboratory, and vice-versa. In the computer-based tutorial each student would work individually on a computer, with guidance available from a tutor. By having half the group active at computers the group size in the laboratory activity was small enough to promote active involvement of all the students in the group.

The approach adopted was to develop interactive computer tutorials where students would navigate their way through pages of an interactive program, with each tutorial designed to take about one hour to perform. Students would have a number of assessable questions to answer, entering their responses in as part of the tutorial with the answers submitted electronically.

Similarly, redesign of the laboratory activity allowed students to perform activities that

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involved much greater hands-on participation than in previous years. In each case the material covered in the computer tutorial and laboratory activity was complementary, with theoretical aspects covered in the tutorial being demonstrated in the laboratory component. Design of the two exercises was such that it did not matter whether students performed the computer-based tutorial or the laboratory exercise first.

It is also possible to use computer-aided instruction for higher levels of learning, rather than simply knowledge recall [2], for example, by structuring assessment to require the application and evaluation of concepts. It offers a dynamic learning environment, where the student is interacting and initiating the learning process. This can enrich the learning experience [3]. Thomas lists a number of benefits of the use of such computer-aided packages, which he suggested applied the principles of mastery, or competency-based, learning [2]. These included a shift in the control and responsibility of learning from teacher to student, active participation by the learner, the ability to cater to individual differences in students' learning styles and the provision of rapid feedback to students. Furthermore, the role of the teacher/demonstrator shifts from providing didactic instruction to acting as a guide, characteristics often associated with the promotion of 'deep' or relational learning [1].

A number of universities already use multimedia and interactive tutorials and have found them beneficial. Included among the reported benefits were that students required less assistance from academic staff, were able to develop self-learning, and were able to set their own learning pace [4–6]. Aldeen and Bork in 1996 predicted an increase in the use of interactive multimedia curricula because it gives lecturers more time, reduces costs and because it provides students with a

learning experience that is flexible, individualised and self-paced [7, 8].

This paper describes the computer tutorials and laboratory activities developed for this course in addition to detailing the intranet-based approach to assessment and feedback. The response from students, demonstrators and academic staff to this new laboratory/tutorial structure follows. Finally, the paper includes discussion of some suggested improvements, based on our experiences.

## METHOD

### *Interactive computer program*

'Engineering Materials', the interactive computer program specially written for the Engineering Materials course, was based on the concept used in an earlier series of computer based teaching modules, 'Microstructures of Engineering Materials' as described by Kofod and others. [9]. The primary intention was for the authors' school to use the program 'Introduction to Materials' as a tutorial during laboratory classes and as a learning resource for students out of class hours. Workstations in the computer laboratory allow student access to the program, with the future possibility of web access, and the program runs without either video or sound components to avoid distraction of other users in a tutorial class setting, although these features could be added in a future development of the program, if required.

The designers used Macromedia Authoring tools 'Authorware Professional' and 'Extreme 3D' to create the program, manipulating image and text with Adobe Photoshop and the Microsoft Office Suite. Bearman [10] reviewed the various authoring tools available for computer-aided instruction, and concluded that Authorware was highly appropriate for the production of teaching

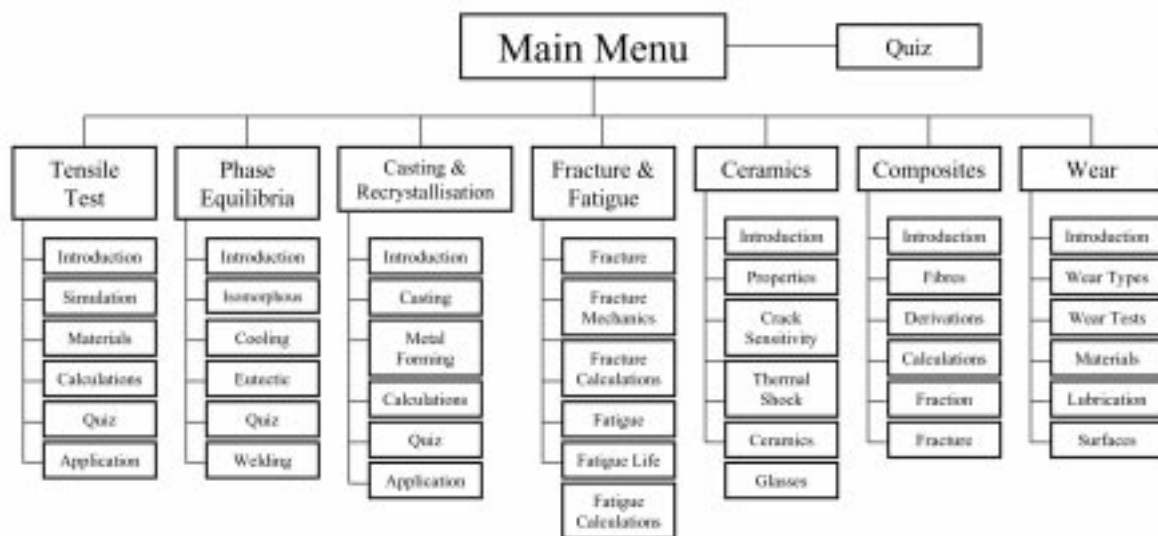


Fig. 1. Schematic Flowchart of the Content of Introduction to Materials.

programs due its ease of use, flowchart-based design and ready ability to modularise products. Although the application runs on the Windows 95/NT platform, it is readily adaptable for Microsoft Windows 3.1 and Apple Macintosh platforms if required, and is recommended for authors without programming expertise. Students undertook the computer tutorials in a dedicated computer laboratory that contains fourteen networked PCs.

To ensure that the content of the computer program complemented the lecture material and laboratory experiments, the designers based the instructional design and technical content of the program on the existing lecture and tutorial material for the Engineering Materials subject, course textbooks and reference books [11–15]. Each tutorial consists of six modules designed for completion by the student within one hour and relates to one laboratory concept. To maintain variety, the design provides a choice during any one year of six topics from the suite of seven shown in Fig. 1.

In addition to the basic material, the program includes a separate 'quiz' module incorporating all seven topic areas, which students can use to test their understanding of each tutorial topic. They can use this if they complete the set tutorial within the tutorial hour or if they want to test their understanding at other times. This quiz module gives students immediate summative feedback, helping them to evaluate their progress in the subject. Each module also provides a glossary of terms relevant to the seven topics in the program.

The design of the tutorials enables them to function as linear programs, (Thomas [2]), with information presented in short sequential segments, where students respond to cues or questions. In the tutorial sessions, students follow a specific sequence, using the main menu to access the tutorial menu before selecting the required tutorial. Students then work through the modules for that tutorial at their own pace, reading and interacting with the text and diagrams and in many cases receive immediate feedback to their responses. Figure 2 shows the tutorial menu for the tensile test tutorial while Fig. 3 shows a typical page of the tutorial. The designers took particular care to ensure that navigation is straightforward and instructions on how to proceed are clear. The introductory module for each tutorial explains its objectives so that students understand clearly what they are expected to have gained from each tutorial and its assessment criteria. A demonstrator, (usually a research student), supervises students during each tutorial session in the computer laboratory, assisting them with any navigational or computer problems and providing assistance with materials-related questions.

By way of illustration, the tensile test tutorial has six modules, (Fig. 2), and each module is typically six to ten pages in length.

- **The Introduction Module** introduces the basic concepts of tensile testing, showing the tensile testing apparatus schematically and illustrating the experimental data output as load-elongation curves.

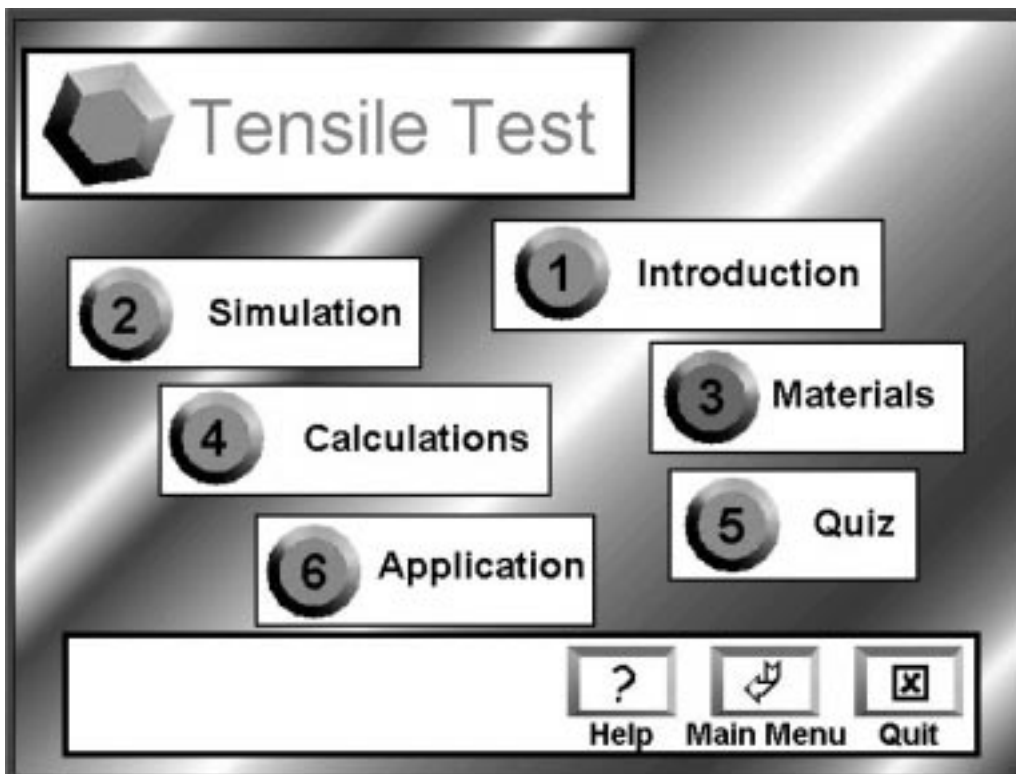


Fig. 2. Tensile Test Module Menu.

3
Materials

Click on each material to see its explanation and then move to the next page.

Now that you have compared the shape of the tensile curve of different materials, please click on the different materials below to examine reasons for the characteristics of the curves of five types of materials:

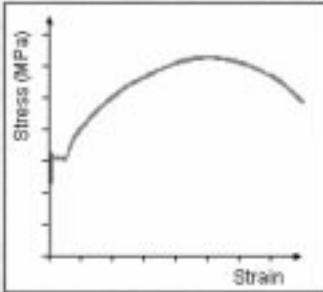
Non-Ferrous Metals

Mild Steel

Polymers


Ceramics


Composites





Some steels and other metals have a standard metal tensile curve, but also have an area at the yield point where stress does not increase continuously as strain increases. This is known as discontinuous yielding, or the yield point phenomenon, and is due to carbon and/or nitrogen atoms in the lattice.


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Fig. 3. Typical page content from the Tensile Test module.

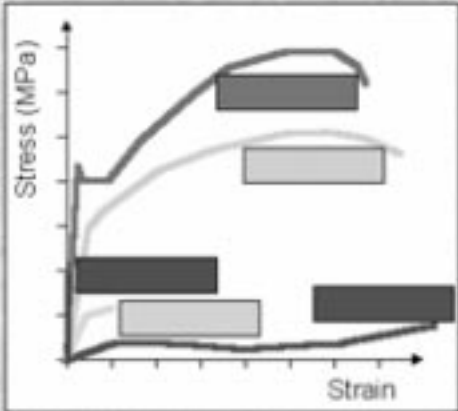
- **The Simulation Module** demonstrates the tensile test showing the changes in microstructure and specimen shape simultaneously with the relative position of the tensile curve, and explains the different regions of the tensile curve.
- **The Materials Module** compares the tensile curves of different materials, and asks students to connect different materials to the appropriate tensile curve in an assessable question (Fig. 4).

3
Materials

Marked Question

Please read the text and drag the labels to the correct box. Then click the submit button.

Please drag the labels below to the correct rectangle on the graph. Once you believe you have the correct labels, press the submit arrow button.




Styrene

Mild Steel


Fibreglass


Glass


Aluminium


Submit  



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Fig. 4. A drag and drop question from the tensile test tutorial.

- **The Calculations Module** shows students how to use a tensile curve to calculate different properties.
- **The Quiz Module** has assessable questions that ask students to identify different regions of the curve and to make appropriate calculations.
- **The Application Module** is a non-compulsory module that asks a number of non-assessable questions (with immediate feedback) to enable students to understand how to use tensile test data in practical situations.

Marked questions forming part of the student's overall subject assessment are spread throughout the modules, with the number and type of questions varied for tutorial. Questions take a number of formats, including text entry questions (both numerical and text entry), multiple choice questions, prediction questions and 'drag and drop' questions and not only test the application of formulae and the explanation of phenomena, but also application of knowledge to *real* situations. For example, in the ceramics tutorial, students are asked to predict which of three ceramic specimens will fail first (the flaws appear schematically on each specimen and vary in size and number). Questions that involve the prediction of phenomena help to test and promote learning objectives such as application, analysis and evaluation. These objectives occupy the higher levels in taxonomies of educational objectives, such as those published by Bloom and co-workers [16].

Figure 5 shows a typical 'drag and drop' question from the tensile test tutorial that asks students to label a tensile curve with the various measures of strength and modulus obtained from a tensile curve. Students drag the four labels to the boxes on the graph, and press the submit button. The program then indicates how many were correct and, if necessary, the labels move to the correct positions to indicate the correct answer, so that students receive immediate feedback on their answer, including the correct response if they have made errors. Many consider rapid feedback to students to be highly beneficial in improving student learning [2, 17].

In some of the questions, such as, for example, in the 'drag and drop' questions described above, students receive immediate feedback. However, tutorials do not immediately display correct answers to short answer or numerical questions to prevent 'copying' of other student's responses in the tutorial class. However, the optional quiz module has non-assessable questions that all give immediate summative feedback for students to gauge their understanding of the seven topics. In another measure to prevent 'copying', the quiz module asks five randomly selected questions for any given numerical question.

A networked database records the results from the tutorial questions to enable markers or lecturers to access the results electronically. Although the computer marks both 'drag and drop' questions and multiple-choice questions, the tutorial demonstrators currently mark typed

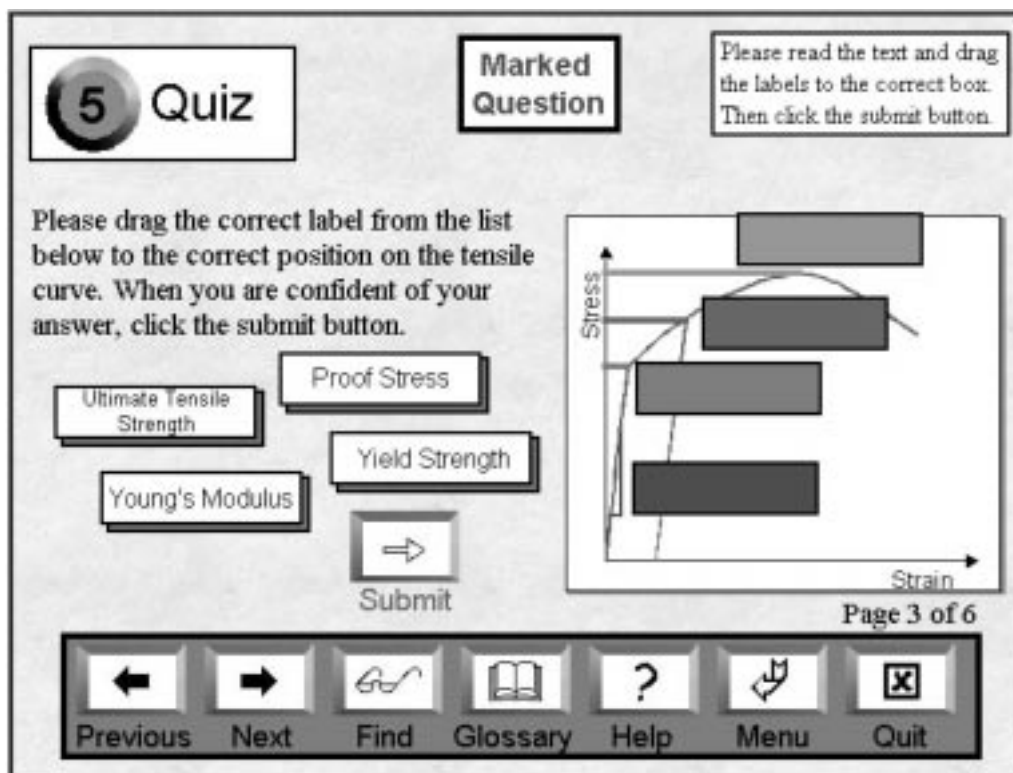


Fig. 5. A drag and drop question from the tensile test tutorial.

responses manually and return them to the students in hard copy form. One advantage of students submitting electronic answers is the use of a predictable format with the correct answer next to the students' answers, making them straight-forward for marking by demonstrators. The marker also does not have to decipher illegible handwriting, and the results are all in the same format. This allows more time for demonstrators to give students more detailed written feedback on their answers. Marking by demonstrators also overcomes any problems that occur through incorrectly keyed responses [18] in computer marking. The program offers future possibilities of complete computer marking and therefore more immediate marking and feedback systems

#### *Laboratory exercise*

The approach taken with the laboratory exercises was to shorten them from two hours to one hour by moving the previously given theoretical explanations to the interactive tutorials and by reducing the group size to twelve, giving the students as much involvement in the exercise as possible. The students can now use the laboratory period to concentrate on phenomenological experiences. For example, having fewer students per group allows each student to view specimens in microscopes or to perform thermal shock experiments on glass slides individually.

As stated earlier, the aim was for the computer tutorial and practical exercise to complement each other. For example the tensile test computer tutorial gave a general background to tensile testing, compared different materials using a simulated test, and demonstrated the calculation of a number of properties based on the test results. In the related laboratory exercise, students carried out tensile tests on three materials, compared the resulting curves and calculated the properties from the curve. In this way, students gained hands on involvement in the tensile test by measuring and loading specimens.

The results were interesting: although demonstrators of the laboratory exercise found little difference in the tutorial group if the laboratory was held before or after computer tutorial, three out of four computer tutorial demonstrators thought that the students were better able to complete the computer tutorial *after* they had performed the practical experiment.

### OUTCOMES

Completion of four interactive computer tutorials allowed initial trials during MATS9520 Engineering Materials students in Session 2 (July to November), 1999, with students surveyed at the conclusion of each tutorial and also at the conclusion of the final laboratory session.

Marking was on the basis of:

- strongly disagree 1
- disagree 2
- agree 3
- strongly agree 4

in response to each of the following statements:

- I finished the tutorial in 1 hour
- I understood the tutorial
- The tutorial presentation was good
- I understand the topic better as a result of the tutorial

A mark of 4 therefore represents 100% of the sample strongly agreeing with a statement.

Table 1 shows the survey data from over 200 students that were surveyed interactively at the conclusion of each computer tutorial.

Their response was, in the most part, positive towards the computer tutorials and laboratory exercises. Results for each individual tutorial showed that students were very positive about the tutorial, they generally understood it and felt that they had learnt from it. Students were particularly positive about the phase equilibria tutorial, a topic that students had hitherto found difficult. The style of learning suited this topic particularly because it enabled schematic display of phase changes simultaneously with the temperature change on the phase diagram. The average 'score' for the phase equilibria tutorial was between 3.3 and 3.4 for all questions and over 90% of students gave positive responses for each of the questions in the survey, as shown in Table 1.

Table 2 provides a summary of the statistics from the survey after the final laboratory, which asked students to provide feedback on their overall impression of the laboratories and tutorials run throughout the session. This interactive survey used a program created in Authorware and occurred at the conclusion of the final computer tutorial. The survey asked students about the relationship between the computer tutorial and practical exercises, the structure of the tutorials, whether it improved understanding or knowledge of materials, the amount of work, and the overall tutorial presentation. The survey also asked students about whether the subject had changed the way they thought about materials. The results of this survey gave an average of 2.8–3.1 for all categories with over 85% of students providing positive responses about the content, structure and presentation of the tutorials and laboratory exercises. However, 71% of students indicated through the survey that the tutorials generally contained too much work to get through in one hour. About 15% of students also added written comments that some tutorials (particularly the composites and ceramics tutorials) were too lengthy.

The survey also asked for written comments from the students. A large number of students made typical comments such as: '*It was very helpful*

Table 1. Results of Tutorial Surveys.

<b>Tensile Test Survey</b>		
Question	Average % Positive Answers (Agree/Strongly Agree)	
I finished the tutorial in 1 hour	2.8	67
I understood the tutorial	3.1	85
The tutorial presentation was good	3.2	89
I understand the topic better as a result of the tutorial	3.2	88
<b>Phase Equilibria Survey</b>		
Question	Average % Positive Answers (Agree/Strongly Agree)	
I finished the tutorial in 1 hour	3.4	90
I understood the tutorial	3.3	93
The tutorial presentation was good	3.3	92
I understand the topic better as a result of the tutorial	3.3	93
<b>Composites Survey</b>		
Question	Average % Positive Answers (Agree/Strongly Agree)	
I finished the tutorial in 1 hour	3.0	76
I understood the tutorial	2.7	66
The tutorial presentation was good	2.9	79
I understand the topic better as a result of the tutorial	3.9	74
<b>Ceramics Survey</b>		
Question	Average % Positive Answers (Agree/Strongly Agree)	
I finished the tutorial in 1 hour	2.8	67
I understood the tutorial	2.9	78
The tutorial presentation was good	3.0	83
I understand the topic better as a result of the tutorial	3.0	80

and educational', and 'Useful and well presented', although many students also added more detailed, comments, such as:

*The computer tutorials were good however more time is needed to fully understand some of the concepts presented in them. They are a great way to learn; however more time is needed for them.*

Revision of the tutorials occurred subsequent to the survey with the amount of text presented in the tutorials being reduced, and some mathematical derivations of formulae being simplified. Similarly, many students with English as a second language found the text was too much to get through in one hour. To combat this problem, students were allowed access to the text and diagrams of the tutorials on the web before coming to the laboratory/tutorial. One response to this initiative said:

*The computer tutorials were very useful in helping to understand the topic. It was much easier to get through the tutorial if the notes were read over first, and this was possible when they were published on the internet before the tutorial*

Responses to learning in an interactive computer environment were positive. Students commented:

- *I thought the lectures dragged on a bit and were hard to follow, however I found the computer tutorials particularly helpful as I could follow the material in my own time. Whenever I didn't understand anything I could click back to read over it again.*
- *. . . they really do help and they give a much clearer understanding than just reading about the subject or even listening*
- *The tutorial provided innovative learning*

Table 2. Results of Final Student Survey.

Question	Average % Positive Answers (Agree/Strongly Agree)	
The tutorials and laboratories complemented the lecture material in this subject	3.0	86
The structure of the computer-based modules was logical	3.1	88
The tutorials and laboratories helped improve my understanding of the subject	3.1	87
The tutorials and laboratories made me think about the way materials behave	3.0	85
There was too much work to get through in the tutorials and laboratories	2.8	71
The computer-based modules were well-presented	3.1	88

- *Use of computer tutorials was a pleasant change from usual question and answer tutorials of other subjects.*

Students were able to relate different strands of the course material to each other, and found that the lectures, computer tutorials and laboratory exercises all complemented each other. Students commented:

- *Tutorials and laboratory exercises] reminded me of material covered in lectures*
- *Often the computer tutorial would clarify the lab if it wasn't understood during the lab*
- *Good in-depth presentation of lectures along with helpful tutorials and very relevant laboratory work which allows one to see things learnt in lectures actually in real life.*

The tutorials also gave the students a greater appreciation of 'materials engineering'. Student comments were:

- *Gave a good practical understanding of the way materials behave*
- *I am more interested in materials engineering.*

The comments made by these students are consistent with the theories of competency-based learning, which suggest that this form of instruction promotes greater student interest in course material [2].

Students also requested guidance on navigation through the tutorial, the location of questions and on which questions would be assessed. A number of later additions to the program made it easier to use and gave students more guidance. A demonstration model enabled students to become familiar with the navigation techniques before the first tutorial so that they could find their way easily. Inclusion of a list at the beginning of each tutorial, showing the number of questions and the location of each question gave students an understanding of the tutorial's requirements and distribution of questions. The program now includes a sign at the top of the page, (Fig. 4 and 5), to indicate when the student is answering an assessable question.

Demonstrators were almost unanimously positive about the changes to the laboratory exercises and tutorials, giving similar responses to the students. One suggestion to improve the correspondence of computer tutorials to the laboratory exercises was to include schematics from the computer tutorials in the handouts for the laboratory exercises.

Three other outcomes of these tutorials were unexpected:

1. After the first tutorial the students realised they had only an hour to complete the computer-based tutorial. The students' punctuality increased significantly thereafter.
2. Overseas students, many of whom encountered difficulties with spoken English, found the computer modules very useful as they could work through the information, which was often complementary to the content of lectures, at their own pace. One such student commented:

*'Tutorials were more interesting than just listening to the lecturer/lecturers talk too fast, and in the tutorial it was possible to go back and read it again'*

These students indicated that by working through information presented in this way, their learning was less dependent on verbal presentations given in lectures.

3. The smaller group size in the laboratory exercise improved the concentration and behaviour of the students.

There is an opportunity to expand this approach to other service subjects taught by the School.

Authorware allows easy modification to tailor content to individual subjects and the tutorial and module approach will allow selection of different tutorials and modules for each subject. It is possible that other schools that teach a significant number of service subjects, such as physics and chemistry, could also adopt this approach.

## SUMMARY

The change to the laboratory and tutorial structure in MATS9520 proved to be very successful. Students felt that they understood materials better as a result, and were able to perform more hands-on work. The responses indicated that it is important to avoid making computer tutorials too long, and provision of the text on the web before the tutorial is also helpful. It is also necessary to provide 'instructions' on how to use the program when students start. The application of this style of teaching would be appropriate to a number of similar subjects.

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**Robin Ford** is Associate Professor and Director of Teaching in the School of Mechanical and Manufacturing Engineering, having joined that School in 1977 after seven years in the aerospace industry. He is particularly interested in ways of encouraging each student to see their engineering education as an important part of their current 'real world', not something to be gone through merely to get a qualification. Increasing the engagement of students in their studies, for example by measures of the kind described in this paper, is a vital part of this.