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The Effectiveness of Teaching Introductory Electronics in an Integrated Teaching Studio Environment*

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City University of Hong Kong has initiated a studio approach to teaching, starting with modules in introductory science and engineering. Studio teaching replaces the traditional large-group lecture, small-group tutorial and separate laboratory work with an integrated approach. It utilises computer-based teaching materials that emphasise multimedia and interactive learning. This paper describes the introduction of studio teaching for an introductory electronic engineering course designed for first-year Mechatronics Engineering degree students. The initial results for assessing the effectiveness of this type of teaching method are presented.

INTRODUCTION

CURRENT TEACHING methodology in Hong Kong is oriented toward lectures and written examinations, and encourages only passive learning and regurgitation. This approach is ineffective for today's students. In addition to a specialised knowledge, the current job market often demands skills (communication, cooperation, leadership, and interpersonal skills) that are taught poorly in a lecture-based format.

Cognitive research also indicates that real learning and understanding are better accomplished through cooperative and interactive techniques. Furthermore, being brought up in an era of TV and video games, today's students have limited attention span but they respond well to multimedia stimuli and interactive activities. To counter the trend of declining student interest in science and engineering courses and to keep pace with advances in information technology, pedagogical reform is urgently needed.

Rapid advancement in technology not only revolutionises the way research in science and engineering is conducted but also the way knowledge and information are communicated. In response to this advance, educators must rethink the content of the science and engineering curricula and reconsider the environment and the materials with which students learn.

There are clearly needs for new teaching materials and methodology that encourage different modes of learning. In recent years, as networking, multimedia, mobile technology, and better software converge, educational institutions are discovering new ways to improve learning, increase information access, and save money [1].

City University of Hong Kong (CityU) has initiated a studio approach to teaching, starting with modules in science and engineering, especially those at the introductory level with large enrolment. Studio teaching is a teaching methodology that emphasises cooperative and interactive learning, using multimedia courseware. It is designed to accommodate the increasing diversity in student background, expectation, learning style and pace.

To adopt the studio approach in teaching science and engineering courses, a learning environment is needed that combines lectures, tutorial discussion, problem-solving activities, and laboratory experiments into an integrated teaching studio (ITS).

In particular, a learning environment is needed that fully utilises computer technology, since sophisticated but inexpensive computer hardware is now available, and computer-based teaching materials that emphasise multimedia and interactive learning are being developed in the UK and USA. Preliminary results indicate that the studio format is an effective teaching/learning environment.

STUDIO TEACHING

Studio teaching is a teaching methodology originally developed for introductory physics courses at Rensselaer Polytechnic Institute (RPI), New York, USA [2, 3]. RPI is a research-oriented university with a strong reputation for quality undergraduate education and innovative teaching. Studio teaching typifies changes in approaches to science and engineering teaching that are being widely discussed and adopted in a number

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of leading institutions. Most of RPI's first-year courses have been converted to studio teaching format, not only in science and engineering, but also across the whole university curriculum.

Essentially the methodology replaces the traditional large-group lecture, small-group tutorial and separate laboratory format with an integrated studio approach which is claimed to be both economically competitive and educationally superior. The focus is on student problem-solving rather than presentation of materials. The emphasis is on learning rather than teaching.

THE INTEGRATED TEACHING STUDIO (ITS)

The philosophy behind the studio teaching format and its ingredients may be summarised as follows. Learning is more effective:

(a) by doing (mini-labs, exercises);
(b) by interactive and cooperative techniques (discussion and group activities);
(c) if more of the senses are engaged (interactive multimedia courseware);
(d) by immediate application and follow-up (in-class assignments).

To adopt the studio approach to teaching, the classroom must encourage extensive interaction amongst students and between students, staff and teaching assistants. The ITS is a specially equipped classroom that combines the traditional approaches in lectures, tutorials and laboratories in an integrated environment enhanced with interactive multimedia learning. Laboratory-based material, instrumentation, simulations and demonstrations are integral parts of ITS.

The two ITSs at CityU house up to 60 students, with 30 worktables. Students sit in pairs at worktables, each of which is equipped with a multimedia workstation [4]. Depending on the class, various interfaces can be plugged into the workstation to provide a virtual laboratory environment.

To eliminate the obstruction of views by workstation monitors and to maximise flexibility in space utilisation, the workstations are embedded beneath the table tops so that the studio can also be used for traditional lectures if necessary. In one studio, the student tables are arranged in an open configuration that facilitates student/student interactions and the circulation of instructors about the room. In the other a more traditional arrangement is used. One studio places the monitors within the desks, so that a completely clear desktop is available; the other uses flat LCD displays that can be folded down to achieve a similar result.

At the front of the studio, to one side, is an instructors' desk housing a workstation, as well as a full-colour visualiser. The outputs from these can be viewed on two high-resolution video projectors. (There is also a conventional overhead projector available.)

The workstations are high-end personal computers linked by a local area network and connected to a server. This has access, via the university intranet, to the Internet/WWW, and/or other terminals in the university.

COURSEWARE FOR ELECTRONICS

A number of courseware packages are available on the market that are aimed at first- and second-year electronic engineering, and related, students. CityU has taken the view that if there are good, well written packages on the market, then it is not necessary to write anything new. After a market survey it was decided that the Electronic Design Education Consortium (EDEC) courseware would cover 80% of the introductory electronics syllabus.

EDEC is part of the Teaching and Learning Technology Programme, a major initiative of the UK Higher Education Funding Councils [5]. Formed by 8 universities in the UK in 1992, EDEC is dedicated to the production of computer-based teaching and learning material to support the education of electronic engineers and computer scientists. CityU was one of the first universities outside the UK to use EDEC courseware. At the same time, CityU has worked closely with EDEC on the further development of courseware, as well as investigating the possibility of designing bilingual components, laboratory-based modules and the transfer of the CD-ROM-based software to the Web [6, 7, 8].

The EDEC courseware only provides a framework for the 'lecture' part of the teaching. Although there are some self-assessment tutorial questions within the EDEC software, it is rudimentary stuff. However, the self-study workbooks are very good.

Consequently, the tutorial part of a studio session is carried out in a traditional way, with pen and paper, even if the questions are on the screen. Any courseware-based tutorials are therefore supplemented by paper exercises.

The EDEC courseware covers about 85% of the first semester course, and 65% of the second semester of the Basic Electrical and Electronic Engineering course. The gaps are in introductory circuit analysis and introductory machines. Packages that can fill these gaps are currently being evaluated, although so far finding any courseware that can compare to the EDEC programs has been singularly unsuccessful. There is the possibility that some courseware may have to be originated at CityU and RPI to overcome this problem.

The modularity of the EDEC courseware, coupled with the ability to customise the presentation sequence of the material, makes it ideal for an integrated teaching studio application. A complementary project [7] will enable the EDEC courseware to be available over the web and not just on standalone machines.

Introducing laboratory content

The lecture course follows very closely that given by traditional means to the first-year Manufacturing Engineering Degree students. This means that any laboratory content must be similar, as assessment, including examinations, tests, coursework, etc. are common to both courses.

The first-semester experiments on the traditionally presented course include a simple low voltage transformer, maximum power transfer, simple proof of circuit theorems, such as superposition, and simple diode characteristics.

The second-semester experiments on the traditionally presented course include the operational amplifier, logic circuits, SCR and an introduction to DC machines.

A number of institutions involved with the development of laboratory-based studio teaching [9, 10], use 'real' instrumentation to carry out the experiments. At CityU this was not possible, as one of the ITSs is a university resource, the other a faculty resource. As they are not a departmental resource, this means that one lesson may be used for EE, the next for management and the next for physics. Consequently there is not enough time between classes to move large amounts of equipment around, or even have a technician present.

It was therefore necessary to design a laboratory course that could rely on the only equipment available all the time—the PC. Unfortunately the standard PC does not have the facilities for doing anything useful externally. Some commercially available interfaces, such as the Universal Laboratory Interface (ULI), as used by the Department of Applied Physics and RPI for their laboratory-based courseware, make use of the serial port, but this limits the number of items that can be connected at any one time, as well as the bandwidth of any signals used.

The interface

After much searching it was decided to use an interface card produced by Eagle Technology in South Africa. The particular board, the PC30GA [11], has 16 A/D inputs and 24 programmable digital I/O lines. The board can support 16 single ended or 8 differential inputs, and 4 analogue outputs. This allowed 8 peripherals to be simulated, namely a dual-beam oscilloscope, two signal generators, two DC power supplies and two digital voltmeters.

Limitations in the 100 kHz sampling speed meant that the useful frequency range was limited for the signal generator and the scope, but that was a small price to pay compared with the flexibility offered. (By the way, the board is far more 'open' and comprehensive than many popular boards on the market and at a fraction of the price.)

Having chosen an interface that could do all we wanted, we now had to find some software to drive it. It's unfortunate that LABView, and other similar software, forces you to use proprietary interface hardware. On the other hand, some other programs are more 'open'. Test Point, from Capital Equipment Corporation (CEC) [12] was chosen. Eagle Technologies provide a good interface for this laboratory simulation package; at the same time, CEC will let you have a site license and use run-time versions of any programs generated, unlike some other companies.

The cost considerations were an important factor in choosing the software and hardware for the ITS. There are 30 workstations in use, so at least that number of interfaces and programs were needed. Any supplier offering site licensing as well as an 'open' configuration would have an advantage over those trying to tie users to a proprietary configuration.

The experiments

It was quite clear that, with the limitations on current and voltage imposed by using an A/D, D/A interface, that most of the experiments in the traditionally taught course would have to be modified or replaced for a course taught in the ITS. For example, the diode used in the diode characteristics experiment would overload the current limit of the D/A as soon as it switched on. Other experiments are just not possible with the a simple PC-based system, for example, the SCR and DC machines experiments.

The DC power supply is limited to ± 10 V, the current to 500 mA, and the frequency limit of the 'scope and signal generators is around 2 kHz for any meaningful measurements. However, even within these limitations it is possible to design quite useful experiments.

Figure 1 shows a workstation in the original ITS. To make the connection to the computer interface card a special interface box was designed. This gives the inputs and outputs for all the instruments using the same connectors as real instrumentation.

Traditionally taught first-year EE lab at CityU uses breadboards and components for the experimental work. It was decided to design the ITS-based experiments in the same way. Figure 1 also shows the breadboard that is used to carry out all the experiments connected to the interface box. This gives students the opportunity to learn about colour coding etc. which they would not be able to do if a pre-wired chassis were used. Each experiment has all its components separately packed in a small polythene bag.

The Test Point software was used to generate the screen GUI for the power supply, DVM, 'scope and generator. Figures 2–5 show the power supply, DVM, 'scope and signal generator screens. All screens were designed to make them look as close to normal bench equipment as possible. This included pulling rotating knobs with the mouse.

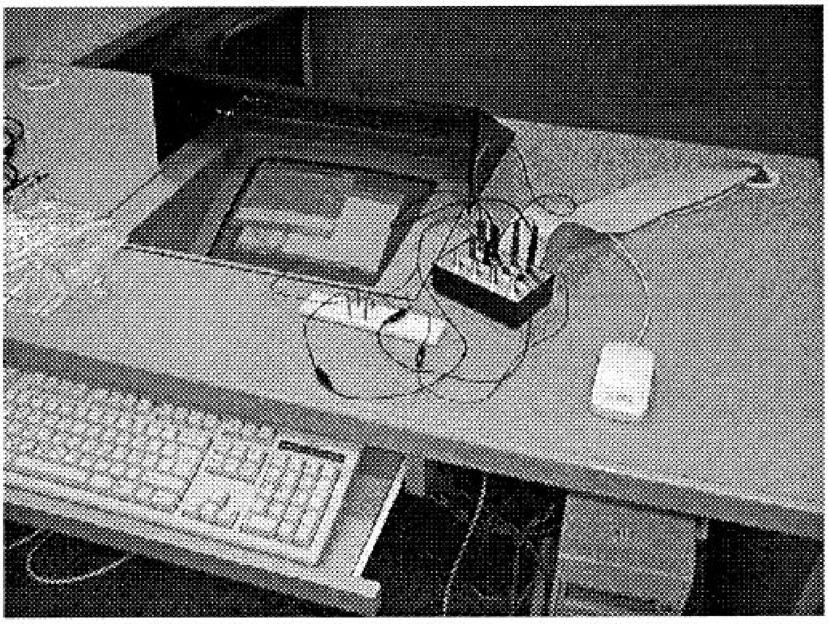

Fig. 1. The workstation showing interface box, breadboard and screen.

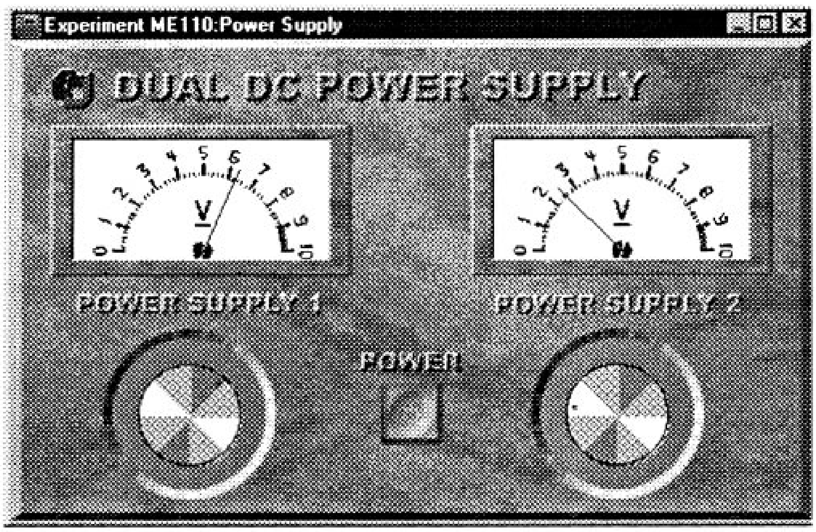

Fig. 2. Dual power supply GUI.

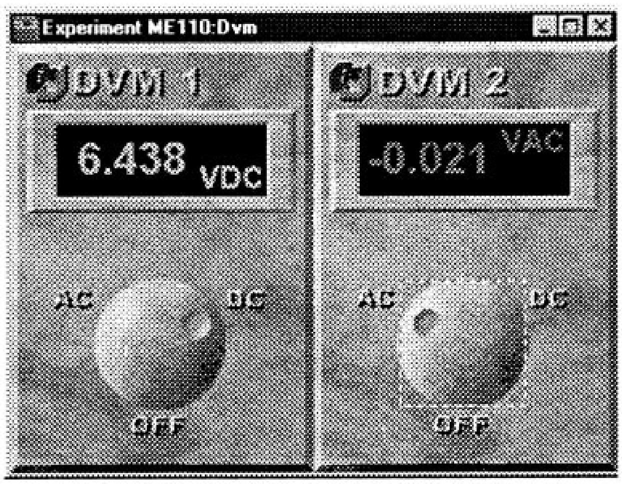

Fig. 3. Digital voltmeter GUI.

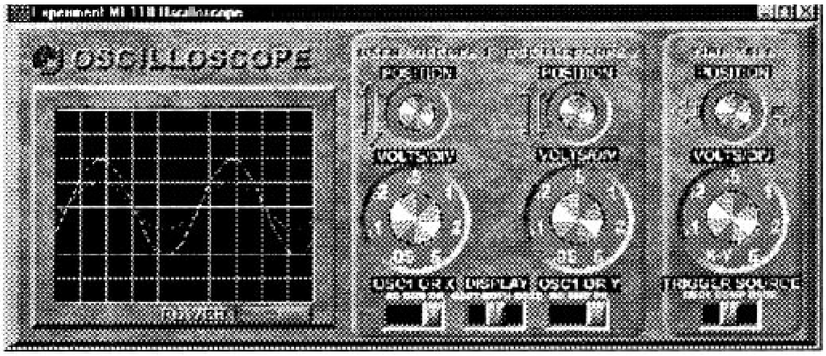

Fig. 4. Oscilloscope GUI.

The laboratory manual

The traditional laboratory manual has been replaced by an on-line manual. This sits on-screen in a separate window to the instrumentation screen. Some of the hyperlinks in this manual refer to sections of the presentation/tutorial courseware, such as the EDEC modules. It is possible, therefore to link the experimental work screen directly to the lecture and tutorial material.

Figures 6–9 show typical screen dumps for the manual. These follow a format that will be used by other lab courses when their lab manuals are put on-line and is designed to fit the full page when the frame is translated to WWW format for future use. This will supplement the current program which is on the university intranet only.

EFFECTIVENESS OF THE TEACHING PROCESS

Very little work has been published on the effectiveness of studio teaching. Part of the research associated with this project is to develop ways of measuring its effectiveness. It was decided to start a three-year longitudinal study of students in the first year of the Department of Manufacturing and Engineering Management (MEEM) at CityU. All students on the Mechatronics Engineering (MTE) and Manufacturing Engineering (ME) degrees take a compulsory introductory electrical and electronic engineering course in their first year. The MTE students continue with electronics, which takes up 25% of their degree. The ME students have one more semester of microprocessor work in the first semester of their second year, and then do no more EE at all.

The class sizes vary, being 40 in the MTE degree and 80 in the ME degree in 1996/7, 40 and 60 respectively in 1997/8, and approximately 40 in each in 1998/9. To try and evaluate the ITS approach the classes were split and the MTE students were taught the course in the ITS, with the ME students taking the more traditional route of lectures/tutorials and labs. The syllabus was the same as were the teaching staff and exams/tests/tutorials questions. Only the mode of teaching varied. Analysis of the student's entry requirements to both courses also showed significant comparability in the beginning, but becoming slightly divergent in the current year. The difference is probably statistically insignificant, but further analysis of the entrance qualifications is needed to make a quantitative judgement.

Preliminary findings of the data collected from three cohorts over three consecutive years indicates

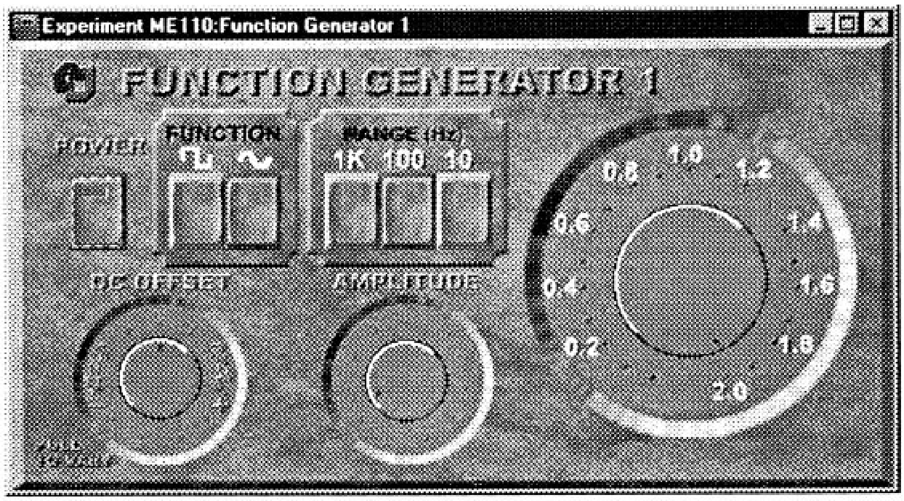

Fig. 5. Function generator GUI.

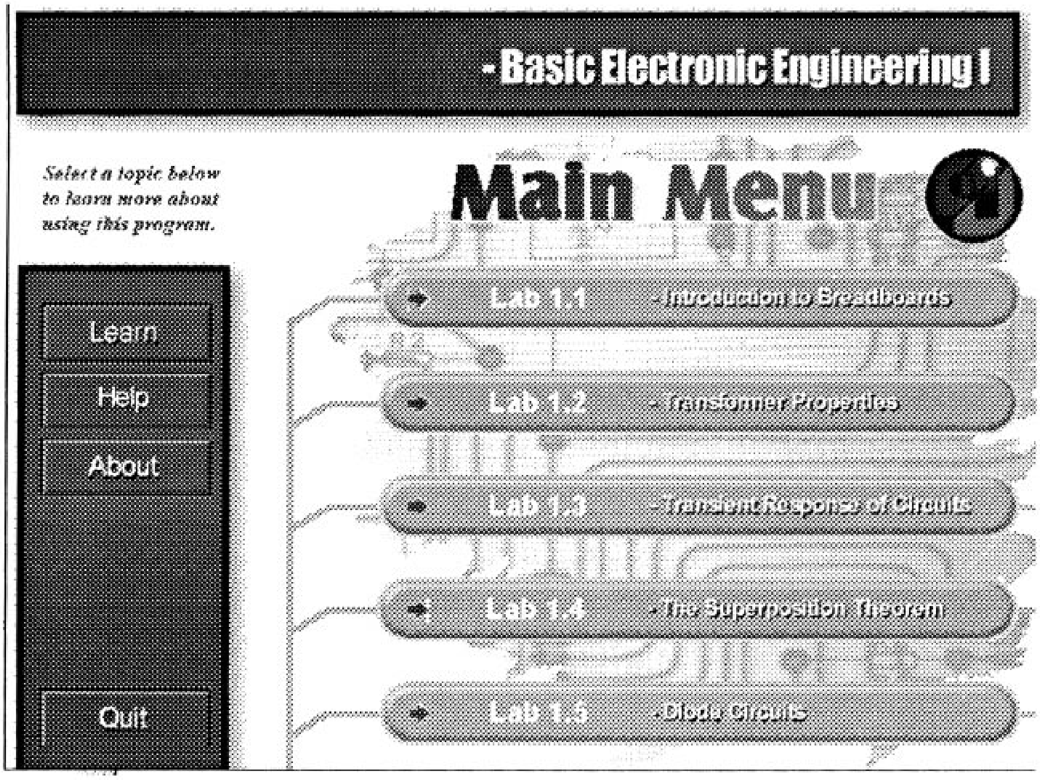

Fig. 6. Introductory screen.

that there are significant differences in understanding and graded results between the two groups, even when there were no significant differences in pre course knowledge or qualifications. In nearly all cases the ITS based groups performed better on simple knowledge tests as well as more rigorous in depth testing. The introduction of the laboratory content into the integrated teaching environment also deepened the understanding of the ITS group.

Both two-sample t-tests assuming unequal

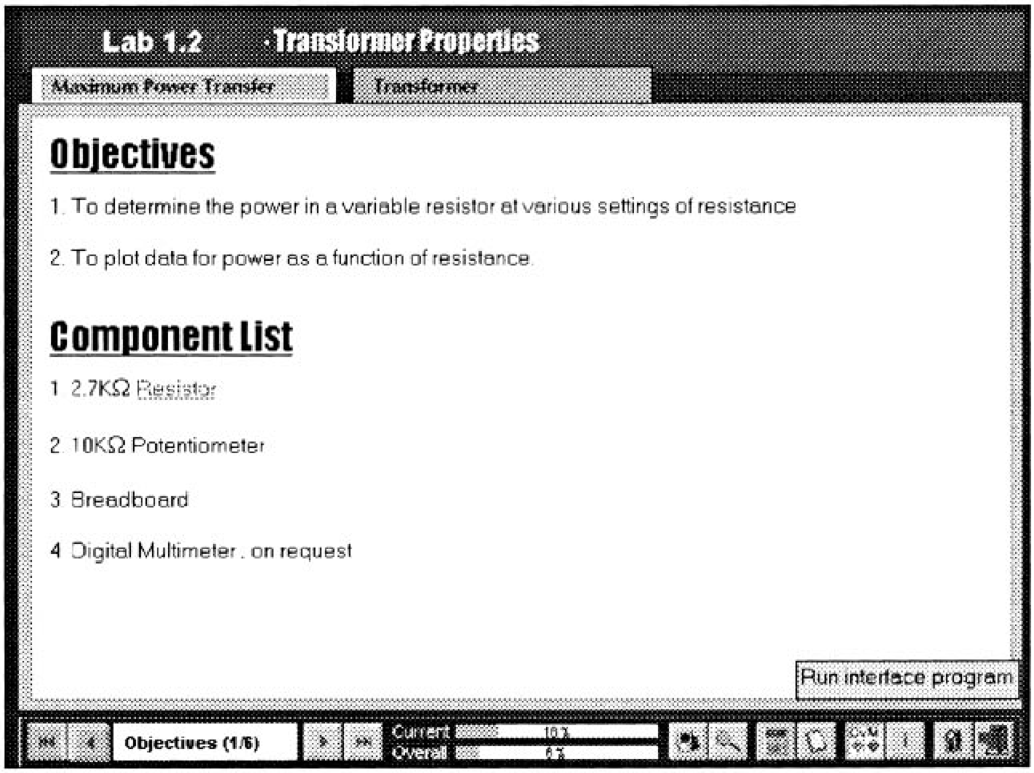

Fig. 7. Component screen.

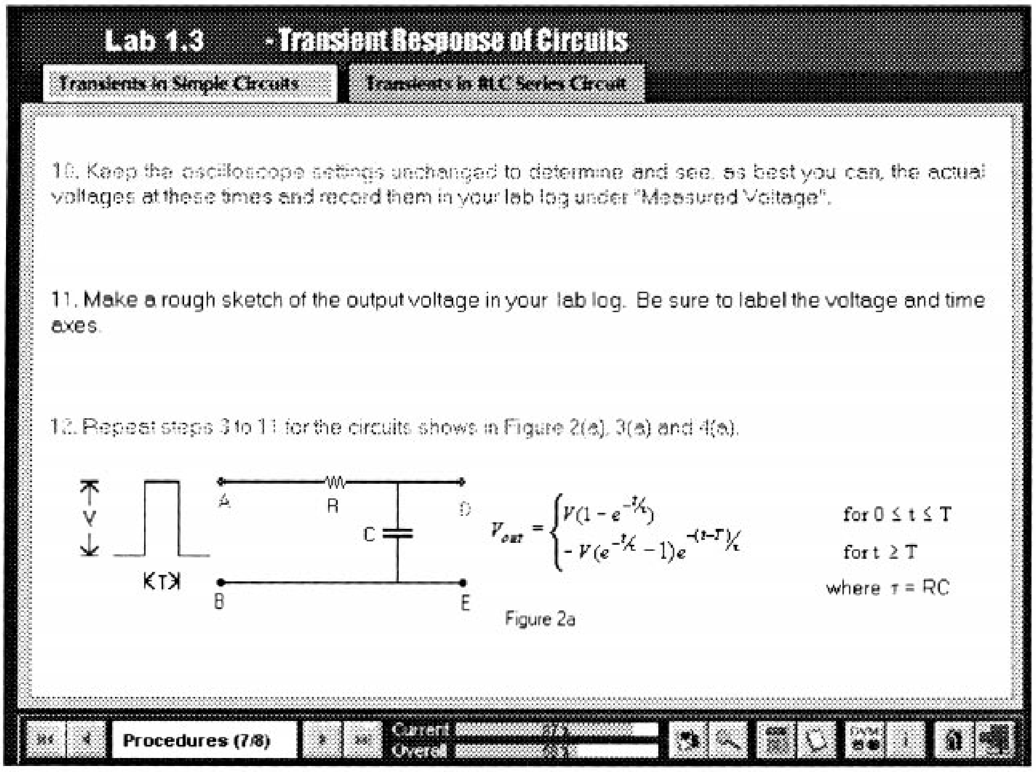

Fig. 8. Experimental page screen.

variances and single factor ANOVA analyses were carried out on each assessment result. First, for all three cohorts, there was no significant difference between the groups according to the semester pre-test. This would seem to corroborate entrance qualification data, although the bare, overall, mark may mask differences in group responses to individual questions.

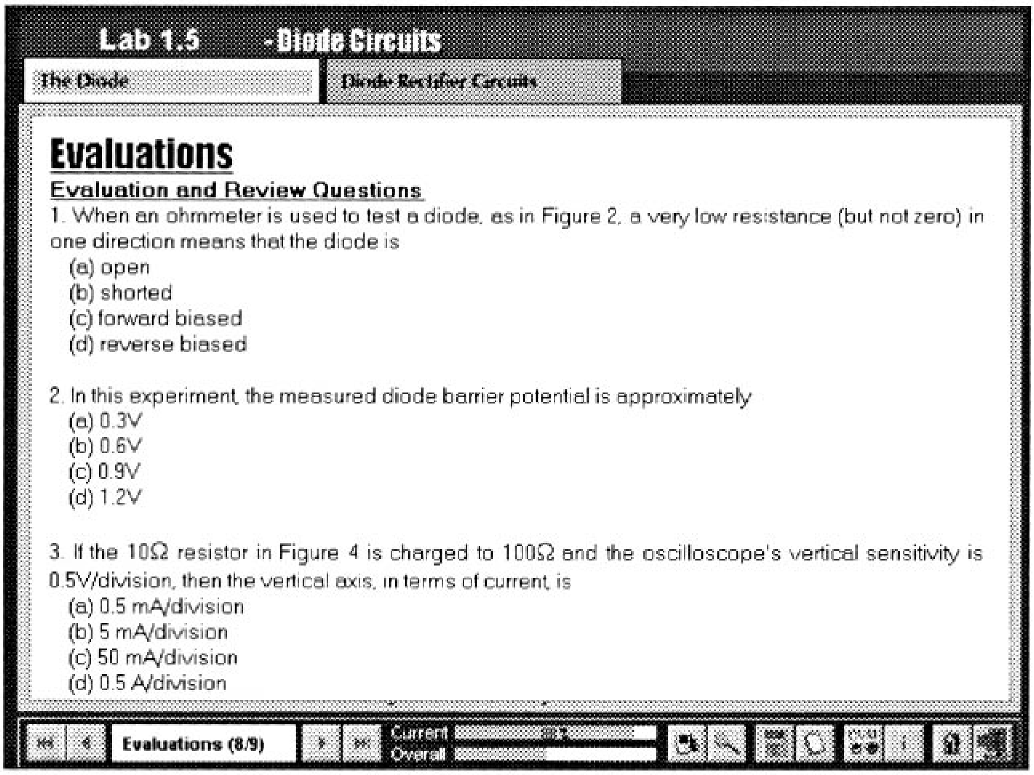

Fig. 9. Evaluation screen.

However, by the middle of the first semester significant differences began to show for all three cohorts. The ITS group is consistently performing better than the non-ITS group. By the end of the first semester the overall grade mark in the final assessment is significantly different for all cohorts, the ITS group consistently performing better than the non-ITS group. If the examination component is extracted from the overall mark, which contains the results of the continuous assessment B lab, assignments, tests etc—the difference between the two groups is even more pronounced. This is especially true when considering the marks for the descriptive parts of the examination; the ITS group clearly shows a more 'in-depth' understanding than the non-ITS group.

CONCLUSIONS

It is clear that, even without the laboratory component integrated into the curriculum, students using the ITS perform significantly better than those being taught using more traditional means. When the laboratory component is fully integrated into the ITS-based curriculum there is significant better performance at all levels. It is also clear that students taught in the ITS have siginificantly more in-depth understanding of the syllabus, as shown by the higher marks in the decsriptive component of examinations.

These findings are similar to those found by other researchers determining the effects of studio teaching. Glinkowski et al [13] found an improvement of about 8.8%. Carlson et al [14] also found an effect although they did not use statistical analysis to assess its significance.

On a more subjective basis, it is also noticed that students are more interested in learning in an ITS environment than in the traditonal lecture-based one. Attendance records show this for the three cohorts examined in this paper. Whereas average attendance rates at lectures and tutorials/examples classes for the non-ITS groups were around 50–60%, those for the ITS groups were around 95–100%. Attendance is not compulsory at lectures and tutorials/examples classes for the courses in this study. There is however a 75% attendance requirement for laboratory work, and attendance for this has been discounted. This increase in attendance with students who use the ITS has been reported by others, including Maby et al [15] and Carlson et al [14] although Glinowski et al [13]) report no long term difference.

Feedback from students using the ITS, which is still being collected and evaluated, seems to indicate that most, once they get used to the environment, are very happy with learning this way. Some do have problems, especially those who come from a more traditional learning background and who are still expecting to be told what to learn, as at school.

Another area of ongoing discussion is the attitude of the teaching staff. As a form of team teaching approach is taken in the ITS, and because planned schemas may be changed depending on the immediate feedback form students, those teaching staff more used to traditional methods sometimes have great problems adapting to, or even accepting the need for, change.

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