Teaching introductory electronics in an Integrated Teaching Studio environment

Robin Bradbeer

Department of Electronic Engineering
City University of Hong Kong
Kowloon Tong, Hong Kong

email: eertbrad@cityu.edu.hk

Abstract: 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. A typical studio session consists of a mixture of discussions, mini-lectures, demonstrations, computer simulations, problem-solving activities, and computer supported laboratory exercises. It utilises computer based teaching materials that emphasise multimedia and interactive learning. This paper describes the introduction of studio teaching for introductory electronic engineering for a 1st year Mechatronics Engineering degree course.

Keywords: Studio teaching, electronic engineering, mechatronics engineering

Introduction

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, as educators we must rethink the content of the science and engineering curricula and reconsider the environment and the materials with which our students learn.

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 specialised knowledge, the current job market often demands skills (communication, co-operation, 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 co-operative 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.

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]

The 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 enrollment. Studio teaching is a teaching methodology that emphasises co-operative 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 developed for introductory physics courses at Rensselaer Polytechnic Institute, New York, USA [2][3]. Rensselaer 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 of leading institutions.

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 co-operative techniques (discussion and group activities), (c) if more of the senses are engaged (interactive multimedia courseware), and (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 ITS at CityU houses 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. The student tables are arranged in an open configuration that facilitates student-student interactions and the circulation of instructors about the room. At the front of the studio, to one side, is a workstation whose monitor can be viewed on a back-projected video screen, as well as a full-colour visualiser, also viewable on the back-projection screen and an ordinary overhead projector.

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/web, 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 course. The gaps are in introductory circuit analysis and introductory machines. We are currently evaluating packages that can fill these gaps, although so far we have been singularly unsuccessful in finding any courseware that can compare to the EDEC programs.

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 being carried out by the author [7] will enable the EDEC courseware to be available over the web and not just on stand-alone machines.

Introducing laboratory content

The lecture course follows very closely on that given by traditional means to the 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 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 include the operational amplifier, logic circuits, SCR and an introduction to dc machines.

Now, a number of institutions also 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 the ITS is a university, 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.

So it was 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. The ULI makes 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 we 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 us to simulate 8 peripherals, namely a double beam oscilloscope, two signal generators, two dc power supplies and two digital voltmeters.

Of course, 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 any National Instruments’ board 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’. We chose Test Point, from Capital Equipment Corporation [12]. Eagle Technologies provide a good interface for this laboratory simulation package; at the same time, CAC will let you have a site licence and use run-time versions of any programs generated, unlike National Instruments, and other similar 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 you to a proprietary configuration.

The experiments

It was quite clear that, with the limitations on current and voltage impose by using an A/D, D/A interface, that most of the experiments in the original programme would have to be modified or replaced. 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 system as designed. 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.

The interface boxes were installed on all workstations - Fig 1.

Fig 1: A workstation

To make the connection to the computer interface a special interface box was designed - Fig. 2. This gives the inputs and outputs for all the instruments using the same connectors as real instrumentation.

Fig 2: The interface box

Fig 3 shows the breadboard that is used to carry out all the experiments. This mimics the same usage as in the normal laboratory.

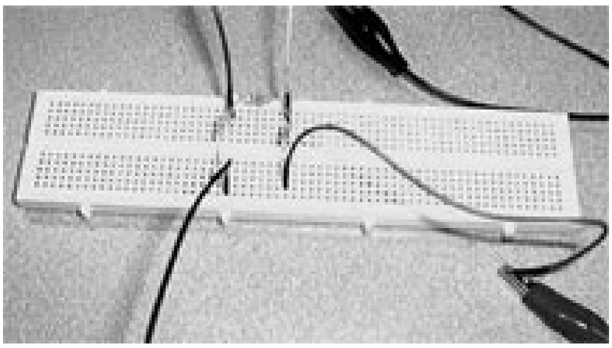

Fig 3: The breadboard

This gives students to opportunity to learn about colour coding etc, which they would not be able to do if a prewired chassis were used. Each experiment has all its components separately packed in a small polythene bag.

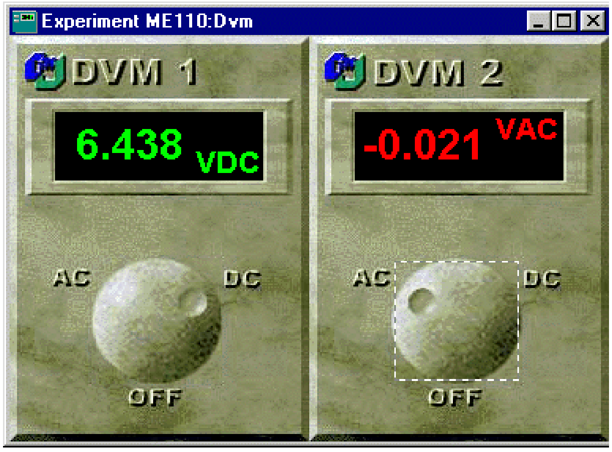

Fig 4: DVM GUI

The Test Point software was used to generate the screen GUI for the power supply, dvm, scope and generator. Figs 4 - 7 show the power supply, dvm, scope and signal generator screens. All

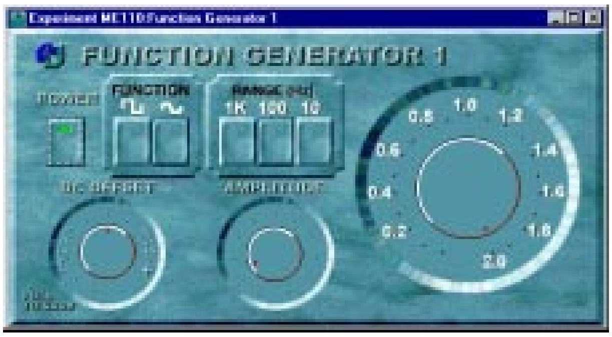

Fig 5: Function generator GUI

screens were designed to make them look as close to normal bench equipment as possible.

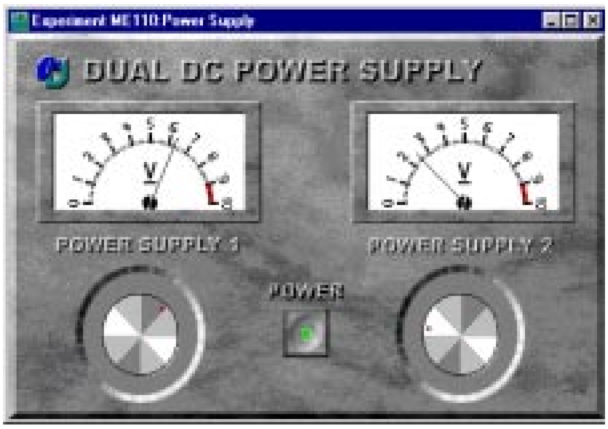

Fig 6: Dual power supply GUI

This included pulling rotating knobs with the mouse.

Fig 7: Dual beam scope GUI

The laboratory manual

The traditional laboratory manual has been replaced by an online manual. This sits onscreen 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.

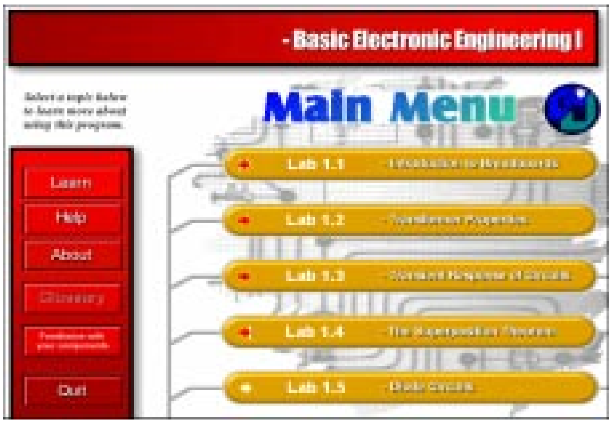

Fig 7: Introductory screen

Fig 8: Component screen

Figs 7 -10 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 online 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.

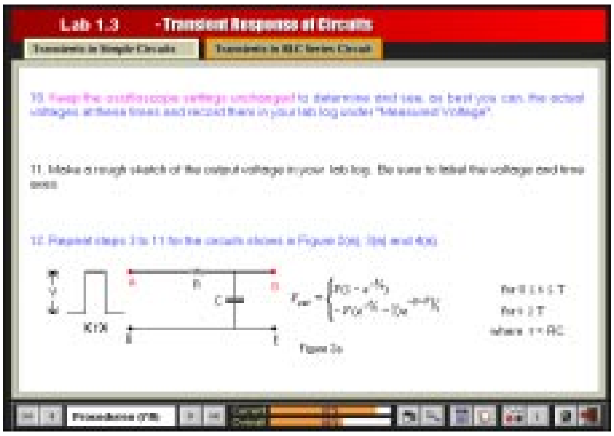

Fig 9: Experimental page screen

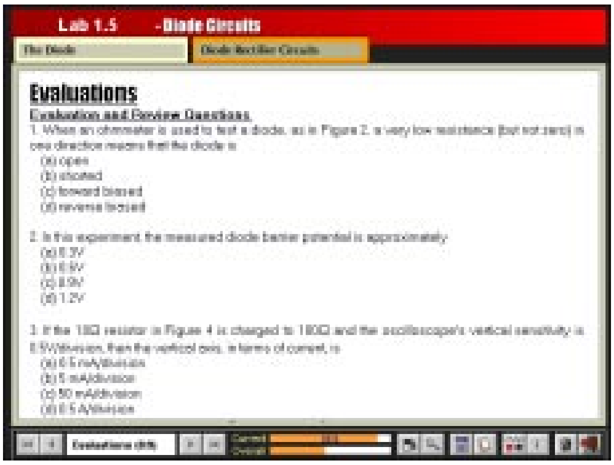

Fig 10: Evaluation screen

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.

Although the results for the first year have been fully analysed, those for 1997/8 are still being looked at, and the ones for 1998/9 are still being collected, it does seem that there is some initial reaction to the studio mode of teaching but that this reverts back to normal' in the second semester. For example, analysis of the results of a multiple choice questionnaire given to all students at the beginning of week 1, Semester A showed a slight advantage to the ME students, although this was not statistically significant. Halfway through semester A a mid term test showed that the average mark for MTE students was about 2.5% above that of the ME students. By the end of the semester, the MTE students had a class average in the final examination that was 7.5% above that of the ME students. This result was repeated for the first two years of the survey.

However, by the middle of semester B the difference had shrunk to 2% and by the end of semester B the difference in the two classes was negligible. The reasons for this are still being investigated. There are a number of significant differences between the behaviour of the two classes. For example, it was significant that the attendance rate of the MTE students in the ITS was nearly 100% for the whole of the two semesters, but that of the ME students was around 40-50% at lectures. (Lab and tutorial have a 75% attendance requirement, so the attendance rate is not relevant here).

Many students were initially wary of being taught in the ITS. Their main worry was the lack of differentiation between the three aspects of the teaching. They seemed to like knowing when they would be doing lab, for example. Hong Kong students are very lax at preparing for classes. They do not read notes or lab manuals before classes, so are not prepared for anything new, or anything that requires prepreparation. This makes teaching in a studio environment very difficult. However, after a few weeks most learn to appreciate the environment and teaching mode, although a small minority seem to find the environment unpleasant and threatening throughout the whole course.

Many of those who had problems did not like the informal setting and the ability to roam the web; some abused this and were found to play games or do other things during the periods when computer-based teaching was carried out. A qualitative study is currently being undertaken to ascertain individual students feelings about ITS teaching and whether this has any effect on their performance. It is still too early to come to any conclusions from the feedback so far.

Conclusion

Studio based teaching does provide a more relaxed environment for students to learn, but it moves some of the onus for that learning from the teacher back to the students. They do not like this! At the same time, students who are prepared to make an effort to use the facilities to their full advantage clearly do better in this mode than in more traditional methods of teaching. However, it does seem that students become complacent, and having achieved quite good grades in the first semester, take things a bit easier in the second and thus lose any advantage they have gained over those taught by traditional means.

Future work on this evaluation project will trace students now in their second and third years of study, and ascertain whether there has been any long term advantage in using the ITS approach. Results from the USA seem to indicate that learning does benefit, in the sense that more in depth' knowledge is required. This, of course, is the claim of many non-traditional teaching methods in the sciences and engineering from Nuffield onwards. A comparison with similar studies in a different cultural setting, eg comparing students in the USA and Hong Kong, is planned to be carried out later in 1999 to investigate any cultural bias in the general acceptance of ITS teaching.

One thing that can be said with certainty; the teaching staff are as divided as the students in their acceptance. Some enjoy the new method of teaching even though it does involve more interaction with the class as well as more preparation. Some will have nothing to do with it, having taken part in classes for as little as a few weeks!

References

[1] For an overview of this, see “Innovations on Campus”, *Science*, November, pp. 843, 1994.

[2] Wilson, J. M., “The CUPLE Physics Studio”, *The Physics Teacher*, Vol. 32, pp. 518, 1994.

[3] Roberge, W. G., “Studio Physics: An Interactive Learning Model for Research Universities”, *Educators' TECH Exchange*, pp. 6, Spring/ Summer 1995.

[4] Leung, C. M., Stokes, M., Bradbeer, R., “An Integrated Teaching Studio at City University of Hong Kong”, *Proceedings of the 2nd IEEE Conference on Multimedia Engineering Education*, pp161-166, July 1996

[5] Hicks, P. J., “A Computer-Based Teaching System for Electronic Design Education”, *Proceeding 1st IEEE Conference on Multimedia Engineering Education*, pp 11, July 1994.

[6] Wong J., Bradbeer R., “Development of a multimedia based teaching programme to support a first year electronic engineering laboratory□£ *Proceedings of the 2nd IEEE Conference on Multimedia Engineering Education*, pp245-252, July 1996

[7] Chan, W. M., Bradbeer, R., “WWW implementation of existing stand-alone interactive courseware”, *Proceedings of 3rd IEEE International Conference on Multimedia, Engineering and Education,* July 1998

[8] Chan, T. Y., Bradbeer, R., “An online multimedia learning system for first year laboratory”, *Proceedings of 3rd IEEE International Conference on Multimedia, Engineering and Education,* July 1998

[9] Jennings, W., “Studio integration across the curriculum”, *Proceedings of 3rd IEEE International Conference on Multimedia, Engineering and Education,* July 1998

[10] Sutanto, D. and MacAlpine. J.M.K., “Development of an integrated electrical engineering laboratory using a multi-media object-oriented approach”, *Proceedings of 3rd IEEE International Conference on Multimedia, Engineering and Education,* July 1998

[11] Eagle Technology Ltd.
http://www.eagle.co.za

[12] Capital Equipment Corporation
http://www.cec488.com