EDEC - A Study of the Role of Educational Technology in the Design of Electronic Engineering Degree Courses.

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Abstract: A consortium of eight UK higher education institutions was established in 1992 to undertake the development of Computer-Based Learning software for use in the teaching of electronic circuit and system design. Known collectively as the Electronic Design Education Consortium (EDEC) the consortium receives funding from the UK national Teaching and Learning Technology Programme (TLTP). The EDEC courseware was developed using Authorware to run on the PC platform and by the end of the first phase of the project in 1995 over 150 hours of material had been produced. The material complemented traditional methods of teaching and learning such as lectures and tutorials and was primarily intended for use by students as a self-study learning aid. It could also be used for demonstration purposes within lectures, tutorials and laboratory sessions. Current work is focused on the embedding of educational technology within the electronic engineering curriculum and an evaluation of its effectiveness, including a cost-benefit analysis. At the same time the EDEC courseware is being adapted so that it can be launched from within a web-based delivery framework. The methodology that has been used to design curricula based on the EDEC courseware is presented and the criteria that have been used in the selection of teaching and learning methods are discussed. A technique for embedding live circuit simulations (using the SPICE simulator) into interactive web pages is also described.

Keywords: EDEC, electronic engineering, digital design, computer-based learning, courseware

1. Introduction

For more than ten years electronic engineering in the UK Higher Education sector benefited from access to high-quality electronic computer-aided design (ECAD) software provided through a national scheme called the ECAD Initiative. This had around 100 members including universities, research establishments and Colleges of Further Education. In 1989 a similar European-wide initiative (formerly EUROCHIP, now EUROPRACTICE) was set up specifically to promote VLSI design education. Access to ECAD software is essential for a modern electronics education. Electronics design, production and manufacture relies universally on computer-based processes from the instant of design conception, through the many different implementation styles, to final testing. All students of electronics must gain practical experience of the methods and techniques embodied in these tools by carrying out design exercises similar to those undertaken on a larger scale in industry. ECAD tools therefore have a great deal of potential as components in a learning environment for electronic engineers, and the power of simulation as a technique that promotes effective learning has been known for some time. What is really required is a tutorial 'shell' that can be used in association with tools such as simulators to help students to understand the concepts that lie behind electronics design.

The Electronic Design Education Consortium (EDEC) was originally set up in 1992 to develop computer-based learning material to support the education of Electronic Engineers and Computer Scientists in the design of electronic circuits and systems. By closely linking the courseware to ECAD tools it was hoped that a way would be found of providing cost-effective tutorial support to students who were learning about electronic design. The members of the consortium are the Universities of Bristol, Essex, Huddersfield, Kent, Manchester and Newcastle,

the University of Manchester Institute of Science and Technology (UMIST) and Oxford Brookes University. Over twenty academic staff and sixteen full-time Research Assistants were engaged in developing the courseware with financial support provided from the UK Higher Education Funding Councils as part of a national initiative called the Teaching and Learning Technology Programme (TLTP) [1]. The declared aim of the Teaching and Learning Technology Programme was to make teaching and learning more productive and efficient by harnessing modern technology.

2. The Electronic Design Education Consortium (EDEC)

2.1 EDEC courseware themes

The EDEC courseware is sub-divided into four major themes. These are:

1. Electronic Circuit Design
2. Digital Design
3. System and High Level Design
4. Testing and Design for Test

The first two each contain approximately 40 - 50 hours of material and cover a substantial proportion of the syllabuses for core courses in electronic circuits and digital logic design at first and second year undergraduate level. The System and Test themes each comprise 30 - 40 hours of material and are aimed at a somewhat more advanced level in the curriculum - typically third or fourth year undergraduate or possibly even postgraduate (MSc) level. More detailed information including module descriptions and demonstration samples from each of the four themes can be obtained from the EDEC WWW site [2].

2.2 The EDEC shell

A standard shell was developed for the EDEC courseware to provide a common framework with a uniform method of navigation and screen layout. A feature of the EDEC shell is the flexibility that it provides for the customisation of modules to suit individual user requirements. This is accomplished by means of a module configuration file that can be easily modified by the tutor to determine whether certain components should be included in the module or left out altogether. Additional user-supplied material may also be integrated into the courseware, where necessary, using so-called 'media links'.

The layout of the screen itself consists of two parts; the main area where the course material is to be displayed, and a panel of control buttons and a status message. The shell has been evaluated by groups of students to test the user interface and a number of iterations have been made to the navigation tools to arrive at a system which has all the required functionality and is also easy to use.

Authorware Professional has been adopted by the Consortium as the standard tool for courseware development and early versions of the shell were constructed using Authorware. It was later found that navigation through the material could be speeded up considerably by constructing a shell in the 'C' language and linking it as a Dynamic Link Library (DLL) component to the courseware modules.

2.3 Courseware design and development

The EDEC material was originally designed for use in self-study mode and each module provides self-contained coverage of a particular topic. In choosing the topics to be included in the courseware some thought was given to areas that could benefit from a computer-based learning approach. Consultation took place with potential users to determine the content of the courseware developed for each of the four EDEC Theme Groups. A formal procedure was devised to guide the courseware development process and this involved clearly identifying the learning objectives before working out how they can best be achieved [3]. Interaction is a key ingredient of successful courseware because it helps to engage the student's interest and this principle has therefore been embodied in the material produced by the Consortium. Extensive use has been made of animation to illustrate dynamic processes and sound and video have also been employed although to a lesser extent. Students are frequently invited to answer questions on the material they have been studying to provide feedback on their rate of progress.

There is insufficient space here to describe the scope and content of the courseware in detail, and the reader is referred instead to the EDEC entry in the TLTP Courseware Catalogue [4] or the EDEC World Wide Web pages

that can be accessed via the Internet [2]. To give some idea of the sort of material that the Consortium has produced so far, it is perhaps worth mentioning just a few examples of module content.

Figure 1. Screenshot from the Digital Design Module "Number Systems"

In the Digital Design theme students are introduced to the basic ideas of Boolean logic, number systems and combinational and sequential logic design through a series of modules that enable them to interactively explore these topics. For example, Fig. 1 shows a screenshot from the Number Systems module that uses a weighing machine analogy to explain the principles of binary-to-decimal conversion. A number of the modules in the Electronic Circuits theme make use of a simulated ' electronic breadboard' on which simple circuits can be built and tested. Thus in one example an operational amplifier (op amp) is connected to a variable power supply and a signal generator is used to supply waveforms of varying frequency and amplitude to the input of the device. The op amp' s input and output waveforms can be inspected using a 'virtual' oscilloscope that employs animation techniques to create the illusion of a real instrument. This arrangement can be used to illustrate many of the basic properties of op amps, for example dependence of closed-loop gain on feedback resistor values, clipping behaviour and so on.

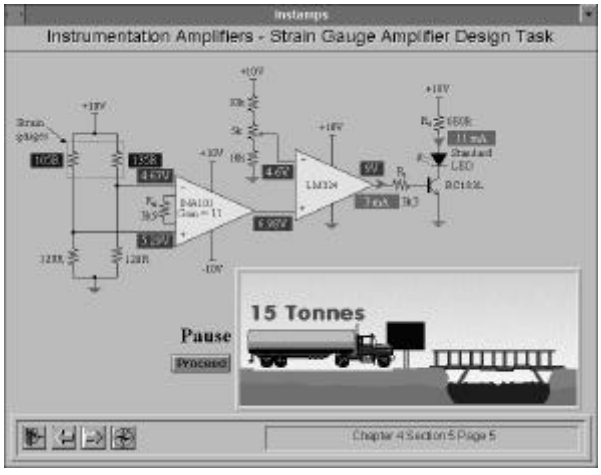

Figure 2. Screenshot from the Electronic Circuits Module "Instrumentation Amplifiers"

Another of the modules from the Electronic Circuits theme provides students with a design exercise to test their knowledge of instrumentation amplifiers, and a screenshot from this module can be seen in Fig. 2. The exercise is

presented in the form of a case study involving the use of strain gauges in a weighbridge that forms part of a system designed to prevent heavy vehicles from using an unsafe bridge across a river. If the student successfully completes the design a heavy truck is warned not to try to cross the bridge. On the other hand an erroneous design leads to the collapse of the bridge and the truck ends up in the river!

Animation is used in a variety of different ways in the Digital Design theme, for example to illustrate the dynamic switching behaviour of logic gates and flip-flops. In another module the differences between analogue and digital control systems are neatly portrayed using animations of the rudder on a ship or the sequence of steps involved in releasing a satellite from the hold of the Space Shuttle. Animation is used extensively in the System and High Level Design theme as well, in this case to show the data flow and state sequencing associated with graphs representing different architectures.

2.4 Courseware evaluation

During the development process the courseware was subjected to several stages of formative evaluation. The first of these stages were conducted within the consortium whereas the latter stages were used to solicit the views of the wider user community. Feedback from the evaluation process enabled the development teams to modify the modules in response to comments from staff and students.

2.5 Courseware distribution and delivery platforms

Altogether some 160 hours of computer based learning material has been produced by the EDEC partners and this consumes around 200MB of hard disk space on a PC running Windows 95/98 or Windows NT. Two methods are currently being employed for distribution of the courseware; electronic file transfer via the World Wide Web (WWW) and CD-ROM. Registered EDEC users can visit the EDEC web site [2] and select the modules they wish to download onto their machine. If required the software can be automatically installed onto the user's machine once it has been downloaded. This web-based system has a built-in access control mechanism (only registered users equipped with EDEC usernames and passwords are able to activate the downloading) and also provides a continuous audit of module take-up. The CD-ROM is supplied with the choice of either run the modules directly from the CD or carry out a full installation onto the system's hard disk; the former option requires around 20MB of disk space whereas the latter needs more like 200MB.

3. User experiences

The EDEC courseware was first released in March 1996 and copies have so far been distributed to some 100 higher education institutions, mostly in the UK. Academics in many electronics departments around the country are currently investigating ways of integrating the EDEC software into their courses, and some data is beginning to emerge which describes user experiences in this area. The University of Newcastle-Upon-Tyne and Oxford Brookes University, both partners in the EDEC project, have independently constructed a number of new courses based on the use of EDEC material as a self-study learning aid. In these case studies the courseware has been used to partially replace lectures and/or laboratory sessions, although other teaching and learning methods (lectures, tutorials, laboratories etc.) are still being employed to some extent as well. Students were invited to comment on their impressions of using the material and to compare the new technology approach with more traditional methods such as lectures and laboratory sessions.

At Newcastle [5] a first year course on Computer Engineering has been restructured to use computer based learning material in place of lectures. Whereas previously this course consisted of some 13 hours of lectures and 12 hours in the laboratory, the students now receive only 4 hours of lectures and use 6 hours of EDEC CBL material to cover the syllabus content. A series of tests were carried out in which the examination performance of students using the courseware was compared with that of control groups taught in traditional lectures. Their findings clearly suggest that carefully designed courseware can lead to a large reduction in teaching time, with no significant difference in learning.

Trials of the software in the teaching of electronics at Oxford Brookes University [6] have revealed some interesting student reactions. The students used a representative sample of EDEC courseware modules and were then invited to give their opinions on the use of courseware as an alternative to conventional teaching methods. The conclusions of this study were that courseware should not replace all face-to-face teaching, although there is clearly scope for some move in this direction (a figure of 25% replacement has been suggested). There is support for the view that multimedia technology presents a major opportunity for enhancing the student learning experience, although it is likely that some incentive will be required to motivate students towards self-learning.

4. Embedding educational technology

Despite reassuring indications of user acceptance the number of degree programmes that have been restructured to take full advantage of the EDEC material is so far disappointingly small. Inevitably it takes time for new course units to be designed and implemented, particularly if new methods are being employed for the first time, but the evidence suggests that with the present lack of guidance on how this should be done and the shortage of time and effort available to staff it will take many years before educational technology achieves significant penetration into the electronic engineering curriculum. The EDEC team has therefore begun to focus its efforts on the production of a number of course exemplars at first and second year undergraduate level in the subject areas already covered by the EDEC material. The objective is to produce complete new courses in the fields of electronic engineering and digital systems design which fully exploit the potential of teaching and learning technology. This will be achieved by adapting and using existing software programs, including the range of courseware modules already developed by EDEC, so that they can be launched from within a web-based delivery framework. The educational effectiveness of the new courses will be evaluated and a cost-benefit analysis carried out.

Feedback from users of the EDEC courseware indicates that one of the key factors determining acceptance of the material by academic staff for incorporation into their teaching programmes is the degree of flexibility that it offers for customisation to suit their own individual teaching style. In spite of attempts that were made by the EDEC developers to overcome this problem the current format is sometimes seen as being too 'closed' and inflexible, limiting the freedom of the tutor to adapt or rearrange the material or combine it with media from other sources. To overcome this problem the granularity of the material should be made finer than it is at present, effectively chopping the present modules up into smaller chunks or 'snippets'. Furthermore these snippets should be post-processed so that they can be launched from within a web browser, thus enabling them to be combined with other media such as simulations or straightforward HTML, for example.

The blueprint described by Laurillard [7] for implementing courses using educational technology is based on the concept of a 'conversational framework' that can be used to guide the process of specifying learning objectives and matching these to the most appropriate learning methods. Of particular interest is the potentially powerful combination of tutorial-style CBL material (of which EDEC is a good example) and the use of simulation as an effective learning tool. Indeed, the intimate linking of these two media has always been one of the key objectives of the EDEC project and a technique for embedding live circuit simulations (using the SPICE simulator) into interactive web pages has recently been successfully developed and tested.

5. Conclusions

The Teaching and Learning Technology Programme succeeded in significantly raising the level of awareness of what educational technology has to offer in higher education and has resulted in the production of some excellent material. The EDEC consortium has produced over 150 hours of interactive computer based learning material to support the education of electronic engineers and computer scientists and this has been distributed widely to universities and colleges throughout the UK. Only time will tell whether courseware similar to that generated by TLTP will achieve the anticipated gains in productivity and efficiency, although early indications are that both staff and students are receptive to this new medium and that it has the potential to significantly enhance the student learning experience.

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