AUSTRALASIAN JOURNAL OF ENGINEERING EDUCATION

Published in Australia by

The Australasian Association for Engineering Education Inc

ISSN 1324-5821

The correct bibliographic reference for this paper should include the web address where it was published:

Australasian J. of Engng. Educ., online publication 2003-01

http://www.aaee.com.au/journal/2003/hussmann03.pdf

THE USE OF WEB-BASED LEARNING AND COMMUNICATION TOOLS IN ELECTRICAL ENGINEERING

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Keywords: web-based, online learning, flexible delivery, assessment, educational outcomes

This paper presents our experiences in introducing two web-based tools, CECIL and OASIS, in the teaching of year one and year two courses in the Department of Electrical and Electronic Engineering at the University of Auckland. CECIL was used to facilitate the flexible delivery of course material while OASIS was employed for formative and summative assessment. The difficulties faced in introducing the new tools and the advantages sought in doing so are discussed in this paper. The experience is evaluated from both the instructors' and the students' points of view. Both tools were favourably received by both parties and the benefits included better communication, reduced instructor marking workload, and improved educational outcomes for students.

INTRODUCTION

Worldwide, increasing teacher workloads threaten the quality of education at all levels. The tertiary sector is no exception to this, where an increasingly diverse student population requires more individualised treatment, while increasing class sizes tend to force a more standardised approach to education [1-3]. The large classes found in engineering typically require lecturers to devote more and more time to assessment. Our own situation is no exception to this global trend: in recent years the numbers of students enrolled at Auckland University School of Engineering in general and in the Department of Electrical and Electronic Engineering in particular have increased significantly [4]. With class sizes as large as 540 at year one, 250 at year two and 180 at year three, the marking of coursework and the administrative tasks related to course delivery amount to hundreds of hours.

The increasing diversity amongst university students would best be met by more individualised programmes. Yet, decreasing funding and increasing class sizes are likely to result in the opposite: more impersonal programmes. Some commentators believe that computers can provide a partial solution to this problem [5].

An analysis by Excell [6] shows that in classes of one hundred or more students the lecturer may well spend more time on the final assessment than on lecturing, lecture preparation, tutorials, etc. Formative assessment and terms tests, etc. further add to the assessment load. Because assessment makes up such a dominant part of workload, a frequently adopted solution to increased workload is to reduce assessment, particularly formative assessment. However, such a reduction certainly negatively affects student learning: the pivotal pole of formative assessment and prompt, regular feedback is well documented [3, 7, 8]. Computer-assisted assessment has the potential to allow an effective assessment regime to be maintained in this era of large classes.

Several computer-based tools (CBTs) such as WebCT [9] and Blackboard [10] have been developed in order to assist instructors in the delivery and assessment of courses. The Faculty of Engineering at the University of Wollongong, Australia has introduced WebCT for their first year and found it to be a very effective method for organizing and running web-based subjects. As a result of their positive experience, they plan to extend WebCT to other subjects as well [11].

The University of Auckland has developed a CBT called CECIL [12]. CECIL is linked to the University's enrolment program, nDeva [13], enabling the course database to be updated each night. Thus, instructors do not have to worry about whether the class roll is correct. All the students' enrolment details, including an ID photograph, are available to the instructors and they can easily upload the students' grades to the enrolment system.

Most computerized assessment systems, including CECIL, have limited testing capabilities, often being restricted to multiple-choice questions [14]. Multichoice's ease of marking, together with its wide availability via CBTs, can lead to an over-emphasis on this form of testing [15]. However, the objectives of most teaching programs cannot be adequately tested by multichoice on its own: it must be used in combination with other forms of testing.

Electrical circuits are the lexicon of electrical engineering as are the times tables for mathematics. The authors' experiences are that students who do not acquire basic electrical circuit skills in the early stages of their electrical engineering studies are not able to attain the knowledge and understanding expected of them in more advanced courses. However, it is particularly difficult to use traditional systems such as tutoring followed by testing and further tutoring to improve the skills of students. The demands on resources and time are too great. To overcome this problem, the Department of Electrical and Electronic Engineering at the University of Auckland developed a novel web-based assessment and tutorial system, called OASIS [16]. This CBT is a strong formative education tool. It provides instant feedback to large numbers of students in a way that most tutors cannot. As mentioned before, education experts agree on the very high value of regular formative assessment coupled with prompt feedback [3, 7, 8].

The combination of CECIL (for communication and administration) and OASIS (for formative and summative skill assessment) provided the instructors with a unique CBT system that was used in both year one and year two courses. Early research results in this area have already published in [17]. The introduction of these tools is now described in more detail.

OASIS

Online ASsessment and Information System (OASIS) is a novel web-based assessment and tutorial system developed in the Department of Electrical and Electronic Engineering at the University of Auckland. It was first introduced to the students in 2000. OASIS allows for practice and both formative and summative assessment. It also provides instant feedback. There are two modes of operation for OASIS: OASIS Practice and OASIS Test. In practice mode, after logging in, students can select their course, choose a topic of their choice from a menu and practise the uploaded questions. In this way they improve their skills while familiarizing themselves with the test environment. In test mode the instructor can set up an assignment or examination where the students attempt the entire task online and receive their marks as soon as they submit their answers.

OASIS consists of a bank of skills-based questions and a database that records students' activities and performances. Instructors can readily create their own questions and load them into the question bank. Because the interface to the system is a web-browser, OASIS can be used to provide students with practice opportunities whenever and wherever they can access the University network or the Internet. OASIS can also be used to provide assignments and tests as frequently as desired.

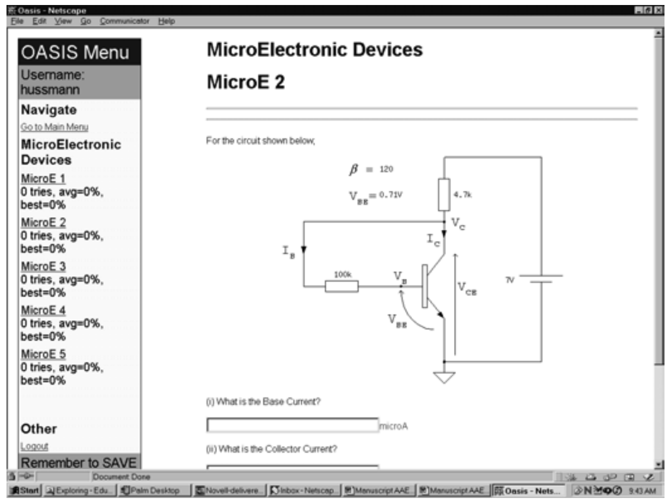

Figure 1: Sample question in *Microelectronics Circuits* within OASIS

A number of important aspects of the courses taught are ideally suited to testing by OASIS. Reflecting the nature of these aspects, currently most problems are numerical, typically involving the solving of circuits. The circuits are displayed with high-quality graphics. After calculating their answers, students enter them in the boxes provided. They then click on the submit button, and, after a wait of a few seconds, they are told the correct answers and whether or not their own answers were correct. An answer within 1% of the correct answer is deemed correct. Should a student request the same problem again, the same question is supplied with different values for the question variables: the variable values are chosen at random from the question bank. To have success, the student must understand the methodology rather than memorize some numbers. In this way, OASIS provides the student with much better opportunities to redo problems than conventional texts. This appears to make doing OASIS problems a more attractive activity than doing problems set from a text. When students get a text problem wrong, they can try that problem again and subsequently get it right. This does afford them some satisfaction. However, being able to do variations on the problem is more rewarding. Students can quit working on a particular problem knowing, for example, that they got it wrong the first time but subsequently got similar problems right the next four times, therefore feeling confident that they have mastered the method. Conversations with students have revealed that, with OASIS, some students actually did aim for this 80% average on each problem.

In test mode, all students log on at approximately the same time. Once a student has submitted the answers to a particular question, that question is no longer available to the student. An unobtrusive display at the bottom of the screen displays the remaining time. After a student's test time has expired, he or she is automatically logged off. Assignment mode is similar, except that the students have more flexibility with the timing of the assignment. For example, students could be given a one-hour assignment to be done at any time during a two-day period. Each student can log on only once. After one hour, logon rights to the assignment expire for that student. At the end of the two-day period, all logon rights to the assignment expire.

The system, being computer-based, has the previously mentioned advantages of such systems. First, students receive virtually instant feedback. Second, regular assignments and formative testing are possible because the computer carries out the marking. Third, plagiarism in assignments and cheating in tests are largely ruled out because each student receives a numerically different version of each problem.

The database records all students' activities, question answers and results, enabling instructors to monitor the performance of each student in both test and practice modes. Instructors can use this information to modify the course delivery to better meet the learning needs of the students.

COMPARISON OF OASIS WITH EXISTING SYSTEMS.

There is widespread acceptance and use of CBTs in engineering courses. However, one international survey shows that engineering faculties are just as likely to prepare their own tools as they are to select an off-the-shelf package [18]. Furthermore, very few commercial packages were found to be used in more than one institution. This suggests that different institutions see themselves as having different requirements and that they also see themselves as having the expertise to produce their own tools.

While there are certainly excellent examples of successful implementation of commercial packages across entire universities [19], in other situations departments have struggled with deficient commercial products. For example, one commercial package recorded only students' aggregate marks for tests but not any data about performance on individual questions. It also automatically logged out students who ran out of test time without any warning and without recording their answers [20].

Many packages, both commercial and in-house, rely on the multichoice format for their testing [19, 21]. In our case it was felt that this was too restrictive. Currently OASIS answers are numerical although future expansions of OASIS incorporating fuzzy logic will move beyond this [22].

There was little hesitation in deciding to deliver OASIS to students via the Web, since this mode of delivery offered great flexibility in terms of student access: it was our experience that virtually all our students had Internet access. In this respect our student body is similar to others [23]. It is also noted that more established systems, ones that initially were delivered by a university network, have now been rewritten for Web delivery as student Internet access has become more prevalent [24, 25].

One key feature of OASIS is that it is able to generate numerically different versions of the same problem. This is important because it enables students to repeat questions and learn from their mistakes. The incidence of plagiarism and cheating is also minimised. Other institutions using CBTs with similar features have been enthusiastic about their use and have also reported a favourable reception from students [24, 26-28]. Not only do these features enable the implementation of meaningful assignments, but they also enable students to take practice tests. Such tests have repeatedly been shown to be of considerable value for students [29-31].

One feature currently lacking in OASIS but found in some other packages is diagnostic feedback [25]. Currently the level of feedback offered is simply right/wrong. Diagnostic feedback may be added to OASIS in the future, particularly if the use of OASIS is expanded into high schools. It is seen as a desirable feature, particularly by students [25], although, perhaps somewhat surprisingly, there is some evidence to suggest that such feedback does not necessarily subsequently significantly increase student performance [32].

CECIL

A Computer Supported Learning system (CSL), usually known as CECIL, was developed by the department of Management Science and Information Systems at the University of Auckland during 1995-1997 [18]. CECIL is a web-based system aimed at supporting academics and their students by providing a highly flexible and reliable system for information and communication. CECIL can also be used to provide multichoice assessment and immediate, guiding feedback.

Within CECIL many communication tools are available. Announcements inform the whole class of relevant course information. Emails can be sent to every student enrolled in the course. Discussion Board and Online Chat facilitate communication among instructors and students. Students can retrieve all information that their instructors have made available to them via CECIL. This information may include lecture notes and PowerPoint presentations, test or assignment model answers, and even sound files of actual lectures. Students can also access their own test and assignment results.

Instructors using CECIL can create their own structure and information categories. For example, the year one course in Electrical Engineering Systems has the following categories: course administration, laboratory work, lecture material, tests, tutorials, and communications. Lecture material is further divided into the four modules in which the course is taught. In this category students can view and print lecture notes, PowerPoint presentations and solutions to in-lecture examples and problems A calendar is also provided, as shown in Figure 2, that presents relevant information about students' papers, such as the due dates for assignments.

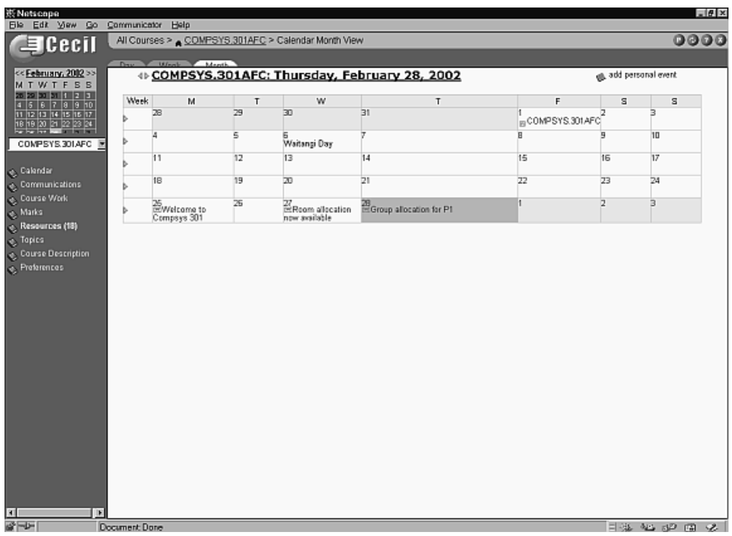

Figure 2: Student view after logging into CECIL

CECIL also contains a computer booking function, enabling students to book computers in the labs ahead of time and from any location. Students can also check the booking schedules for computers to assess whether computers will be free on a particular day. This function can be a helpful time saver.

With large classes, many of the above tasks would be virtually unmanageable by conventional means. Even issuing each and every student with a single information sheet becomes a major exercise when over 500 students are involved.

Instructors have access to much information about each student: official and preferred names, ID numbers, email addresses, the full record of emails sent to each student, test results, a colour photograph, and so on. Marks can be scaled and manipulated and the final grades calculated. More information about CECIL can be found in [12].

EVALUATION OF OASIS AND CECIL

This course evaluation comprises two components. The first part deals with the instructors' responses to the use of both tools while the second part evaluates students' feedback.

Instructor Evaluation

Becoming familiar with and setting up the new tools was time-consuming for the instructors. However, they were prepared to put in the time required because they believed that

- time spent initially would be more than repaid by time saved in the future
- course delivery and assessment would be improved in several respects
- a better learning environment for the students would result.

In engineering, much of the learning needs to build on concepts that may take some time and practice to be appreciated. Therefore, one of the biggest problems is ensuring that students do enough work progressively throughout the course. This problem becomes more pronounced as increased staff workload can lead to fewer assessment instances. Since the final exam is usually regarded as essential, usually it is the formative assessment opportunities through the course that are cut back. As a result, students tend to put off most of their practice until much of the course has passed and the final exam is looming. Further, the traditional approaches to in-course practice and assessment certainly have difficulties associated with them. Sets of problems are only useful if the students actually do them and learn from them. In the traditional situation the instructor has no easy access to knowledge about this. Traditional assignments give the instructor some of this knowledge but with these it is difficult to detect and stop copying. Further, the workload associated with marking is huge and feedback is often delayed for two weeks or even longer. Traditional tests, while answering the copying criticism, still suffer from the same problems of workload and delayed feedback.

In our experience, OASIS helps overcome some of the limitations of paper problems and assignments and is also extremely useful in the test environment. Students frequently practise the problems because immediate feedback is available and because problems can be re-attempted usefully: each new attempt generating new numerical values for the problem. Problem sets, once created, are valid for many years. Students can choose when and where to tackle a particular problem, either remotely from home or on campus computers. They appreciate the opportunity to receive feedback without losing marks [19]. Instructors get immediate feedback on student performance and can modify, if necessary, their lectures or tutorials to meet the students' requirements. All the evidence to date suggests that use of OASIS raises student performance levels. In the year one course, for example, a large section taught for the first time this year with OASIS support returned a raw examination failure rate of 15% whereas this rate had previously been 35%. There had been no significant change in the ability of the student group and the examination questions for this section were, if anything, more demanding than previously. In fact, one very experienced lecturer remarked that, with OASIS improving the skill levels of students, examiners had to be careful that they did not unconsciously raise the difficulty level of examinations to an unreasonable level. Other users of web-based tutorial systems have made similar observations [24].

Our observation is that there is considerable reduction in wasted time for both staff and students in the courses using OASIS and CECIL. CECIL has significantly streamlined the information flow between students and staff. Students can access course materials such as lecture notes, course descriptions, datasheets, model answers, test results, etc. online without contacting the instructors. It is also quicker for instructors to upload files to CECIL than it is to hand out documents in lectures or physically pin up sheets on notice boards. Using CECIL's versatile communication platform, students can take part in discussions and solve many problems themselves without needing the help of instructors. This does not altogether eliminate student contact: students still do approach the lecturers, usually in small groups, and usually to resolve conceptual understanding problems. The time saving here is not large: after reflection on our own practice and discussions with colleagues we estimate it at about one hour a week per course.

The most significant savings of time are produced by the automation of assessment. In what follows the time estimates are again derived through reflection on our own practice and discussions with colleagues. Consider a typical one-hour test. The time needed to create a test and produce it in its final form is estimated to be 16 hours for traditional tests and 40 hours for OASIS tests. The latter time is greater due to the programming nature of OASIS. This time is independent of the number of students. Test supervision time is omitted from the present discussion because it applies equally to both traditional tests and OASIS tests. The time to mark a test, check the marking, and enter the marks into a spreadsheet is estimated at approximately 22 minutes on average per student for a traditional test. For OASIS the corresponding time is approximately zero. OASIS automatically marks questions and marks can be copied directly into a spreadsheet.

Based on the above, it is possible to produce a graph for both traditional and OASIS tests showing the instructor person-hours required as a function of the number of students (Figure 3). Excell [6] produced a similar plot for a two-hour exam in electromagnetics using computer-automated multiple-choice questions. His figures suggest that the time to mark a one-hour traditional test, check the marking, and enter the marks into a spreadsheet is between 12 and 42 minutes on average per student. By comparison, our estimated time is somewhat on the low side. In spite of this, Figure 3 shows that, for class sizes in excess of 66, OASIS saves assessment time. For a typical year two course such as *Microelectronic Circuits*, the saving is about 50 hours. For a year one course (540 students) the saving is about 170 hours. The savings are even greater if questions from previous tests can be reused.

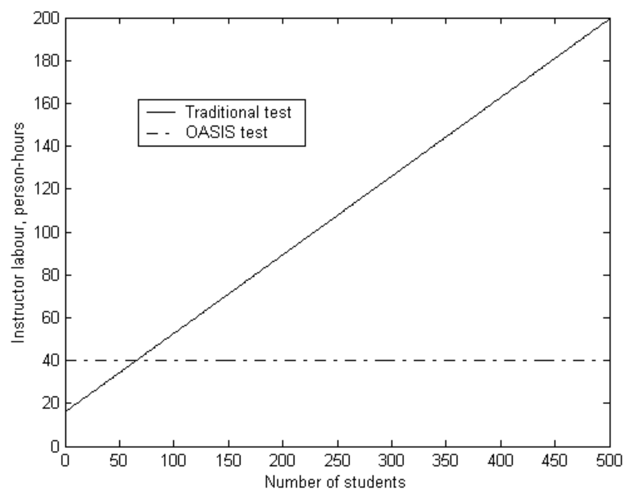

Figure 3: Instructor person-hours required for assessment.

Comparison for traditional and OASIS one-hour tests.

The figures above indicate academic staff time savings in excess of 50% are readily achievable. Others have reached similar conclusions. For example, at the University of Luton, researchers found that there was "an average saving in academic staff time of 50% for first-time computer-based examinations... A further saving of 50% was achieved for subsequent updates" (p. 150) [20].

Student Evaluation

The year two course, *Microelectronic Circuits*, was surveyed twice by The University of Auckland's Centre for Professional Development (CPD). The first survey looked at the introduction of the new CBT tools while the second was a general course evaluation. The course itself was taken by 197 students, with 148 completing the first and 80 the second evaluation sheet. The students were asked to rate the following statements on a "Strongly agree" to "Strongly disagree" scale.

a) CBT-tools survey form

The eight questions used are listed below.

1.) I often access CECIL and OASIS.
2.) I come to campus less often because of CECIL and OASIS.
3.) The tools provided are easy to use.
4.) I like the instant performance feedback using OASIS.
5.) OASIS helped me to prepare for the tests.
6.) OASIS helped improve my skill level.
7.) I like the supplementary material within CECIL (handout, tutorials, marks etc.).
8.) The communication between lecturer and student was improved by using CECIL.

The results of this survey appear in the left half of Figure 4. The following abbreviations are used: *SD: Strongly Disagree; D: Disagree; N: Neutral; A: Agree; SA: Strongly Agree; NA: Not Applicable*.

The survey results were most encouraging. Most students (61%) found the tools easy to use, while 11% did not. 86% of students agreed or strongly agreed that they often accessed CECIL and OASIS. This is certainly supported by observation. For example, in one 24 hour period two days before the first year exam over 400 students logged on to OASIS, with 30 students logged on between midnight and 1am!

CECIL and OASIS do offer students the flexibility to undertake learning when and where they want. However, having access to these tools did not lead to students coming to campus less often. Only 18% agreed or strongly agreed that they came to campus less often because of CECIL and OASIS. This is an important consideration because keeping the students on the campus is essential for the University community. The campus is the natural meeting place where students can discuss and solve problems together. They can also easily contact their instructors for help. Keeping students on campus also increases the academic and community spirit and makes it less likely that individual students feel isolated.

The instant feedback that OASIS provided was greatly appreciated and students also felt that it helped them prepare for the tests and helped improve their skill levels. For example, 79% agreed or strongly agreed with the statement "I like the instant performance feedback using OASIS" while 77% agreed or strongly agreed with the statement "OASIS helped improve my skill level".

Students also found CECIL useful, with 79% of them agreeing or strongly agreeing with the statement "I like the supplementary material within CECIL (handouts, tutorials, marks etc.)" while the majority (59%) agreed or strongly agreed that "communication between lecturer and student was improved by using CECIL". Only 15% disagreed or strongly disagreed with this statement.

b) General course survey form

The eight questions used are listed below.

1.) I had a clear idea of what was expected of me in this course.
2.) I received helpful feedback on how I was going in this course.
3.) The teaching staff showed an interest in the academic needs of the students.
4.) The volume of work in this course was appropriate.
5.) This course helped deepen my understanding.
6.) The assessment measured my learning fairly.
7.) The course materials helped me to learn.
8.) Overall, I was satisfied with the quality of this course.

The results of this survey are reproduced in the right half of Figure 4. The abbreviations used are as previously mentioned. Since the course in question was delivered by lecturers new to the course it is misleading to make comparisons with other years. Further, since the course was a half-semester course it is misleading to compare it with other courses done by the same students: the other courses are full-semester courses and are seen in a different light by students. However, the survey is included here because it shows that the course was well regarded by students in spite of the potential disadvantages mentioned above. It is interesting to note that the question returning the highest positive score was question five: 55% of students agreed or strongly agreed that the course helped deepen their understanding, with only 21% disagreeing or strongly disagreeing. The assessment of the course (47% OASIS, 30% CECIL, 23% traditional) was also favourably received, with 42% of students agreeing or strongly agreeing that it measured learning fairly, with only 22% disagreeing or strongly disagreeing. 47% of students agreed or strongly agreed that the course materials (delivered in part by CECIL and OASIS) helped them to learn, with only 19% disagreeing or strongly disagreeing. Finally, the question with the smallest negative score revealed that 53% of students agreed or strongly agreed that the teaching staff showed an interest in their academic needs, with only 10% disagreeing or strongly disagreeing. This is encouraging since there is the danger that the use of computers to communicate with and test students may lead to staff appearing too remote and uninterested in the students.

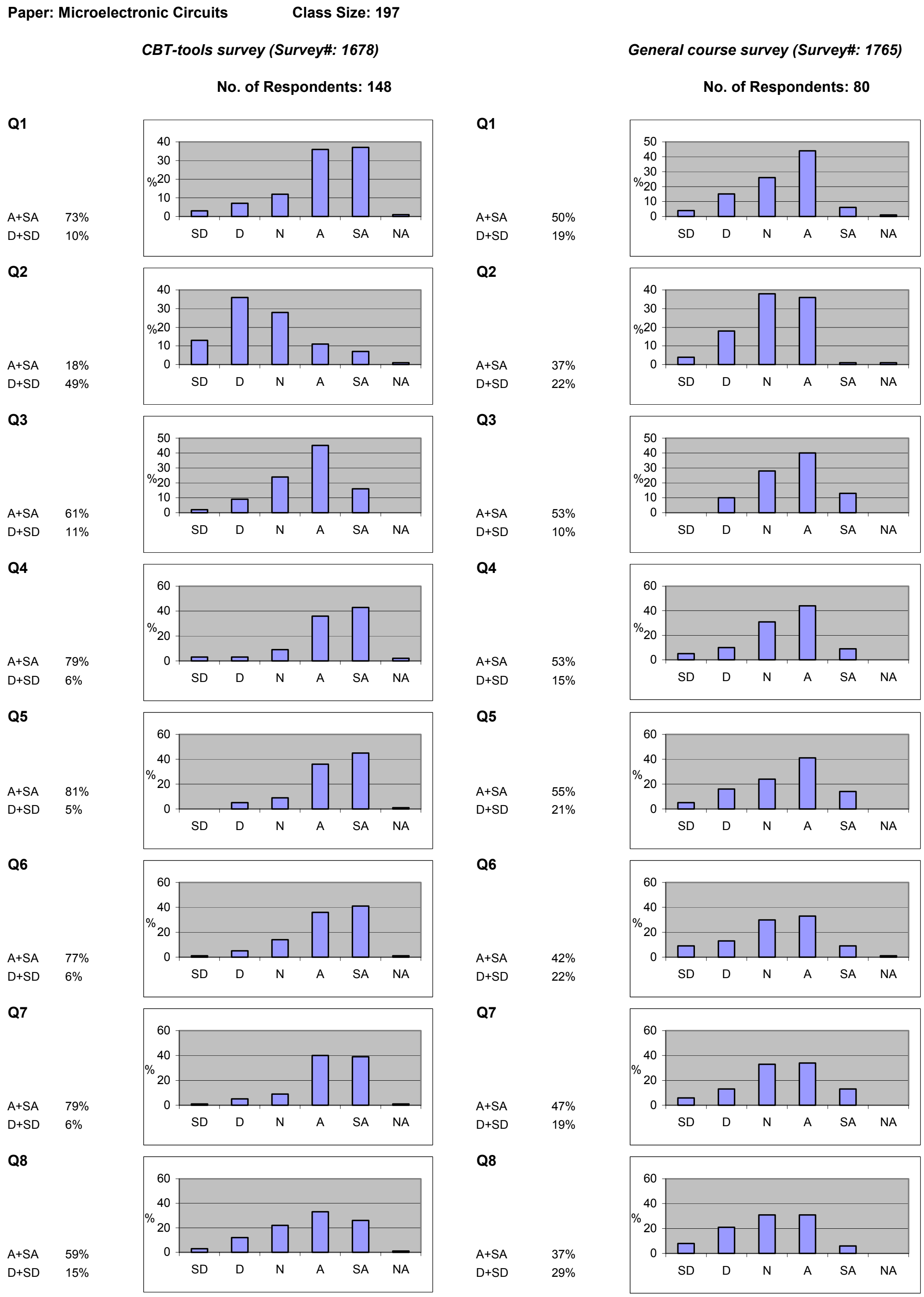

Figure 4: *Microelectronic Circuits* Student Survey Results

CONCLUSIONS

This paper looked at the impact of introducing two web-based tools in year one and year two courses in the department of Electrical and Electronic Engineering at the University of Auckland. Both tools were well received by the students. They appreciated being able to use them and they used them often. CECIL was found to be effective in facilitating better communication between teachers and students as well as among students. Students felt that they had achieved higher skill levels through using OASIS and staff observation certainly supported this notion. Staff also were strongly of the view that the use of CECIL and OASIS had helped reduce student contact hours and test marking time significantly, the latter by at least 50%. The evidence is that the use of OASIS and CECIL has both reduced staff workload and enhanced educational outcomes.

This paper reports action research in progress. The intention is to expand the use of OASIS in courses where it is already used and to introduce it into further courses, including some from other departments. Further investigation will be carried out into student perceptions of OASIS by conducting interviews and focus group discussions. More data about student performance will be collected and analysed. For example, it may be that there is a correlation between duration of OASIS use and examination mark, even when prior achievement is controlled. Future directions will be determined after reflection on the results of the investigations and analyses outlined above.

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BIOGRAPHICAL NOTES

Stephan Hußmann was born in Bonn, Germany, on August 11, 1969. Coming out of the trades (radio and TV technician) he received his master's degree in 1995 and his doctorate in 2000 in the School of Electrical Engineering and Information Technology at the University of Siegen. From 1996 to 2000 he worked half-time as a research associate at the University of Siegen's Center for Sensor Systems (ZESS) in real-time signal processing, 3D object recognition and multisensor systems. The remaining time he worked for Aicoss GmbH in Siegen developing and implementing optical multi-sensor prototypes. Since 2001 he has been working as a lecturer in the Department of Electrical and Electronic Engineering in the area of computer systems engineering (CSE) at the University of Auckland. His interests include wireless optical sensors for the industrial environment, low-cost multi-sensor system design, high-speed image processing with linear sensors, embedded systems design, and the use of computers in engineering education.

Chris Smaill was born in Auckland, New Zealand, on April 14, 1952. From 1969 to 1972 he attended the University of Auckland and gained degrees in Physics and Mathematics. In 1973 he attended the Auckland College of Education and trained as a secondary school teacher. From 1974 till 2001 he taught secondary school physics and mathematics, most recently as Head of Physics at Rangitoto College, New Zealand's largest secondary school. His involvement with education on a national level saw him setting and marking national examinations, preparing resource materials, and facilitating training days for secondary school teachers. He has also published several physics texts. During the eighties he pursued some part-time university study that culminated in a degree in philosophy. Currently he is enrolled in a doctorate in engineering education. OASIS is the subject of his doctorate. Since the start of 2002 he has been lecturing in the Department of Electrical and Electronic Engineering at the University of Auckland.