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Effective Teaching and Learning in Engineering Education using a Novel Web-based Tutorial and Assessment Tool for Advanced Electronics*

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This paper presents experiences using a novel Web-based tool called OASIS (Online ASessment and Integrated Study), in the teaching of a Part 3 course in the Department of Electrical and Electronic Engineering at the University of Auckland. OASIS was employed for formative and summative assessment. The difficulties faced in introducing this new tool in an advanced engineering course and the advantages sought in doing so are discussed in this paper. The experience was evaluated over two academic years from both the instructors' and the students' points of view and found to be well received and beneficial to both parties. Principal benefits include reduced instructor marking workload and improved educational learning 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 part one, 250 at part two between 130–240 at part three and as many as 140 in some part four electives, the marking of coursework and the administrative tasks related to course delivery amounts 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 Excel [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 role 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], Blackboard [10], Questionmark Perception [11] and I-ASSESS [12] 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 organising and running Web-based subjects. As a result of their positive experience, they plan to extend WebCT to other subjects as well [13].

Most computerised assessment systems have limited testing capabilities, often being restricted to multiple-choice questions [14] although commercial packages such as Questionmark perception and I-ASSESS have more sophisticated facilities. The ease of marking multiple choice questions, 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 multiple choice on its own: it must be used in combination with other forms of testing.

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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 use of OASIS provided the instructors with a unique CBT system. Early research results in this area have already published in [17, 18]. The experience gained after using OASIS for two years is now described in more detail.

ONLINE ASSESSMENT INTEGRATED STUDY (OASIS)

OASIS is a Web-based assessment and tutorial system developed in the Department of Electrical and Electronic Engineering at the University of Auckland. The initial design was begun in late 1998 and tested during 1999 with the aim of creating a package that would allow both formative (with suitable feedback) and summative assessment. Approximately 800 hours developer time was required in the initial stages followed by one day a week maintenance during semester when OASIS was in use. At the time of development, no suitable commercial package was found available that would handle the student numbers and allow randomised numerical questions to be created in a relatively simple way by academic staff teaching courses.

The interface to OASIS is a web-browser that enables students the opportunity to practice 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. The first version of OASIS was introduced to the students in 2000 enabling a minimum of 250 simultaneous users, by which time a suitable commercial package, Questionmark Perception [11], had become available but was found to be expensive and supported only a limited set of WEB browsers. This would have excluded some students who used non-Microsoft products such as Linux. A further package called I-ASSESS [12] also has recently become available and allows similar question types to be generated but here question authoring is restricted.

A second version of OASIS was completed during 2002 that extends the capability of the original package by supporting more than 550 simultaneous users, with further advanced features for question set generation. To date, the total development time since 1998 has been approximately equivalent to one man year, with additional time required by Staff utilising the package to create suitable questions for the database. To the authors knowledge Questionmark Perception and I-ASSESS are the only comparable commercial-based equivalents.

There are two modes of operation for OASIS: OASIS Practice and OASIS Test. The **Practice mode** provides the formative assessment as a tutorial in which the students can select their course, choose a topic from a menu and practice the available questions as often as they like. For every attempt, OASIS selects a random set of parameters for the problem. After submitting their answers, OASIS marks them and returns a score and the correct answer in each case. As discussed by Gordijn and Nijhof [19], this level of feedback appears more than sufficient to aid learning. In this way students improve their skills while familiarising themselves with the computer environment. In Test/Assignment mode the instructor selects a subset of these problems which the students attempt online. The Test mode appears identical to the Practice mode except that only selected problems are available and these may be time limited. In this case OASIS will display a timer, warn the student when the last five minutes of the test are remaining and will automatically log the student off after the time limit has expired. On completing the test, OASIS marks their answers and can display their test score immediately, or email the results a day later as desired by the Lecturer involved in the course.

OASIS consists of a bank of skills-based questions and a database that records students' activities and performances. The course instructors can readily create their own questions and load them into the question bank.

Figure 1 shows a sample question in a year three course titled 'Electronic Devices and Technology' together with the answer feedback page after the student has submitted her/his answer. The design flow for creating such a problem in OASIS is similar to that of a regular paper test. First a suitable problem is constructed on paper. Next the equations are derived using labels (i.e. R1, C3 etc) instead of numeric values and then verified using appropriate simulation tools off-line (e.g. Micosim PSpice and Mathworks Matlab for electronic circuit problems). The parameters which will be randomised are then identified and their actual values selected (problem space). Solutions for each of these parameters are computed (solution space) and stored in a database linked to OASIS and the question. The problem is then drawn using a drawing tool and saved as an image. This image, the

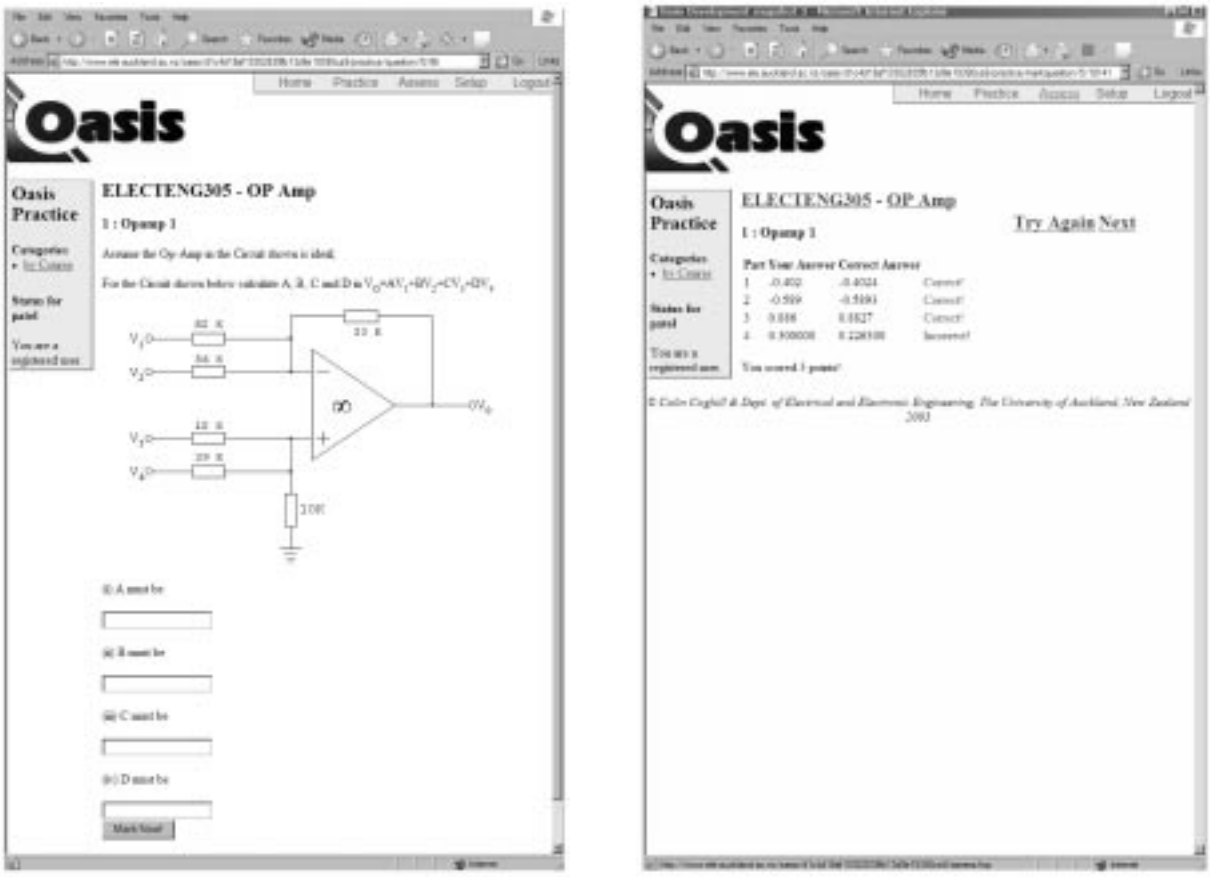

Fig. 1. (a) Sample question in Electronic Devices and Technology within OASIS and (b) the answer feedback page.

problem space and the solution space forms a complete OASIS problem. The utilisation of a database to store questions and answers substantively speeds up the selection and answer process within OASIS, so that despite network speeds OASIS responses appear immediate.

A number of important aspects of the courses taught are ideally suited to testing by OASIS. Reflecting the nature of these aspects, most problems currently within the database are numerical and typically involve the solving of circuits that are displayed with high-quality graphics. After deriving the equations and calculating their answers, students enter them in the boxes provided. On clicking the submit button they are told the correct answers and whether or not their own answers were correct. An answer within a suitable tolerance level (e.g. 1%) of the correct answer is deemed correct. This tolerance level is set when the question is first created. Should a student request the same problem again, the same question is supplied with different question parameters chosen at random from the problem space. 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. Since the equations have to be derived the student must understand the methodology. By creating a large number of problems, the memorising of formulae is reduced. Conversations with students have revealed that, with OASIS, some students actually did aim for this 80% average on each problem. These statistical values (number of tries/average/maximum) are available to the student.

In the **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. At the bottom of the screen an unobtrusive timer 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 mode. Instructors can use this information to modify the course delivery to better meet the learning needs of the students.

EXAMPLE OF CREATING A FILTER DESIGN PROBLEM

Design of filters is a common enough task for hardware design engineers and they should be able to use the Filter Design Tables. The theoretical background on active filters is covered in the course. At the University of Auckland, it is about 19% of the course. The rest is based on topics in feedback, op-amp applications and frequency response of BJT amplifiers. Any simple filter design exercise involves the selection of a suitable polynomial (i.e. Butterworth, Chebyshev, etc), determining the necessary order of the filter to meet the specifications and extracting a suitable normalised transfer function that must then be de-normalised for actual implementation using suitable circuits. Partitioning this into various problem sets helps the students as well as the examiners. The students also see this as fair since it maximises their chances of increasing their course marks.

Figure 2(a) shows the first part of the problem. Here the students are presented with a set of frequency response specifications and are asked to determine the parameters for a Chebyshev polynomial. The specifications vary each time the problem is tried, so that the order of the filter will vary and therefore the problem, while similar, is different each time it is tried in practice. In a test mode, each student will essentially be solving a different problem using identical theory developed during lectures. Normally such filters are realised using a cascade implementation, whereby higher-order polynomials are factorised into first- and second-order terms. Each of these terms can then be implemented using standard first- or second-order realisations. The second part of this problem can be examined using various types of op-amp circuit implementations, an example of which is given in Fig. 2(b). Here a second-order Sallen-Key circuit is presented with component values. The student's task is to determine the transfer function of the circuit. It should be noted this circuit also bridges the circuit analysis and op-amp applications theory taught in other sections of the course.

A filter design problem naturally offers an opportunity to de-couple the skills aspect from the understanding aspect. The relevant reference material, in this case coefficient and de-normalisation tables, can be hot linked into the text thereby eliminating the need for distributing it with test scripts when used in the test environment.

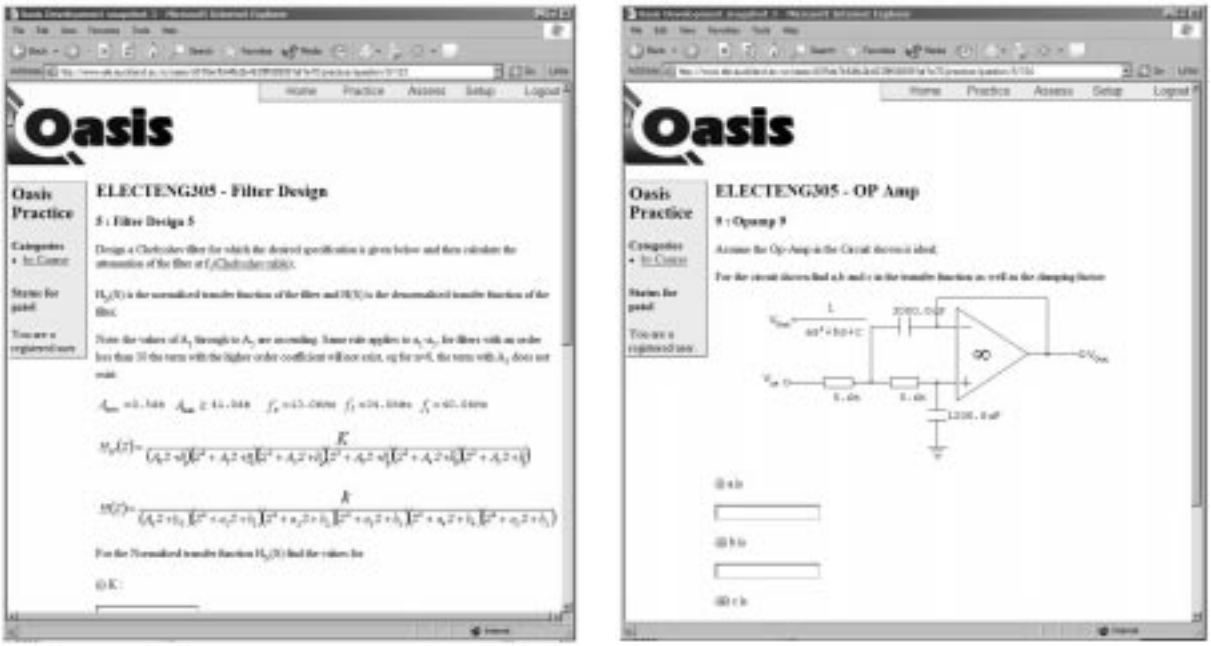

Fig. 2. (a) Chebyshev filter design and (b) Sallen-Key filter implementation.

USING OASIS IN ENGINEERING EDUCATION

There are several reasons why as a teacher you might want to use a package like OASIS, or commercial equivalents such as Questionmark Perception and I-ASSESS in any class environment. One reason is to free up time from marking. However, by far the best argument is to provide a better learning environment for the students. In engineering, one of the biggest problems is how to ensure that students do enough work progressively throughout the course given that much of the learning needs to build on concepts that may take some time and practice to be fully appreciated. In the past often this was achieved by creating problem sets and generating assignments and/or tests to force students to look at these problems. Such problems are essentially regurgitated year after year with slight variations, requiring new answer-sets to be created. But they are only useful if the students actually do the problems and learn from them. As such, it is debatable that assignments (outside of design-based courses) are in fact useful when teaching large classes, since here it is difficult to detect and stop subtle copying. While tests help overcome this problem the marking time is still considerable and consequently feedback to students is slow.

With tools such as Matlab-Simulink and PSPICE, students have become used to solving problems on computer and getting feedback in minutes that a decade ago would have taken many pages and hours of work. In consequence, students have come to expect quick feedback, and sadly are unlikely to spend hours trying to solve a problem or creating 'new' problems that take a significant time if there is a chance that this time is 'wasted' because they have taken a wrong computational step.

In our experience OASIS helps overcome some of the limitations of paper problems and assignments and can also be extremely useful in some test environments. The problems are also more likely to be tried by the students, because they are not static and immediate feedback is available.

Once a problem set has been created, it is valid for many years. Students can choose when to tackle a particular problem either remotely from home or on campus computers, and don't have to wait for the answer sets to be generated as there is immediate feedback on problem set answers and tests. The problems can be worked at, and once the student is confident that they know the principles they can try the same question which will often be sufficiently different so as to test their general understanding of the specific problem as well as their skill levels.

Having used OASIS now for three years in selected courses, an interesting observation is that there is a considerable reduction in wasted time for both staff and students in the courses using OASIS. Students actually do try the problems, and tend to only come looking for the lecturers to answer conceptual or understanding problems.

FITTING OASIS TO ADVANCED ENGINEERING EDUCATION

When the authors first considered using OASIS in a third-year electronics course of a four-year bachelor degree, the issues deemed important were: how to most appropriately break down the problems and fit them into the OASIS environment and how best to use OASIS to maximise the educational value to the students. At the early stages of all engineering degrees there is a significant level of skill-based teaching, and therefore it is easy to use computer based on-line assessments. However as students progress through their degree, the problems typically become more challenging and introduce more design freedom. Students seldom want to spend more than 15–20 minutes on one problem at a time, thus in our experience breaking down design-related problems that rely on previous information into manageable sets is important.

Because OASIS does not mark the students working, each problem needs to be phrased to ensure that all questions don't rely on previous calculated answers. If not, it is possible that despite correct working an early calculation error will ripple through causing all answers to be marked wrong. A fair balance can be achieved by restricting the breadth of each individual question, and if done right students are happy to accept this limitation because they get to try each question many times and learn from their mistakes. This disadvantage within OASIS (and similar packages) is being addressed at present.

The latest version of OASIS allows any simulation tool to be launched in the background. Thus if desired, problems can be solved in real time (subject to local network constraints) or reworked, for marking purposes, offline. Such features add a further flexibility to question–answer generation, allowing desirable features such as re-marking of student tests after the test answers have been submitted, using an incorrect answer supplied by the student. For example, if a student were to incorrectly calculate the order of a filter problem, all other answers would undoubtedly be wrong. However if the student were asked to state the order of the filter they believe is appropriate, then even if incorrect this answer could be used to determine appropriate answers for all other remaining answers in the question. Checking these against the student's answers enables partial marks to be allocated for the working undertaken (as might normally be the case in a written test). Such features need considerable thought, and questions need to be phrased appropriately to take account of such features. These and other additions will be considered for incorporation into future question databases for this course and are

expected to help student acceptance regarding the fairness of computer-assisted grading.

THE ASSESSMENT METHOD

If the question database in OASIS is not comprehensive OASIS-based test problems could be self-defeating as the tendency would be to memorise formulae. Also, in light of educational value, a significant proportion of the entire test must be based on questions they have not seen. Thus the lecturer can get a better assessment of the level of understanding. Recognising that OASIS is better suited to skill-based assessment the authors chose to split the course test into two sections: one part on OASIS while keeping the other part written. The written questions allow deeper understanding to be evaluated. In principle the split is about 50% for each part, but this has varied slightly over the last two years as discussed later.

This split was considered advantageous for the following reasons. From the students' perspective they get to sit a test in which a greater proportion of the questions are familiar. Since the students have the opportunity to practice the methodologies by trying out similar problems (with different numbers) their level of confidence was expected to increase and hence enhance their overall understanding of the course. From the examiners perspective, the time spent on preparing, checking and marking the test is reduced and often this saving is greater than the proportion allocated to OASIS since the breadth of material being marked is smaller making the process less tedious. This also facilitates fast return of the scripts to students for feedback purposes. In consequence, descriptive or essay-type questions that test understanding and are often more time consuming to mark, are now justifiable in a 50-minute test if used in conjunction with a package like OASIS.

COURSE WEIGHTING AND EVALUATION

In 2001 the on-course assessment for the third-year paper under consideration (titled Electronic Devices and Technology) was 40% with 60% marks in a three-hour final exam. This on-course assessment included a 20% project and two tests weighted 10% each. The test durations were 50 minutes and students were instructed that 20 minutes should be spent on the OASIS section. In 2002, the on-course weighting of the paper was reduced to 30% because of a desire by the department to restrict all project-based learning to design papers, and thereby spread the workload more evenly across the academic year. In consequence the on-course assessment was changed to three 10% tests, and a 70% weighting on the final exam. As a result of increasing the database of questions in OASIS, there was also a subtle change in the weighting of the OASIS component in the tests. OASIS formed approximately 25–30 minutes of the 50-minute test.

The University of Auckland's Centre for Professional Development (CPD) surveyed this course each year in the final lecture using the questions listed in Table 1. In 2001 and 2002, 107 and 126 students took this course respectively. 47 completed the evaluation sheet administered by CPD in 2001 and 76 in 2002. The students were asked to rate the statements in Table 1 on a scale of Strongly agree . . . to Strongly disagree, the results of which are presented in Fig. 3.

As discussed earlier, a key educational goal was to use OASIS to help provide a good learning environment in which students progressively worked at selected problems throughout the course and thereby had time to process the information and gain confidence in the material presented. This was attempted by splitting the course into sections, with each section having appropriate OASIS questions for the students to attempt, knowing that some of these questions would appear within the test environment. Survey Questions 1 and 2 attempt to gauge the effectiveness of this approach. The results for both years are similar with approximately two-thirds of the class stating their understanding and skills improved as a direct result of using OASIS. This result is extremely pleasing, and justifies the use of tools like OASIS in advanced courses, providing they are used appropriately.

Questions 3 and 4 attempt to determine the effectiveness of OASIS in the test arena. Approximately 80% of students felt that OASIS gave real help in test preparation, which might be expected given that some of the questions in the test were based on OASIS material. The results from Question 4 reflect feedback as to the appropriate mix of written versus OASIS-based test questions. When comparing the various survey results between years a small yet discernible difference here seems to indicate that the move from a 40% OASIS test component in 2001 to between 50–60% in 2002 was less desirable. Despite this, the majority of the class felt happy that the test fairly assessed their abilities. Thus an approximate 40:60% balance between OASIS and written questions seems about right for this level of course for future years.

While OASIS is not used in the final examination process, approximately 40% of the questions

Table 1. Evaluation sheet questions

Q1.	OASIS helped improve my skill level at solving electronic circuit problems
Q2.	The problems provided in OASIS helped me understand the course material better
Q3.	OASIS helped me prepare for the tests
Q4.	The balance of OASIS and written problems in the tests provided a good assessment of my abilities.
Q5.	OASIS helped me prepare for the exam
Q6.	I was more confident about the course material after using OASIS

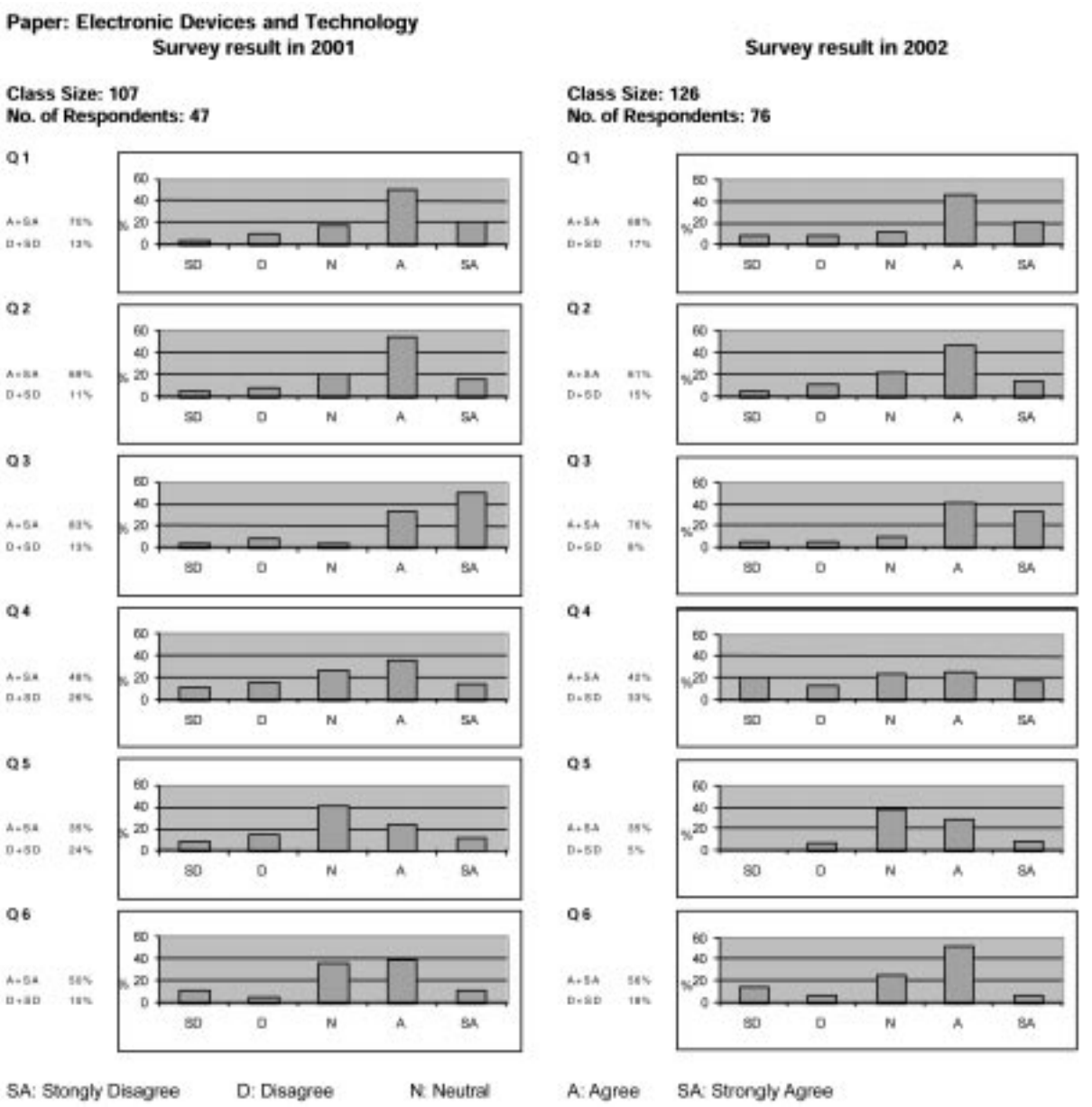

Fig. 3. Electronic devices and technology student survey results.

are skill-based. The student feedback from Question 5 seems to reflect this balance, indicating the usefulness in the minds of many students of OASIS for exam preparation.

The final survey question, while similar to Question 2, attempts to address the feeling of confidence instilled by using OASIS. The pleasing aspect here is that despite the limitations of OASIS, the majority of the class has gained confidence through its use.

Based on the above result, the authors believe that tools such as OASIS can be used effectively to build up confidence in papers that students usually find challenging. The consistent student feedback regarding the way OASIS was used in the course has justified its implementation and continued use. Future work will be focused on extending the database of questions and utilising new features in OASIS to improve the assessment of the students' ability. Furthermore, as this is one of the only courses using OASIS at this advanced level within the department of Electrical and Electronic Engineering, the authors will extend the survey to determine if the availability of OASIS has (as perceived by the students) improved their skills relative to simple paper and pen assignments in similar advanced courses.

CONCLUSIONS

This paper looked at the impact of introducing a web-based tool in a third-year advanced electronics course of a four-year bachelors degree programme within the Department of Electrical and Electronic Engineering at The University of

Auckland. Class evaluations taken over two years show very similar results which strongly support the view that OASIS was well received by the students and enhanced the educational outcomes, justifying its use as an integral part of the student learning cycle. Students felt that they had achieved higher skill levels and a better understanding of the course material as a direct result. OASIS also helped reduce unnecessary student contact hours and significantly reduced the test-marking time of those staff involved.

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