AC 2011-1155: WORK IN PROGRESS: VIRTUAL OUTREACH - FACILITATING THE TRANSITION TO UNIVERSITY STUDY

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Work in Progress: Virtual outreach - facilitating the transition to university study

Abstract

Globally, too few people are choosing engineering careers, and many engineering faculties are attempting to address this problem by reaching out to schools. This paper describes how a home-grown, web-based software tool, already used successfully in university-level engineering and physics courses, is being modified for high-school use. The software package, OASIS, comprises a large question database and server-side program that delivers individualized tasks, marks student responses, supplies prompt feedback, and logs student activity. OASIS can be used for both skills practice and formal assessment. Because the Web server carries out all processing, students need only a computer with internet access and a standard browser, making OASIS well suited to student-centered and distance learning.

Introduction

Many countries are currently experiencing a critical need to increase the number of people choosing careers in engineering and technology [1-5]. In particular, IPENZ (The Institution of Professional Engineers New Zealand) has recently stated that New Zealand has a severe shortage of graduate engineers and needs to produce twice as many engineering graduates as it currently does to match other OECD countries and to meet its own requirements [2]. However, meeting this demand for an increased number of engineering graduates is extremely difficult since high-school enrollments in mathematics and physics have declined significantly in recent years [3]. This problem is exacerbated by the shortage of appropriately-qualified teachers: students of senior physics are by no means guaranteed a teacher who majored in physics. Such students are most likely disadvantaged in terms of both subject skills and inclination to further study. The American Society for Engineering Education, reflecting the nation's anxiety over the situation in the U.S., in 2003 established a K-12 & Pre-College Engineering Division (website available at http://k12division.asee.org/).

Many universities are now funding outreach programs to increase the number of engineering undergraduates [4-15]. Ideally, such outreach programs should have two positive outcomes: participating students should be both better prepared for and better informed about engineering careers. The University of Auckland's (UoA's) Faculty of Engineering does already have outreach programs that involve both visits to schools and visits by school students to the university. However, these programs, without a massive increase in resourcing, can only target students from a relatively small number of local schools. Further, some of the outreach endeavours aim simply to interest students in engineering careers rather than up-skill them in relevant pre-cursor subjects. The ideal outreach initiative should:

(1) reach all students in all schools nationally
(2) up-skill students appropriately
(3) increase student interest in engineering
(4) achieve the above three goals in a cost-effective fashion.

Here it should be noted that the UoA's intake of students into its Bachelor of Engineering degree is effectively limited by government regulation. The university already has far more students applying for its BE degree than it can take. The aim of the Faculty of Engineering's outreach programs is to attract more highly-achieving students, rather than just more students.

In order to maximize return for investment, it was decided that an internet solution was appropriate, in-person visits to schools on a national scale simply being not feasible. It was also decided initially to target just one subject area, physics, and to cover the final three years of high school (in New Zealand these are known as years 11 to 13). Further subject areas may be added later as resources permit. High-school physics was targeted for three reasons. First, physics is a key prerequisite for engineering. Second, physics is the high-school subject students find hardest to understand; often discouraging further study. Third, given the shortage of appropriately-qualified teachers, physics is the subject area most needing support.

OASIS (Online Assessment System with Integrated Study)

The Department of Electrical and Computer Engineering (ECE) at the UoA had previously created and implemented a software package, OASIS (Online Assessment System with Integrated Study), which is used on a daily basis by both engineering and physics students for skills practice, and on a regular basis by instructors for formal assessment [16]. The effectiveness of the software implementation had been previously validated by an action-research study [17]. This study showed instructors considered the software enhanced student engagement and learning, while students described OASIS as easy to use and helpful in improving skills and understanding. Given this positive evidence, it was decided to provide high-school students with their own version of OASIS (School OASIS), the dual aims being to improve the physics skills of incoming engineering students and to promote the University's engineering courses. Additionally, since appropriate ethical requirements have been met, the wealth of data collected by School OASIS can be used in judging student-intake quality and for educational research.

The first version of OASIS was written in 2002, in PHP and using a MySQL database. This software package was well-regarded by instructors, who saw it as both reducing their workload and lifting student achievement, and the decision was made to develop it further. Subsequent versions have been written in Python and utilize a PostgreSQL database.

Comprising a large question database and server-side program, OASIS delivers individualized questions to students, marks their responses, provides instant feedback, and records all student activities, including time logged on, time taken, questions attempted, answers submitted, and the correct answers to attempted questions. Because the web server carries out all processing, students need only a computer with internet access and a standard browser, making OASIS well suited to student-centered and distance learning. And, since the software carries out all marking, OASIS can be used to provide prompt, regular feedback through tests and assignments without the workload issues associated with paper-based assessments. This is particularly significant for large classes, where instructors may be reluctant to set regular assessments since the workload involved in marking is too great. For such classes, there is the further problem of the time taken to return results to students: the turnaround time for paper-based assessments may be two or three weeks, whereas for online assessment, such as that performed by OASIS, it is instant. Given the overwhelming support in the research literature for the motivating power of assessment [18-21] and for the importance of prompt feedback [22-24], these are critical considerations for all instructors.

The record of student activities maintained by OASIS also enables instructors to gauge progress and skills at both course and individual level. For example, instructors can identify at-risk students, who may reveal themselves through a lack of practice activity, a tendency to practice only immediately prior to assessments, or a high failure rate on attempted questions.

Timely remedial action can then be taken. Instructors can also identify questions that students find difficult. Instructors may then address these questions in their teaching.

Students are encouraged to practice OASIS questions from day one. In this way they can improve their skills and understanding and receive timely feedback on their progress. Each numerical question has 200 to 300 different variations, so students can practice each question until satisfied they have mastered the particular skill, situation, or concept. As students practice and improve their skills, they also become familiar with the environment that will be used for assessments.

School OASIS: question bank

Once the decision was made to make OASIS available for high-school use, it was clear that considerable work was needed in two areas, namely question creation and software modification. This section focuses on the question bank. Subsequent sections address software considerations.

While hundreds of OASIS questions do already exist, written for university physics and engineering courses, most of these are not suitable for high-school use. Questions aimed specifically at years 11 to 13 physics needed to be written. Unfortunately, the high-school situation in New Zealand is complicated by the fact that students aiming for university entry in New Zealand can pursue one of three distinct qualifications. These are: National Certificate of Educational Achievement (NCEA - see http://www.nzqa.govt.nz/ncea/), Cambridge International Examination (CIE - see http://www.cie.org.uk/), and International Baccalaureate (IB - see http://www.ibo.org/). As NCEA is the one supported by government and also by far the most commonly-pursued qualification, it was decided to focus on NCEA Levels 1 to 3, corresponding to high-school years 11 to 13. Each NCEA subject at each level consists of several achievement standards. For example, NCEA Level 3 (year-13) Physics consists of one internally assessed achievement standard (relating to practical work) and four externally-assessed achievement standards: “Demonstrate understanding of wave systems”, “Demonstrate understanding of mechanical systems”, “Demonstrate understanding of atoms, photons and nuclei”, and “Demonstrate understanding of electrical systems”. The aim is to cover all externally-assessed achievement standards in years 11 to 13 physics. In order to ensure the questions are appropriate for and appeal to high-school students, an experienced high-school teacher was employed two days a week to write questions. Through 2010, around 400 questions were developed. These questions are designed to appeal to all students and allow them to monitor their academic progress whether they are struggling to pass or aiming for excellence. As well as working on the School OASIS project, the teacher also advises high-school science teachers two days a week and teaches high-school physics one day a week. Thus he is ideally placed to develop, promote and receive feedback about School OASIS. So far, feedback from both teachers and students has been most positive. This employment arrangement will continue through 2011 at least, by which time the question bank will be well stocked and School OASIS will have been widely promoted.

Most questions are numerical, involving a fixed situation but with variables which change in value from one variation of the question to the next. However, in a minority of questions, slightly different configurations exist within a single question. For example, students repeating an electric-circuit question are normally confronted with the identical circuit but with changed values for the relevant quantities, though some electric-circuit questions contain different circuit configurations so that students repeating these questions are confronted with a non-identical, but similar, circuit. For multiple-choice questions, while the answers may not change, the order can, so that the letter answers (A, B, C, D, or E) may also change from one attempt to the next. Figure 1 shows a typical numerical question for year-13 physics.

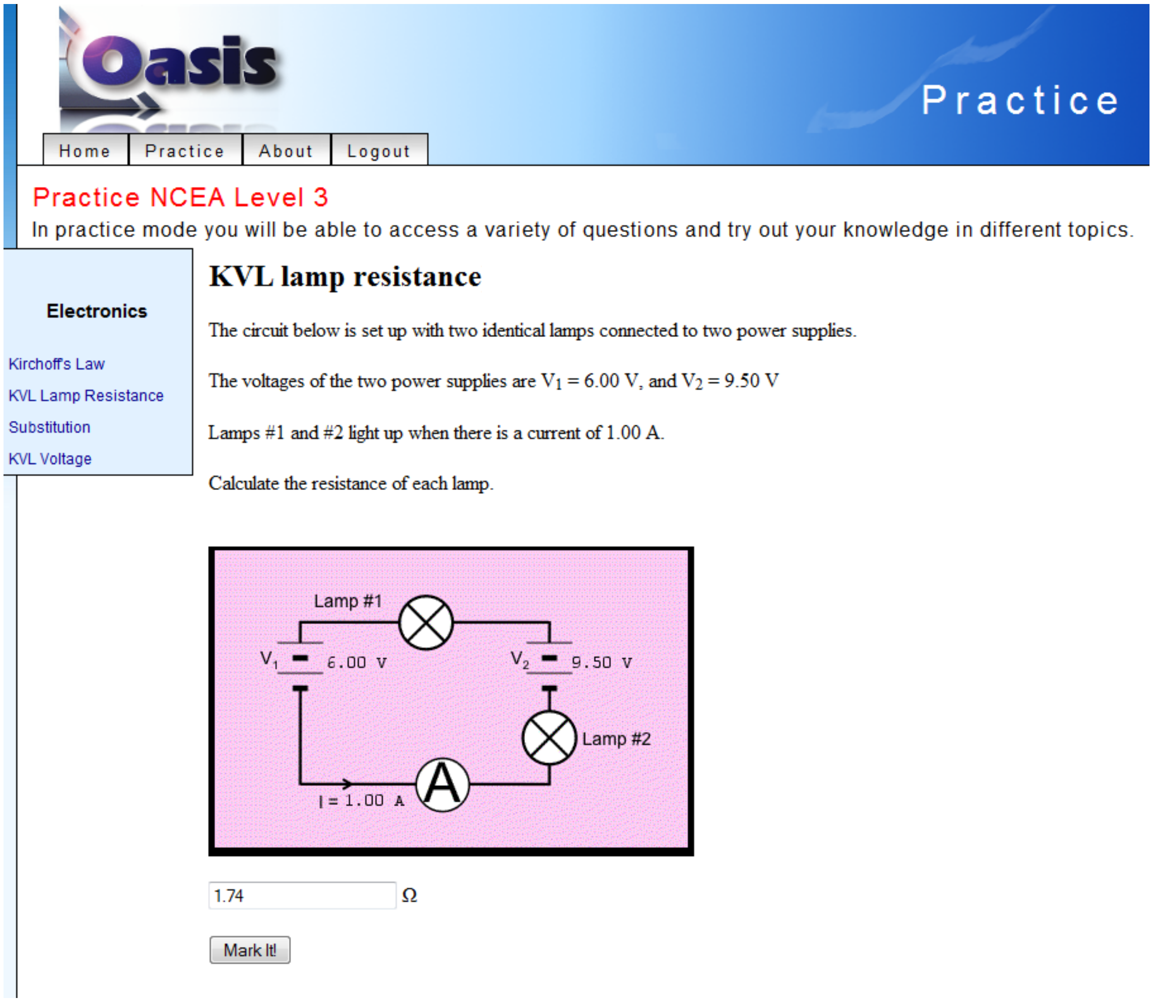

Figure 1: OASIS question for Year-13 Physics.

The answers for all variations of each question are already stored in the question database. Consequently, marking generally involves comparison rather than calculation and poses only a minimal load on the computer. Even though some multi-part questions are marked consequentially, involving a somewhat greater load, a few thousand concurrent users could be comfortably handled by any current mid-range home-office desktop computer without loading problems. Although the largest course using OASIS contains fewer than one thousand students, a larger number of concurrent users can occur if, for example, one course is taking a test while another is completing an assignment and other students are practicing questions.

By default, an answer within 1% of the actual answer is deemed correct; however this tolerance can be adjusted for each question. For example, it may be appropriate to mark a question requiring graph interpretation to a wider tolerance. Figure 2 illustrates a typical screen display after a student submits an answer to the question shown in Figure 1.

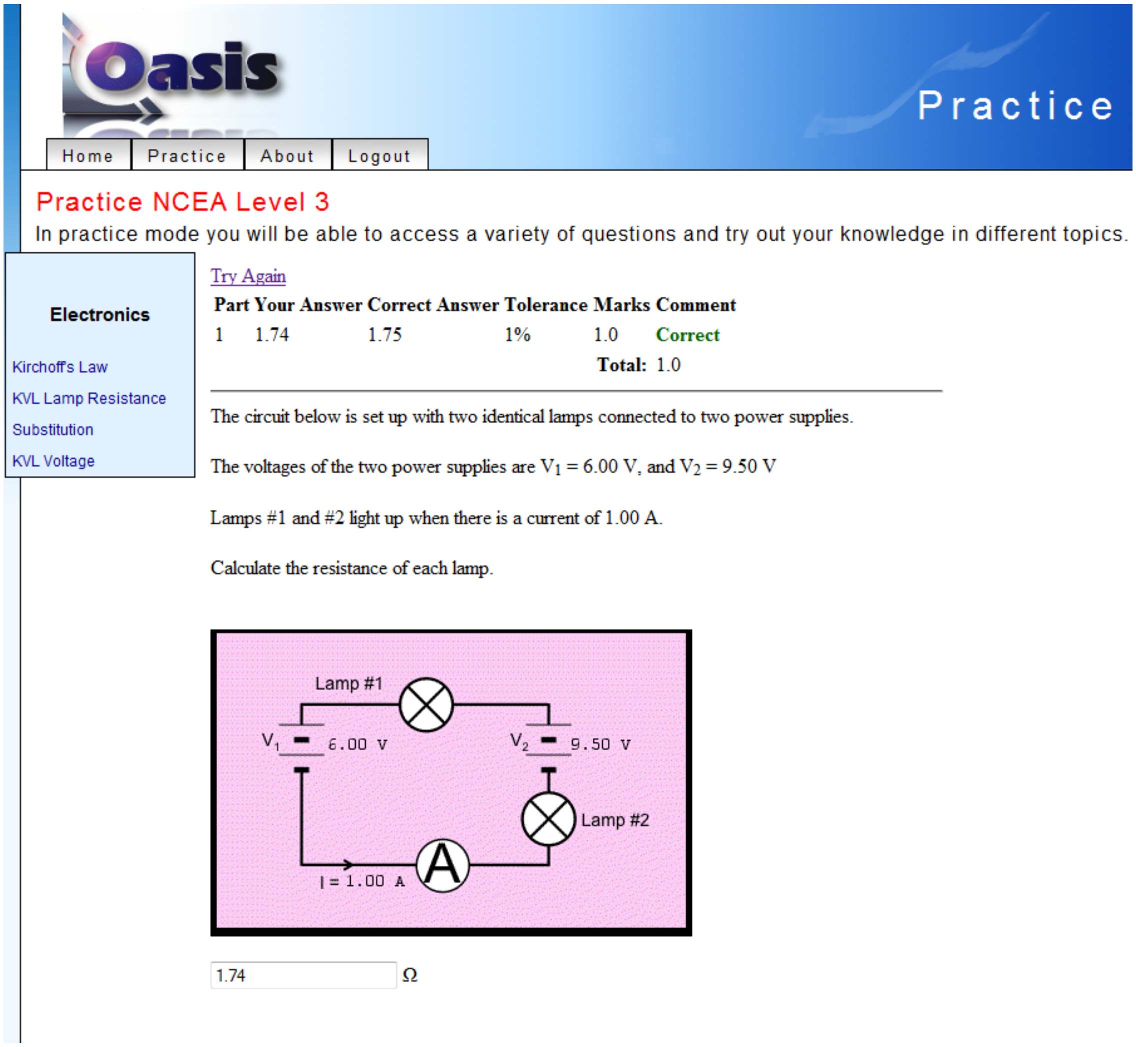

Figure 2. OASIS response to student answer submission.

The answer of 1.74 is marked correct as it is within 1% of 1.75. However, 1.8 would have been marked incorrect. For most questions, the Comment is simply “Correct” or “Incorrect”. However, a few questions trap common errors; for these the Comment can include feedback which identifies the error. Clicking on the “Try Again” link delivers a numerically-different version of the same question.

School OASIS: software development

The existing OASIS software provided the basis for School OASIS, but some modifications were deemed desirable or necessary. For example, it was deemed desirable to refresh the software package’s appearance to give more visual appeal for high-school students. An undergraduate student was employed late 2009 to design and implement a new, more-attractive interface that also provided access to NCEA questions via year level and topic area.

The current version of OASIS is designed to handle up to 5000 concurrent users. School OASIS potentially has to support far more students, so the system, servers, database, and related components were all re-architected to achieve this support reliably. CouchDB rather than PostgreSQL is used for the School OASIS database.

A number of further necessary changes centred on student identification and login, and instructor data-access rights. Here there are clear differences between high schools and universities. For example, at UoA a course coordinator can access all data for all students who have attempted any questions for the course, whether for practice or assessment. The great majority of these students will, in fact, be enrolled in the course, although any student enrolled at UoA can access the practice questions for any course. However, the teacher of a particular high-school class should normally have access only to data for students in that class, one exception being that a school's Head of Physics should be able to access data for all students at the school. This functionality is not yet implemented but will be prior to the start of the new school year, February 2011. It could be achieved as follows: first, each teacher applies to ECE for class registration. Once the teacher's credentials are validated, he or she is provided with a code number that contains both a class and a school code. This code number is then given to each student who provides it together with her or his name when registering for OASIS. The association of code numbers with student groups enables teachers to gain access to their class data, and Heads of Physics to gain access to their school data.

Two variations on the above are as follows. First, particularly in the short term, there are students who want to use OASIS whose teachers do not wish to register them, or lack the motivation to do so. For this reason all students have been allowed access to OASIS practice questions whether or not they are registered. Of course, teachers of unregistered students cannot access data for them. However, students whose teachers are using OASIS for both practice and assessment will wish to register so that their teachers can credit them for their OASIS assessments.

Second, in the longer term, some schools are likely to host OASIS themselves. Such hosting would require only a very small commitment of resources (for example, a very modest 1.8 GHz server with only 1 GB RAM can handle more than 1000 users concurrently without loading problems) and would provide schools with more control over all aspects of the operation. Such schools could manage OASIS in the same sort of way that the University manages its OASIS operation, with students logging in with their school ID number.

Formal assessment

A GUI assessment generator enables instructors to construct OASIS assignments and tests for their students relatively easily without any specialized knowledge. Such formal assessments consist of a small number of questions to be done by students within a certain time-frame.

For tests, all candidates log on at the same time in a supervised environment. The fact that OASIS uses numerically different versions of the same questions makes cheating extremely difficult. Only the first submissions of students are marked; this prevents students submitting their answers, seeing the correct answers, and then using the 'back button' on their browsers to resubmit the correct answers. However, students can enter and revise all their answers as often as they like before actually submitting them. It is important that computerized tests offer the same flexibility as traditional written tests in this regard [25]. OASIS actually records all student answers; even those entered on the screen but not submitted. This function has been appreciated by students whose computers have crashed part-way through a test prior to answer submission. Remaining time is displayed throughout the test; when time expires, the student is automatically logged off. A five-question test is illustrated in Figure 3.

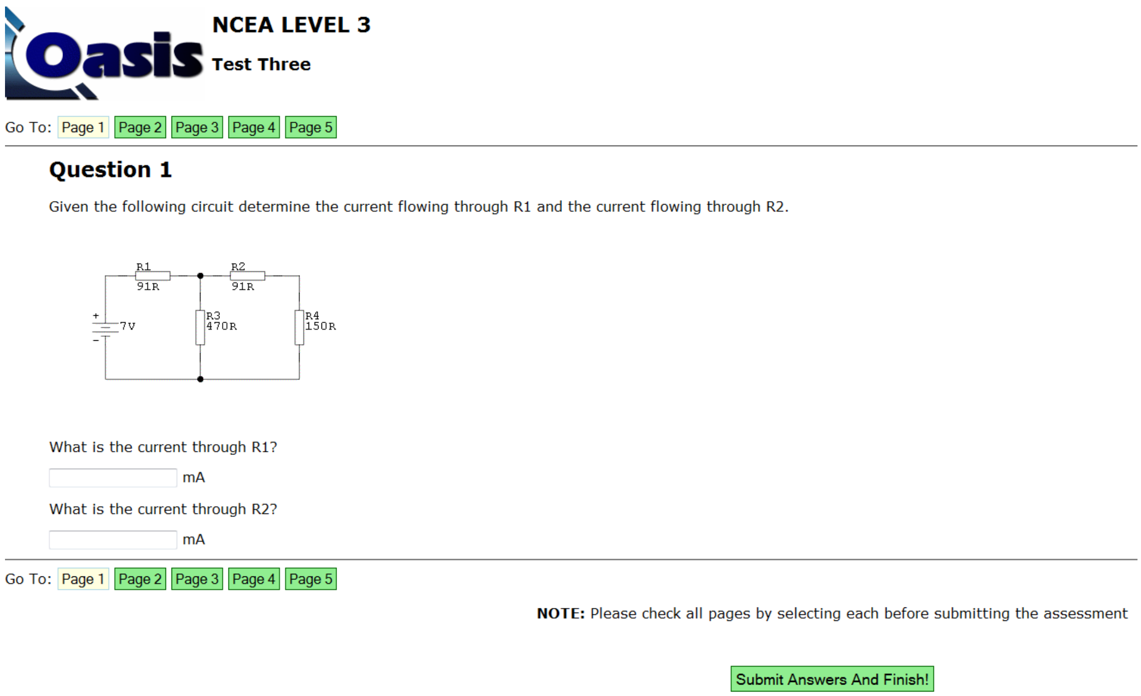

Figure 3: An OASIS test comprising five questions.

Some courses are too large to be assessed by tests as described above: there are simply insufficient computers. Assignments may be used to assess such courses. Assignments are similar to tests but are unsupervised, can be taken by students wherever they have internet access, and have a less stringent time constraint. Normally, students are required to complete an assignment in a single one-hour period within a twelve-hour period: one hour after a student logs on, the assignment is closed. However, a student can change computers within the hour.

Question creation

School OASIS will provide questions that completely cover NCEA levels 1 to 3. However, teachers may also wish to create questions. In particular, teachers preparing students for an IB or CIE rather than an NCEA qualification will be teaching a few topics not covered by NCEA and therefore not covered by the School OASIS question bank. For example, knowledge of operational amplifiers is required for CIE but not NCEA. Teachers working with IB or CIE are therefore particularly likely to wish to create some questions for their own students. A GUI question composer currently exists that enables instructors to construct OASIS questions for their students relatively easily without any specialized knowledge.

However, the school situation is different from the university situation. In the university situation each problem set is used by a single group of students, and a single instructor (or perhaps a very small group of instructors) has an interest in maintaining and adding to it. In the school situation each problem set is used by a very large number of groups of students and many teachers potentially have an interest in adding to it. Issues around quality control are therefore important. For example, a question added by one teacher may be perceived as inappropriate, misleading or of poor quality by others. The answer supplied may not even be correct. Such issues have occasionally marred national examinations in physics, so it is certain that they will sometimes affect School-OASIS questions too. Consequently some quality control needs to take place before a question is made available for general use. Currently all questions being added to School OASIS are checked by two people before release. In the future it is envisaged the checking will be carried out by at least two teachers from a small group of experienced teachers prepared to take on this extra duty. Only after a question has been approved would it be added to the question bank. In this way the pool of questions available for student use will become larger and more diverse through time.

One alternative scenario is that when a school creates its own questions they are not checked by independent teachers and are just available for use within that school. This scenario is less favored as it does not increase the question pool except for that school, and it also increases the chance students may be faced with some substandard questions. Of course, a school that hosted School OASIS on its own server would be able to create its own questions and limit their use to within the school. Fortunately, only larger schools are likely to choose to host School OASIS themselves. Such schools have large numbers of students using the questions, together with multiple teachers associated with each problem set. In this situation, any quality issues with a particular question would most likely be rapidly identified and corrected. This has certainly proved the case at university level. However, for many schools in New Zealand, only small numbers of students study physics at each level and the number of teachers with an appropriate physics qualification is low or even zero. For such schools, an external quality-control system around question creation is clearly desirable.

Conclusions and future developments

The OASIS software package has been successfully used for university engineering and physics courses for several years. There are 200 to 300 numerical versions of each question, allowing great opportunities for repetition, facilitating student skills practice and development, and making assessment more secure against cheating. Assessments can also be further individualized, with different students receiving different questions. Consequential marking for multi-part questions and repeat attempts for partial credit can also be implemented in assessments to make the process fairer and more student-friendly.

At the end of 2009, ECE began work on School OASIS, a version of OASIS for high-school use. School OASIS will provide practice and assessment opportunities for students in their final three years of high-school physics study. It will completely cover the topics necessary for NCEA Levels 1 to 3, the qualifications most-commonly sought by high-school students in New Zealand, and will cover most topics necessary for the rather less-popular IB and CIE.

As School OASIS potentially has to support far more students than OASIS, the system, servers, database, and related components were all re-architected to achieve such support reliably. The user interface has also been redesigned to appeal more to younger students.

In 2010, around 400 questions were written for School OASIS by an experienced high-school teacher, and some teachers and students were already using the software for skills practice.

The feedback from these early adopters is encouraging, and consistent with the feedback received from university users. Throughout 2011 the question writing will continue and further feedback from students and teachers will also be collected by survey and interview. This feedback, together with the usage data automatically collected by School OASIS, should be sufficient to inform and validate its continued development and implementation.

Further software enhancements are to be implemented prior to the start of the 2011 school year in February. In particular, the issues of student identification and instructor data-access need to be addressed, so that teachers can access practice and assessment data for their students but not for others. The assessment generator will also be improved. In most respects it is easy to use, but instructors wishing to provide different students with different questions (rather than different versions of the same questions) must currently follow a non-intuitive procedure. The question composer also requires some effort to master and a simplified version is planned for 2011 in order to encourage greater teacher use. Once these changes are implemented and School OASIS is operating smoothly, links will be added so students can readily access information about engineering as a career, university engineering courses, and other relevant matters.

With the above changes in place, it is considered that School OASIS will be able to meet its two aims: to improve the physics skills of high-school students, and to increase the numbers of students wishing to study engineering at tertiary level.

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