Work in Progress - A Web-Based System for the Delivery and Analysis of Course Concept Inventories

Gerard Rowe and Chris Smaill
Department of Electrical and Computer Engineering, University of Auckland
Auckland, New Zealand gb.rowe@auckland.ac.nz and c.smaill@auckland.ac.nz

Abstract - A commonly-reported observation is that some seemingly academically well-prepared students struggle with their studies once they reach the mid-points of their degrees. Furthermore, these same students often report excessive study times for courses and appear unduly stressed. We hypothesise that these students have misunderstood core concepts. We describe work in progress to develop a tool which delivers a test of core concepts in a subject and automatically marks individual students’ attempts. The development specifications for this tool also require the ability to analyze the results to provide the lecturer with a quantitative measure of the level of class understanding over a range of core concepts. By delivering and analyzing pre- and post-tests, such a tool can also facilitate the quantitative assessment of the effectiveness of particular teaching interventions or student engagement strategies. It is also intended that the tool could be used over successive years to reliably quantify entry standards into various courses.

Index Terms - Concept inventories, automated marking, student misconceptions, electrical engineering education.

BACKGROUND

Study of concept mastery is well developed in Physics Education Research. Such research arguably began with Halloun and Hestenes “Mechanics Diagnostic Test”, later further developed into the well-known “Force Concept Inventory” [1]. Only recently have concept mastery studies received attention in Engineering Education Research, with inventories currently being developed for several fields, including electromagnetic waves, signals and systems, strength of materials, thermodynamics, materials science, statistics, heat transfer, fluid mechanics, electromagnetics, chemistry, biology and circuits [2]. Most Concept Inventories (CI) are delivered and marked manually, often significantly delaying feedback from large classes. Automated delivery, marking and analysis would benefit instructors significantly. Such automation is the primary goal of this project.

METHODOLOGY

At the University of Auckland the BE degree is a 4 year programme. Our pilot study is centred on a Year 3 elective in Transmission Lines and Fields. Four steps are involved. The first step was to develop a trial Transmission Lines and Fields Concept Inventory (TLFCI) to fit the engineering electromagnetics curriculum structure at the University of Auckland. The second step was to implement this trial TLFCI on OASIS (a Web-based assessment system developed at the University of Auckland) using a Question Editor (also developed “in-house”). The third step is to develop the OASIS code required for the statistical analysis of the trial TLFCI results. Finally, a trial of the automatically-delivered TLFCI is planned for Semester 1 of 2008.

DEVELOPMENT OF TRIAL CONCEPT INVENTORY

The method of CI development typically described in the literature involves a four-step process:

1. Identifying the important and difficult concepts (often using a multi-round Delphi process, involving subject experts from a number of institutions).
2. Identifying common misconceptions for those challenging concepts (often using student interviews, “think alouds”, unmoderated group discussions).
3. Designing questions with one or more right answers and several distractors based on these misconceptions. (The design of distractors which align with student learning models and represent commonly held misconceptions is perhaps the key step in concept inventory design.)
4. Validating the concept inventory through peer review, qualitative analysis, and psychometric analysis of trial runs.

Ultimately a TLFCI will be formally developed using the above process. However, as the focus of this project was on investigating the efficacy of a tool for the delivery, marking and analysis of concept inventories, access to a trial concept inventory was needed. Funding provided via a Teaching Improvement Grant enabled the authors to develop sufficient candidate concept inventory questions for a 30 minute test. This development was carried out using input from local subject experts and a perusal of existing electromagnetic waves and electromagnetics concept inventories.
OASIS

The Department of Electrical and Computer Engineering at the University of Auckland saw computer-based assessment as the best way to maintain educational standards in the face of increasing workloads. Partly for reasons of cost, and partly because of perceived deficiencies in some commercial packages, the Department produced its own software package, OASIS, (which stands for Online Assessment System with Integrated Study). OASIS is a Web-based tool used for skills practice and summative assessment. OASIS is written in the Python programming language and uses the PostgreSQL database for data storage. It runs on the Linux Operating system. The tool delivers individualized tasks, marks student responses, supplies prompt feedback, and logs student activity. OASIS comprises a large question database and server-side program that delivers questions to students, marks their responses, provides instant feedback, and records students’ activities. 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-centred and large-class learning. The present version of the OASIS software package has been successfully used since 2003, with a prototype version being used prior to that [3]. We now seek to extend the capability of OASIS, beyond the current areas of skills practice and assessment, further into the realm of educational research. This paper represents the first formal reporting of this extension to OASIS.

PROGRESS TO DATE

The first phase of the project is complete. A 15-question Transmission Lines and Fields concept inventory (TLFCI) has been developed. Both multiple choice questions (MCQ) and multiple true/false (MTF) questions are included. We are aware that some researchers consider an MCQ-only approach to be better for pinpointing misconceptions. However, in the longer term, we wish to be able to probe cognitive development levels as well as simply identify the extent to which common misconceptions are held. Knowledge of multiple correct answers has been tied to the levels of learning as presented by Bloom’s Taxonomy of Educational Objectives [4]. For this reason we have deliberately included a number of MTF questions in the trial TLFCI.

The second phase of the project is also complete. The implementation of the trial TLFCI on OASIS was straightforward and well within the current capabilities of OASIS. The only difference was that the TLFCI uses MCQ and MTF questions (with many graphical items) whereas most practice questions on OASIS are numerical. The implementation of these MCQ and MTF questions did however necessitate a small number of changes in the OASIS Question Editor software. If automated concept inventory delivery tools are to be widely adopted, it is important that the entry of questions is easy and requires no special expertise. The Question Editor, supplemented with a standard software package for the production of graphics, spares instructors the need to become familiar with the HTML mark-up language.

The third phase of the project is on-going. We are currently working on the development of software to analyze student performance on the trial course concept questions. The project software specifications require statistical analysis of correct answers and also, more importantly, of misconceptions held by students. Preliminary results of this third phase will be available by the time of the 2007 FIE Conference.

Results of the fourth phase, the Semester 1 2008 live trial, will be presented at subsequent FIE and ASEE conferences. Should OASIS be judged an appropriate tool for the delivery, marking and analysis of concept inventories, a subsequent (multi-year) project will be undertaken which will replace the trial TLFCI with an appropriately designed and validated Transmission Lines and Fields Concept Inventory.

DELIVERABLES

The primary deliverable of our research is an on-line tool which can automatically deliver Concept Inventories to students and analyze their responses. Rather than rely on student surveys or examination results, an instructor can obtain a quantitative assessment of the effectiveness of particular teaching interventions and student engagement strategies by using such a tool to deliver and analyze pre- and post-course tests of student understanding of core concepts.

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REFERENCES