BRIDGING THE GAP BETWEEN ASSESSMENT, LEARNING AND TEACHING

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Abstract

This paper looks at how learning, teaching and assessment can become misaligned resulting in an education system that does not support student learning. It discusses a number of issues that, if addressed, could narrow the gap between teaching, learning and assessment:

- The need to use the same software tools throughout the education process
- The need to assess what the student has learnt rather than what is easy to assess
- To consider the possibility of assessing qualitatively not quantitatively
- To consider the possibility of assessing the application of knowledge, rather than its acquisition

This paper outlines how past work developing a software tool combining simulations and assessment (Thomas et al 2004, 2005) has been used to produce exemplar teaching material that uses the same software throughout the educational process. The system is capable of handling the needs of traditional e-Assessment and of providing the tools to investigate innovative assessment that focuses on performance and the quality of learning. Whilst the principles discussed are not subject specific, an exemplar in the area of Mathematics is used in this paper.

Introduction

The interconnection between assessment, teaching and learning is undeniable. As Ramsden (1992) pointed out:

"The process of assessment influences the quality of student learning in two crucial ways: it affects their approach and, if it fails to test understanding, it simultaneously permits them to pass courses while retaining the conceptions of subject matter that the teachers wish to change"

If teaching methods and assessment are not aligned to the learning activities stated in the course objectives, then a discordant teaching system results which does not support student learning (e.g. Biggs 1999).

For many years, much summative assessment has consisted of timed, closed book, pen and paper examinations. Some workers have expressed doubt about whether traditional forms of assessment are properly aligned with the teaching and learning. Biggs (1999) points out that the declarative knowledge (or knowing about things) and functioning knowledge (using declarative knowledge to solve problems) are frequently assessed in the same way and that students state what they have learned rather than show it performatively. Jonassen (2003) suggested that we should assess the performance of the learning activity rather than simply the outcome.

Other workers, such as Biggs and Collis (1982) have advocated qualitative, rather than traditional quantitative assessment, focusing more on how well students had understood a concept rather than how much they had understood. They put forward a taxonomy (Structure of the Observed Learning Outcomes, or SOLO) that was designed to distinguish between learning outcomes of low and high quality. The taxonomy is in 5 levels:

- **Pre-structural:** no understanding is demonstrated.
- **Uni-structural:** a very basic understanding with focus on one component or aspect of a complex problem only.
- **Multi-structural:** understanding of several components of a problem, but no understanding of how they relate to one another.
- **Relational:** understanding of several components in an integrated fashion so that logical conclusions can be drawn.
- **Extended abstract**: students are able to generalise their understanding into new areas and draw new general conclusions.

If there is misalignment between learning and assessment where learning does not involve ICT, does the situation improve with the increasing use of ICT to support learning? E-assessment is being gradually introduced in the domains of education and training, but it is currently at a stage where its primary function is to improve efficiency and reduce costs by duplicating the functionality and rationale of traditional assessment (Bennett 1998). Until now, the focus has been on what is easy to automate rather than what we actually wish to measure (Ridgway et al 2004) - this does not improve the alignment between learning and assessment.

Issues of alignment also arise when ICT is used in only parts of the educational process (e.g. in learning but not assessment or vice versa).

"Currently, we have bizarre assessment practices where students use ICT tools such as word processors and graphics calculators as an integral part of learning, and are then restricted to paper and pencil when their 'knowledge' is assessed."

Ridgway et al (2004)

Conversely, Harding and Craven (2001) point out the difficulties of introducing ICT into summative examinations in advance of learners routinely using such software and note that:

"It is however self-evident that in order to be fair, a summative assessment system must be based on activities that are familiar to the learner."

There are a few examples where commercial ICT is used in both learning and assessment for instance, the use of Computer Algebra Systems (CAS) in the Baccalauréat Général Mathématiques examination in France and in the College Board's Advanced Placement Calculus test in the USA.

The aim of this paper is to outline the design and development of an e-Learning project that attempts to close the gap between learning, teaching and assessment and addresses the issues identified which can lead to misalignment:

- The need to use the same software tools through out the education process.
- The need to assess what the student has learnt rather than what is easy to assess.
- The possibility of assessing qualitatively not quantitatively.
- The possibility of assessing the application of knowledge, rather than its acquisition.

Whilst the principles discussed are not subject specific, an exemplar in the area of Mathematics is used in this paper. Examples of other subject areas can be seen at http://www.jelsim.org/ourwork.html, and the application of multiple interfaces is well illustrated by the Solar Transit Model at http://www.jelsim.org/content/applets/solar/index.html.

Technical Background

In 2004 Thomas et al described a fledgling system for integrating simulations and assessment in a way that allowed a range of parameters and activities from within the simulation to be monitored from within the assessment engine. The paper outlined how the system could be used to test higher order skills (classified according to Blooms revised taxonomy). The paper focused on assessment, it did not include a consideration of learning and teaching within the process. In 2005 an enhanced system was described (Thomas et al 2005) and learning and assessment were linked as the paper considered learning objectives which could be met using simulations, and ways in which these learning objectives could be assessed. A number of examples were produced (see http://www.calm.hw.ac.uk/sims-asses.html).

However, using the simulations solely for assessment effectively only considers half of the education picture. In fact the system allows the simulations to be re-used and repurposed in a number of ways throughout the education process (Thomas and Milligan 2004). It is this potential that is being explored in this project in order to address the issues outlined in introduction.

The Pilot System

The underlying tools

The system used in this pilot is an integration of the JeLSIM simulation toolkit (Thomas and Milligan 2004) with the PASS-IT assessment engine (PAE) (see http://www.calm.ac.uk/sim-asses.html) presented at the CAA conference in 2004 (Thomas et al 2004). With JeLSIM tools, a programmer creates the algorithm controlling the behaviour of the simulation (the model), and the educationalist (a non-programmer) can create the user interfaces (visualisations) to the model. One model can have many, very different, visual interfaces and different initial states. Attention can be focused on a specific concept by changing how the model is exposed to the user, and how much of the model the user can manipulate.

Choice of exemplar model

A number of new simulation algorithms (models) have been designed from scratch for this system. They have been designed to be extremely flexible as they will be required not only to fulfil current educational needs but also to permit exploration of different approaches to assessment.

In this paper we will use examples from one of these models – the curve laboratory.

The model behind the curve laboratory has a number of general features:
- a number of families of functions can be used (including straight lines, trigonometric functions and quadratics),
- controls which allow learners to manipulate the graphical representation of these functions,
- details of the expressions for the graphed functions,
- the ability to obtain information regarding the state of the model from an external source (the assessment system or learning environment),
- the ability to communicate a user determined state to an external system (i.e. communicate "answers" or user state to the assessment system or learning environment).

For this exemplar system we have used the curve laboratory and focussed in on the relationship between the expression for a trigonometric function and the associated graph. In Scotland, students usually encounter this area in Mathematics at the Scottish Qualification levels of Standard Grade / Intermediate 2 and Higher.

Often students learn about this topic by plotting functions by hand, or by comparing static graphs (as in Figure 1) to understand the relationship. Whilst it is important that students can manually create graphs of functions, creating these by hand can be tedious and may result in the general concept being lost, either due to the time taken to draw the graphs, or due to a lack of understanding about how to draw the graph. The exemplar system removes these barriers and allows the quick manipulation of various parameters to explore the relationship at a conceptual level. There is therefore the potential here to examine the approach a student takes to this exploration (be it free or

directed). In addition, the model has the potential for a high level of reuse in a number of contexts via the creation of a number of visualisations for the model, and the use of randomised and fixed initial states.

More specifically here we are concentrating on the following objectives (note: these are not always taught all at once, and not necessarily expressed in this manner). In general a student should become familiar with the relationship between changes in the expression and the graph (and vice versa) for the following manipulations:

  a. changes in amplitude

  b. changes in period

  c. horizontal translations

  d. vertical translations

In other words, students are exploring the link between the graphs and the following general expression[1],

$$a \sin(bx + c) + d$$

where the parameters a, b, c & d relate to each of the points above.

For example, a student may begin by exploring the concept of a change in amplitude, and how that relates to the parameter a in the simplified form of the above expression of $a \sin(x)$ – see Figure 1.
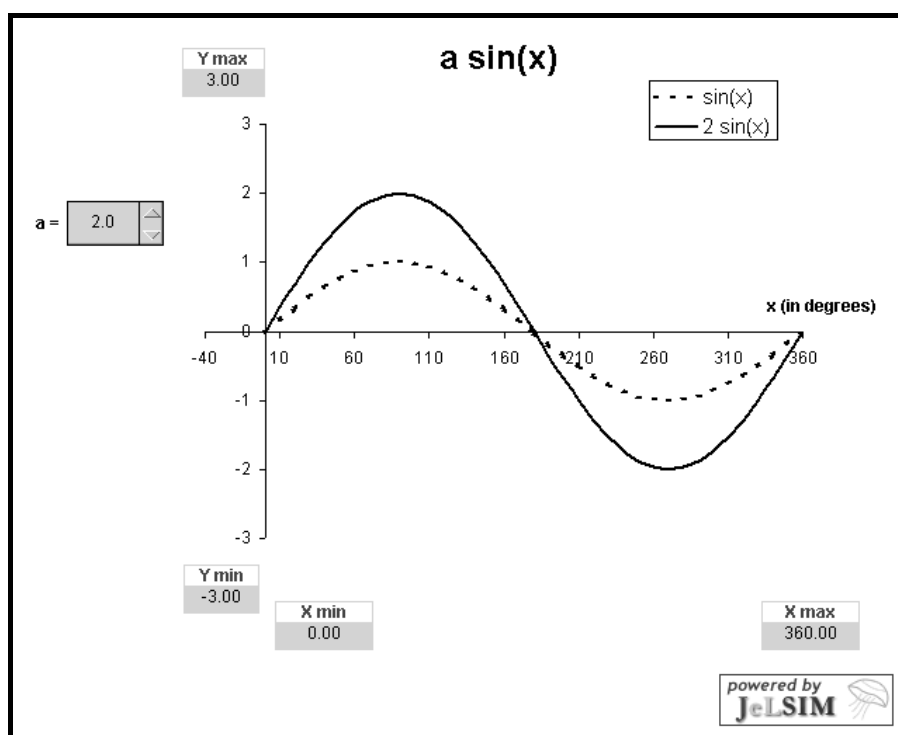

Figure 1: Graph of sin(*x*) (dashed) and 2sin(*x*) (solid)

Visualisations[2]

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[1] This general expression is only one of a number of general expressions that can be utilised within the curve laboratory.

The models are used to create simulation visualisations (interfaces). Many different visualisations can be created from one model (Thomas and Milligan 2004). A key way in which visualisations can be varied is by the degree of freedom to explore that they allow the learner. This could range from no freedom where the learner sees a pre-set demonstration through a directed task, to open exploration. This means that the visualisations can be used to suit a range of teaching modes and styles. To illustrate this point some of the different types of visualisation that can be created with a simulation are listed below followed by an example of how they might be used to deal with a typical learning objective:

- **A teacher's mode** – suited for demonstrating concepts in a lecture. Such visualisations would be suitable for display on an overhead projector (using large font and highly visible colours). They contain minimal description and additional material, since a teacher will be present to provide explanation. They may also have preset functionality provided via a button click for ease of presentation.

  A teacher might start by showing a visualisation in which one parameter can be varied and demonstrate the effect of varying this parameter, getting students to predict what will happen as the parameter is changed.

- **A course material view** – suited to exposition of the subject (describing and explaining a topic) demonstrating points within online learning material.

  The course material could back up the classroom teaching by allowing the students to cover this at their own pace and in their own time. It could progressively introduce students to more variables, providing situations where the student must predict, check the feedback and adjust their own understanding.

- **Exploratory views** – suited to activities, which require the student to explore a topic. This form of visualisation can provide guided exploration where the student is prompted to undertake an activity or free exploration where the student can explore as they wish. It is possible to collect and analyse information about how the student explores the environment.

  Exploratory views are generally more open than course material. The degree of exploration (number of parameters which can be altered) can be increased as students gain expertise. This mode is designed for students to ask their own questions, make predictions to build up their own rules of how the curve and expression are related. It can also act as a "laboratory" to obtain information to solve the more complex tasks set in the problem solving view.

- **A problem setting view** – used in combination with a problem scenario or task. The simulation is set to an appropriate starting state and the student

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[2] The term visualisation is used to include not only the appearance of the simulation, but also its initial state.

is asked to solve a problem. Student activity and answer generation can be linked to the assessment engine and its reporting system.

> *The problem solving view sets a task, which may be fairly complex, and provides access to the other views as resources for the students to solve the problem.*

Example course material will be available at www.calm.hw.ac.uk/CAA2006.

Creation of visualisations

An important feature of the system is that it should be capable of use by non-programming teachers. In the pilot study, the teacher is very familiar with PAE but not with JeLSIM. Teachers are not expected to create JeLSIM interfaces from scratch, a number of templates covering common question types in this subject have been created. (These question types have been selected from the SQA Higher Mathematics National Assessment Banks (NABs)). Each template has a designer's "overlay" screen, which is only visible in editing mode (not when the student runs the visualisation). The designer's overlay provides access to important variables and a tutorial in how to use them. These provide a starting point for novice designers wishing to create learning material or new assessment questions.

Combining resources to form learning material

Visualisations can be used in a variety of ways to create resources for use within a course on a subject (either as standalone objects or as components in other resources). The visualisations take the form of Java applets that can be used within any web page or learning environment.

Summary

The system as described above is capable of being used in teaching, learning and assessment, and as such has the potential to overcome the first issue identified as a problem in the introduction. In the remainder of the paper we look at how assessment, both traditional and more performance based, can be enabled by the system.

Assessment within the system

Traditional assessment

Past papers (Thomas et al 2004, 2005) have shown how traditional assessment was aided by the combined PAE-JeLSIM system where it could be used to quickly set questions and mark answers. The same approach applies when the "assessment enabled" simulations are embedded within additional learning material. The outcome of a simulation activity can be passed to the assessment engine for marking and feedback, and the student can be directed to appropriate remedial activity.

A number of questions can be grouped to produce a test. This can be used to provide e-Assessment versions of traditional paper based tests (e.g. SQA Higher NABs). The system can also be used in diagnostic assessment at a

higher level (e.g. 1st year university) to highlight and remediate weaknesses of students entering university.

The type of assessment described above is unusual in its focus on simulations and their use in assessment, but it still functions within the milieu of traditional education and its learning objectives. There are however, opportunities for learning and assessment outwith the traditional areas.

Alternative assessment techniques

As well as a traditional form of quantitative assessment, the system is being used to look at qualitative assessment and how well students make use of the knowledge they have acquired. It is useful to assess the quality of learning, not only to determine a student's mastery of a subject, but also to allow teachers to evaluate the quality of their teaching.

The SOLO taxonomy provides a convenient way of categorising the quality of learning. In terms of the type of learning expected from students using the "curve lab" this ranges from: *uni-structural*, where the student can cope with one variable, through *multi-structural* where they can handle more variables, through *relational* where they can understand the interrelationships between the variables and can easily solve problems in the domain, through to *extended abstract* where they can make generalisations to other families of curves. When the learning deepens and becomes higher quality, rather than applying rules they have been taught, it is anticipated that students will begin to build their own rules and use their own strategies to solve problems.

Can an assessment strategy be adopted to ascertain the quality of learning? The assessment must provide information about more than whether a student can determine the answer to a problem: it must look at *how* students solved the problem and the strategies they adopted.

Suppose, for example, students were shown two curves on a graph and were given the equation of one curve and asked to work out the equation of the other. They would be given access to the curve lab whilst undertaking this task. It would be of interest to know whether the students adopt a structured approach to determining how each variable affects the shape of the curve or adopt a "pot luck" approach randomly selecting variables to try. Do students engage in a form of informal self-assessment when they engage with simulations? Do they predict what will happen if they carry out an action? Do they test the result of the action and then if necessary revise their understanding? The curve lab can monitor the actions a student takes when manipulating curves and our aim is to determine whether it is possible to distinguish different types of approach from reviewing the sequence of actions undertaken by the student. Research to establish an initial baseline to link recorded actions to types of solution strategy will be carried out by (audio) recording students "thinking aloud" as they work through a problem. Asking students to "think aloud" will also be used to determine the construct validity of new forms of questions.

Often, students are given rules to allow them to solve a particular problem type, but ultimately students need to be able to develop their own

understanding and rules if they are to be able to extend their expertise to variants of that problem type. One method that will be investigated to assess this is "teach back", a form of assessment in which the student presents their understanding of a concept to a teacher, examiner or classmate. In this case, students would be teaching their own rules for solving a particular type of problem. Within this system, this "teach back" could potentially be computer-based, as non-programmers can create visualisations and other resources. (Currently some training is required to allow a teacher to create simulation resources or assessments and some improvement of user interfaces would be required if student novices were to use the system).

Finally, students can be asked to create questions for other students. There is a considerable body of work on the benefits to learning of students creating questions (e.g. Draaijer and Boter 2005) Again this system, with its authoring capabilities, lends itself to this type of non traditional question. It is recognized that both this and "teach back" are not usually of use as teaching material, but of more use to the student. An approach such as this may also have links into other developments in the areas of learning and e-learning, such as the use of portfolios and reflective logs.

Summary

The system as described is capable of providing support throughout the educational process. Teachers can create learning material (including assessments) and students have access to learning material, assessment and feedback. It can support traditional assessment linked to learning.

The capability of the system is being further exploited to consider new approaches to assessment that enable qualitative measures to be undertaken.

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