COST EFFECTIVE USE OF SIMULATIONS IN ONLINE ASSESSMENT

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Abstract

Use of simulations in online assessment is a new development. Production of simulations can be a costly process and the development of simulation-type questions will only become routine if cost effective use of simulations is possible. To accomplish this, it will be important to maximise re-use of simulations and establish a low cost production process.

Initially, staff using simulations in online assessment will be uncertain about the potential of the technique and under confident at developing new questions types. This paper examines the way in which simulations are used in education and how these uses may be assessed. Tables of generic and specific examples of the range of simulation types provide a framework for new staff to work within.

The paper examines the level of functionality of the simulation assessment system that would typically be required to deliver the various question types. Finally, the paper uses the framework to outline the potential of two existing exemplars and looks at some of the practicalities of using simulations in online assessment.

Introduction

Recent developments in simulation and assessment engine technology [1,2,3] have made the inclusion of simulations within online assessment possible. However, even simple simulations can be expensive and time consuming to produce. A major problem is that typically simulations are delivered as compiled software code that cannot be customised or modified without the help of a programmer. This is in contrast to current assessment practice, where re-use through simple modification and randomisation of parameters has proved an important means of cost control. To justify their routine inclusion within tests, the process of creating new simulation question types must become cost effective: it must be easy to create re-usable simulations, and re-usable questions.

If it were possible to repurpose simulations, there are still two factors affecting the range of questions that could be created from a simulation:

- 1. The form of the simulation: The complexity and design of the simulation will influence the range of simulation questions that can be produced using it. More complex simulations using a pedagogically neutral model provide the potential for a wider range of questions.
- 2. The assessment technology: The functionality provided by the assessment system may be insufficient to cope with the complexity of some simulation questions, particularly where communication between simulation and assessment engine (AE) is involved.

The aim of the paper is to investigate and review these two factors and to use this work to develop a framework that allows:

- question developers to understand the potential of pre-existing simulations within their chosen assessment system;
- developers of new simulations to consider all possible uses for simulations in assessment at the beginning of the design process.

Integrating simulation and assessment technology

There are a number of possible levels of integration of simulation and assessment. These can be summarised as follows

- 1. No integration: The simulation can be included in a question as a media object, but there is no communication between simulation and assessment engine.
- 2. Low level of integration: The simulation can pass an 'answer' to the assessment engine, but there is no facility to set up questions or pass back anything more complex than a single variable.
- 3. High levels of integration: There is two-way communication between the AE and simulation to set up and mark questions

Not all question designers have access to fully integrated systems but most have the ability to include a simulation as a media object within a question. Although the system discussed here (integration between JeLSIM and PAE) is bespoke, we have tried to create a communication architecture that could act as a template for communication between assessment engines and all interactive objects.

Figure 1 explores some of the options in linking and delivery of simulations and assessment. A simulation can be used both in setting the question and, optionally, to allow the learner to provide an answer.

Setting the question

The primary reason for using a simulation is as an interactive component, however, it is possible to use non-editable simulation output, such as a graph, in a question in the same way as an image would be used. This is particularly useful when complex output is involved, as it may be much easier to include a simulation set to a given state than attempting to create accurate graphs using a drawing package. If a programmer were required to modify the simulation starting state, then the cost would be prohibitive. It is less expensive if a non-programmer can modify the simulation, and the most convenient and cost effective way of including this form of reusability in a system is to allow control of the simulation state (either randomising or fixing simulation variable values) from within the assessment engine. If the assessment engine can randomise the simulation starting state then this allows the production of random images (which can accompany randomised questions – one of the benefits of computerised assessments).



Figure 1. Options integrating simulations into online assessment

Getting the answer

The learner could give the answer to a question using formats available from within the assessment engine, or by using the simulation. Technically, the simplest option is to use the assessment engine; this requires no integration of simulation and assessment engine. The simulation acts as a media object included within the question: the student may examine it (if it is used as a fixed graphic); or interact with it (if it is used as a simulation). The student determines the answer and enters it as a single numeric value, multiplechoice answer or free text entry within the assessment engine.

The second option for answering questions, which allows a greater variety of more complex questions to be set, is to collect data from the simulation for use in the marking process. In this case, a question will be posed which involves modifying the simulation in some way. When the task is complete, the student will indicate this by the press of a button and data will be sent to the assessment engine. The data could be: a single variable (e.g. a score); a number of variables (defining a simulation state); or an expression made up from a combination of simulation variables that can be evaluated in the assessment engine. It can also be useful to pass information about

simulation variables at a number of points during the task when a more complex or procedural task is involved.

The PAE – JeLSIM system

The system used in this study is an integration of the JeLSIM simulation toolkit [4] with the PASS-IT assessment engine (PAE) [5] presented at The CAA conference in 2004 [6]. With JeLSIM tools, a programmer creates the algorithm controlling the behaviour of the simulation (the model), but, then, non-programmers can create the user interfaces to the model (the visual interface). One model can have many, very different, visual interfaces. This enhances cost effectiveness as it provides reusability of simulations without the added expense of a programmer. Combining such a simulation toolkit with a flexible assessment system (PAE) that is also geared to re-use provides a system that empowers the non-programmer to produce questions utilising sophisticated interactivity.

Figure 2 shows the PAE–JeLSIM system diagrammatically. JeLSIM Java simulations are made available as applets for use in questions that are set, answered and marked using PAE. The question setting teams have control of the simulation interface and starting state as well as the types of questions posed and the way in which the questions are asked. Communication between the simulation and the assessment system allows initial state information to be sent from the assessment system into the simulation, or student answers and feedback given by the simulation to be sent from the assessment system for recording and marking.



Figure 2. The PAE - JeLSIM integration

The PAE-JeLSIM system provides the highest level of integration detailed in Figure 1, and allows the greatest number of simulation question types to be created. This provides a reusable and cost effective system.

Educational uses of simulations

Simulations are, as Alessi and Trollip [7] point out, one of the few media that have been "embraced equally by behavioural versus cognitive psychologists and by instructivist versus constructivist educators". They are accordingly used to enhance education in a wide range of domains. The opportunities for using them in assessment should be equally broad. To understand the possibilities of assessment using simulations, it is sensible to first review the rationale for simulation use in education and training. Broadly, the uses can be grouped into three categories:

1. Understanding the simulated system:

Simulations are used to allow students to develop a feel for the relationship between the underlying factors governing a system, develop an understanding of what constitutes an actual condition within the system, to promote an appreciation of appropriate ranges for system parameters [8], and to give a qualitative feel for the system before the introduction of underlying theory [9]. In scientific discovery learning [10] learners use simulation to discover concepts for themselves by hypothesising, designing and performing scientific experiments. Techniques like "Prediction-Observation-Explanation" can be used with simulations to challenge learner's alternative conceptions (e.g. [11], [12]). Methods used to promote understanding of the simulated system fall in four broad groups:

- understanding relationships between variables,
- understanding cause and effect,
- developing an appreciation of appropriate ranges for variables ,
- understanding conditions and phenomena.

2. Developing thinking and problem solving skills

There is some overlap between educational activities involving understanding the system and the development of thinking skills. In this categorisation, development of thinking skills is taken as comprising more complex holistic activities than those designed to promote understanding of the system. The types of activity that fall in this area include troubleshooting, faultfinding, case based scenarios or role-play. Often learners are placed in a hypothetical problem situation, which they must solve or analyse.

3. Learning about processes and procedures

Another major area in which simulations are used, is in training, to allow trainees to practice procedures and to develop skills before performing in the real world. These types of simulator often involve use of additional hardware such as flight simulators.

Assessing simulations

Online assessment that includes simulations is novel and is not included in typical classifications of online assessment types (e.g. [13]). It will fall outside the experience of most staff developing questions who will be uncertain of its potential and may lack confidence is developing new questions. The aim of

this section is to examine in detail the three broad groups outlined above and to consider how assessment of learning enhanced by simulations can be undertaken. The tables of examples generated in this section can be used to provide a framework reviewing the potential of existing simulations and in formulating the design of new ones.

Understanding the system

There are a wide range of ways in which simulations have been used to aid understanding of a simulated system. In table 1 below, a number of examples of the types of questions that could be asked are listed, together with possible answer mechanisms. These answer mechanisms can involve use of the simulation or the assessment engine (see Figure 1).

Question Type	Generic Examples	Specific Example	Possible Answer Mechanisms
Relationships between variables	If variable X is increased what happens to variable Y?	If inflation increases, what happens to unemployment?	 Multiple choice Numeric input (entered in simulation or AE) Free text entry Mark on a scale or graph
Cause and effect	If condition A is changed what will the outcome be?	What will happen to concentration over time if the initial concentration is changed? *	 Multiple choice Free text entry Sketch on a graph
	Discover relationships. (In new or unfamiliar systems)	Establish the genetic laws of inheritance for a virtual animal	 Free text entry Be able to predict result of changing conditions (see row above)
	What is the value of the missing variable?	Examine the behaviour of the sun to determine your latitude. *	 Multiple choice Numeric input (entered in simulation or AE)
Appropriate ranges of variables	What are typical values for variable Z?	What is a typical level for background radiation?	 Multiple choice Numeric input (entered in simulation or AE)
Conditions and phenomena	What combination of variables leads to phenomenon H?	Under what conditions will a vehicle skid?	 Free text Simulation variables automatically passed to AE
	Set the simulation to condition J.	Set a system of vibrating masses to resonance	Simulation variables automatically passed to AE
	At what value of variable X does condition Y occur?	At what level of blood alcohol does peripheral vision deteriorate?	 Multiple choice Numeric input (entered in simulation or AE)

Table 1. A range of question types and examples related to an understanding of the simulated system. (Specific examples marked with an asterisk can be seen online [14])

Note that a large number of these types of question have simple answer formats that can be handled by a traditional assessment engine.

Development of thinking skills

Table 2 shows some of the question types based on simulation exercises designed to develop thinking skills. For each type, typical examples and possible answer mechanisms are given.

Question Type	Examples	Specific Example	Possible Answer Mechanisms
Trouble shooting/ problem solving	Put the simulation in a state where it functions in a specified way.	Keep an endangered population from extinction	 Scored in the simulation score passed to AE for marking. Combination of simulation variables passed to AE
Case-based scenarios	Evaluate the viability of a simulated scenario	Given a cash flow and trading forecast, comment on the viability of a business. *	 Free text entry. Combination of simulation variables passed to AE
Fault finding	Locate the broken components in a system.	Which resistors are malfunctioning in a circuit? *	 Scored in the simulation score passed to AE for marking Combination of simulation variables passed to AE

 Table 2. Some question types and examples related to development of thinking skills

 (Specific examples marked with an asterisk can be seen online [14])

In most of these cases the suggested answer mechanism involves use of the simulation and the more highly integrated simulation-assessment system would be required to deliver them. The exception is the free text entry required by the critique of a case study.

Training in procedures and skills

In training in procedures, it may well be important that the student undertakes a series of tasks in a particular order; this could be assessed by logging the student's choices or other simulation variables throughout a procedure or by checking a score generated by the simulation. The testing of skills is similar, but in this case the focus is more on the outcome of the task rather than the process (see Table 3).

Question Type	Examples	Specific Example	Possible Answer Mechanisms
Following procedure	Follow correct protocols to complete a task	 Follow emergency resuscitation procedure. Shutting down a nuclear power station 	 Record variables as task proceeds. Single variable out (score) Multiple variables out (simulation state).
Testing a skill	Demonstrate a skill	 Landing a plane Performing a surgical procedure. 	 Single variable out (score) Multiple variables out (simulation state).

Table 3. Some question types and examples related to development of procedural and process skills

This section has provided a range of examples of different types of simulation question. The more complex and open ended a simulation, the more opportunities there are to re-purpose it. The more flexible the simulation-assessment system, the more possibilities there are for delivering a greater range of questions using simulations.

Exemplars

In this section two exemplar simulations are explored and, based on the review of simulation question types above, suggestions for the identified types of question given. Two exemplars are used to explore and demonstrate the range of simulation types in more detail. Like most simulations, these two are not universally flexible and although fairly complex with an open pedagogic approach they do not yield examples of every type of simulation question. (The simulations can be seen at http://www.jelsim.org/talks/caa0705/ a page supporting the presentation and this paper.)

DC Circuit

This exemplar is a simulation of DC current in a circuit with up to 10 resistors. It is effectively a simulation of Ohm's and Kirchoff's laws. Designers can change the circuit layout to simulate a number of typical circuits. Given the value of resistors and the input voltage, the simulation model is able to calculate the voltages and currents in all part of the circuit. The designer can include broken resistors in the circuit. Table 4 list possible question types, which could be developed, based on the DC Circuit model.

Question type	Examples
Relationships between variables	If voltage increases what happens to current. What effect does changing a resistor have?
Cause and effect	If the resistor is changes what will be the effect on a graph of current vs. voltage for a specific resistor
	Given a circuit with a number of resistors work out the value of some of those resistors.
Conditions and phenomena	What value of resistor X gives a voltage of Y across it?
Trouble shooting/ problem solving	If a component requires a certain voltage to operate, given a set of resistors and voltage sources, which combinations allow the component to operate?
Fault finding	Determine which resistors are short or open circuit.
Following procedure	Follow a procedure to determine the location of a fault. (Differs from fault finding in that it is a preset condition and protocols for dealing with it are clearly laid down)

Table H Examples of simulation questions doing a be should simulate

A number of these assessment questions have been created using the PAE-JeLSIM system they can be seen at [14].

Business startup

This exemplar is a business start-up simulation exploring cash flow, trading forecast and break-even analysis. The learner can be asked to create cash flow and trading forecasts from scratch or these can be provided in complete or nearly complete form to set up a range of scenarios.

Question type	Examples
Relationships between variables	As overheads increase what happens to the break-even point?
Cause and effect	If sales are 5% below target what will happen to the bank balance
	Some figures are missing from the trading forecast – work out what they should be
Appropriate ranges of variables	What are typical costs for various overheads in the simulated business?
Conditions and phenomena	Adjust the selling price to achieve a specified breakeven point.
Trouble shooting/ problem solving	A business is projected to make a loss. What can be done to bring it into profit?
Case-based scenarios	Given a cash flow and trading forecast consider the viability of the business and the validity of the assumption made
Fault finding	There is an error in the trading forecast – locate it.
Following procedure	Given data for a start up company, generate a cash flow and trading forecast

 Table 5. Examples of simulation questions using a business startup simulator

A number of these assessment questions have been created using the PAE-JeLSIM system they can be seen at [14]

Practicalities

Not all simulation-assessment systems have sufficient functionality to use all question types but even those with only minimal integration of simulation and assessment engine can use a substantial proportion of the less complex questions listed in the framework assuming the design is sufficiently open and flexible.

If no appropriate simulation exists in the domain in which assessment is required then there is an option of creating a new simulation. However, unless there are a very large number of users of a simulation question it may not be cost effective to write a bespoke application from scratch just for the assessment. When creating a new simulation it is important to maximise its usefulness and to consider all the possible uses it could be put to, not just the assessment requirements. If it can be used for other educational purposes as well as assessing then not only is cost effectiveness increased but it will also lead to more authenticity of the assessment process if the students are taught and assessed in the same system.

It is easier to modify an existing resource than create a new one and it eases the simulation question production process, particularly for novice users, if template question types for specific questions can be created. In the JeLSIM-PAE project a number of such templates were created which provided a straightforward resource that can be modified by non-programmers to create new questions. Each resource consisted of:

- a JeLSIM model;
- a template JeLSIM interface that closely approximates to an interface which can be used in a question (i.e. only details need to be modified by the question designer and there is no need for a programmer);
- a question set in PAE that sets up a typical example and utilises the communication between simulation and assessment engine;

Conclusion

Reusability of simulations is crucial if the use of simulations is to become widespread

Reusability is fostered by:

- allowing the question designer to set/randomise the initial simulation state;
- providing easy customisation of the information to be communicated from the simulation to the assessment engine (generally the "answers");
- including easy customisation of the visualisation interface.;
- ensuring that the staff developing simulation questions understand the potential of the process and the importance of re-use(This

paper has provided the start of a framework for a structured exploration of the use of simulations in assessment); and by

• constructing template simulations and questions that allow easy customisation of a simulation from the assessment question.

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