The enhancement of simulation based learning exercises through formalised reflection, focus groups and group presentation

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ABSTRACT

Computer based simulations and games can be useful tools in teaching aspects of construction project management that are not easily transmitted through traditional lecture based approaches. However, it can be difficult to quantify their utility and it is essential to ensure that students are achieving the learning outcomes required rather than just learning to play a game. Maintaining engagement and encouraging reflection are critical elements in ensuring that effective learning is occurring.

Recent work using simulation games for teaching construction project planning and control is described with reference to a range of methods employed by the authors. The paper focuses on a teaching module at the University of Nottingham employing simulation games as the primary source of instruction in a self-directed learning exercise. This style of teaching is not suited to all students and current work to extend the learning experience to suit a wider audience is described.

Preliminary findings from the work are given along with discussion of plans for further development.

1. Introduction

Guidance from engineering accreditation bodies both nationally (QAA, 2005) and internationally has indicated a need to move from traditional teaching methods to include a wider range of progressive methods and greater use of experiential learning or Problem Based Learning (PBL) exercises in the education of engineering students. This need for change has been highlighted in a range of research studies (e.g. Felder & Silverman, 1998; Mills & Treagust, 2003; Woods, Felder, Rugarcia, & Stice, 2000) and the engineering industry itself has also shown great interest in the development of skills beyond standard technical knowledge. Mills and Treagust (Mills & Treagust, 2003) highlight team working, communication and the application of technical knowledge to project based problems as areas in which traditional lecture based instructional methods can prove to be limited. They describe how experiential learning or PBL can be successful in the delivery or a broader set of skills.

Simulation games have been shown to be an effective tool in the teaching of management techniques (Gilgeous & D'Cruz, 1996) and engineering (DeshPande & Huang, 2009) and have been widely used a part of an experiential learning or PBL exercise. Construction management in particular is well suited to the use of simulations and games for teaching (e.g. Nasser, 2002; Wall & Ahmed, 2008) as it combines both elements of management and engineering. Two simulation games have been used at the authors' institutions for teaching at various levels of academic achievement. They require students to plan and control large civil engineering projects within a set of constraints and have been shown to be an effective and engaging method of teaching aspects of construction management (Gribble, Scott, Mawdesley, & Al-Jibouri, 2006; Long, Mawdesley, & Scott, 2009). However, it has been noted that the learning process engendered by these simulations does not suit all students and the learning experience could be improved by the application of various learning mechanisms from the field of educational research (Long, 2010).

This paper describes the two simulation games used and the teaching modules that employ them.

Results and experience from the teaching in recent years is discussed to demonstrate both the effectiveness, and the limitations of this approach to education. Current research and development work to enhance the learning experience by introducing greater student reflection, focus group exercises and group based presentations. Changes to the teaching and assessment related to this are described along with preliminary results from an initial prototyping exercise carried out.

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2. Method

The authors have utilised simulation games in the education of engineering students at their various academic institutions and beyond for a number of years. A range of teaching methods have been employed in using these games. These were determined by a range of factors including the educational requirements of the student groups, the format of the teaching course or module and the operational features of the simulation game used. One of the simulation games described in Section 3.1, the Muck Game, has been used in its current form for teaching both postgraduate students and as an introductory exercise for starting undergraduate engineering students.

The former exercise with postgraduate students at Twente University in the Netherlands (Al-Jibouri & Mawdesley, 2001) was carried out in a fully supervised classroom environment and showed that the Muck Game could provide students with an effective teaching experience and introduced students to concepts not easily taught through traditional lecture-based content.

At Curtin University in Australia, the Muck Game has been run as part of a module in the common first year taken by all engineering students (Gribble et al., 2006). In any one year, up to 200 students would take the module and run the game. The aim of the game was to teach the students the importance of the Plan – Operate – Monitor – Assess cycle and how it is affected by uncertainty. After an initial lecture, the students formed small teams of 4 or 5. Each member took a specific role (finance, safety, etc) in the project management. The team had to produce plans for the project before they were allowed to do any 'real' construction. Each group were only allowed a single run of the game and no re-starts were allowed if mistakes were made. Overall, the implementation is considered a success by both staff and students and continues to be used to introduce students to the features and challenges of managing complex engineering projects.

Experience gathered from this previous work was used in the development of a teaching module to utilise simulation games as the principal learning mechanism at the University of Nottingham.

2.1. A teaching module focussing solely on the use of simulation games

Applied Construction Project Management (ACPM), is offered as an optional teaching module for Masters level students. It requires students to play through two simulation games (described in Section 3) a number of times. Students are initially provided with access codes to run each game four times though additional runs are granted to students on request. The ACPM module employs self directed learning whereby the students themselves are responsible for the pace and extent of their learning.

The instructional design for the module was also informed by the learning needs of the students and by the institutional regulatory framework in place at the University of Nottingham with regard to the design of teaching modules. The main features of the module as initially designed were:

- An introductory lecture to describe the module and ensure that students are fully aware of the type of teaching and learning that will be provided and expected of them is the only concession to traditional teaching methods. No other formal lectures are provided
- The Canal game (see Section 3.2) is used to force the student to apply the knowledge learnt in a different scenario.
- Weekly seminars/clinics are run where students can access module staff for assistance
- Student feedback is collected as follows:
  ○ Automated in game feedback (triggered at tutor defined progress points).
  ○ Through student generated in-game messages
  ○ Informal semi-structured interviews with students
  ○ Recording of student queries at weekly seminar/clinics
- Traditional teaching materials are provided to students but they are not forced to view them, though it is recorded when they do. These include sets of lecture notes, presentations, links to appropriate websites and references to key published work in the subject area.
- Assessment is based on a single piece of coursework (30%) and an examination (70%)
- Coursework is a report to the fictional directors of the company that the student is employed by in the Muck or Canal game. The report focuses on a single run of the game, chosen by the student, and the student is tasked with the production of a suitable report that their managers would wish to see reviewing the project and providing lessons learnt for future projects.
- No guidance on report content, length and style is provided deliberately to test the students' ability to write concisely and clearly and to tailor their report to their audience. This non-technical skill had been highlighted by employers as a skill that is often lacking in otherwise well educated and qualified graduate engineers.
- A set of potential examination questions given to students at start of module. Students are provided with all potential exam questions and told that four of these questions will be included on the exam paper, of which they are required to complete three questions.
- Each examination question requires the student to discuss and describe a key issue in the management of construction projects and expects them to make specific references to their experiences from playing the games in order to fully answer the question.
- Students are monitored continuously and records kept of all their actions through the MCG Umpire tool (see Section 3.3).

2.2. Incorporating greater engagement and reflection to the teaching method

Findings from the initial fours years of running the ACPM module have informed research and a brief summary of relevant results are given in Section 4.1. From these it was determined to introduce changes to both the simulation games and the teaching methods employed in order to provide an improved learning experience for those students who are not fully suited to a purely self-directed learning exercise. To this end support was sought and gained from the Centre for Integrative Learning at the University of Nottingham.

The changes proposed to the ACPM module in order to achieve the aims of the work include:

1. Addition of a group based presentation exercise to the module. This provides a mechanism to increase engagement through peer group competition, requires students to reflect on the simulated exercise, introduces an element of team working into the module and increases student's communication and presentation skills.

2. Use of focus group based exercises for the purposes of revision in the final weeks of the module. This provides increased student input into the revision element of the module and requires them to work in groups to review the learning outcomes and reflect on the simulated experiences.
3. Addition of pre- and post- teaching questionnaire exercises in order to assess learning by students. This is a commonly used method (see for example Schaffer, 2006) for assessing learning and will be used to assess the success of the project.
4. Introduction of new coursework element, the Project Manager's Diary, to introduce greater reflection on the learning experience throughout the module.

These changes will be fully implemented in full in the coming academic year (2009/2010) and the revised assessment scheme for the module is: Examination 60%, Coursework 1 (Report) 20%, Coursework 2 (Diary) 10%, Group based presentation (10%).

Changes 1–3 were introduced in prototype form in order to ascertain their potential for full implementation in the last academic year (2008/2009) though student assessment for the module remained as stated in Section 2.1. Due to this, the group based presentations were used as a formative rather than an audited exercise. Questionnaires were designed and distributed to students. There are 46 questions in total on the questionnaires, though some questions require students to both ascribe a value and provide a textual description. Questions remained constant between each questionnaire for this initial trial. Change 4 required changes to the teaching module specification and will be incorporated into the module for the next teaching session.

Proposed changes to the simulation games and software tools used to operate them are described in Section 3.4.

3. Materials

Two simulation games form the focus of the teaching and learning experience in the ACPM module – The Muck and the Canal game. Both games are intentionally similar in terms of their user interface and the underlying construction processes simulated. This enables the testing of the students' ability to apply knowledge learnt in one simulation games in another. The two simulation games are briefly outlined in Sections 3.1 and 3.2.

In order to manage the players and monitor their progress, the Muck and Canal Game Umpire (MCG Umpire) software tool was created. The MCG Umpire performs a range of vital functions in the use of the games for teaching and is described in Section 3.3.

3.1. The muck game

The game involves the student in a project to construct a 30 m high dam of rock and clay based on an actual dam built in the UK in the late 1960s. The dam must be constructed within a specified time limit (typically 40 weeks) and project income is fixed and is awarded for each completed metre of rock and clay in the dam. The actual settings and project parameters can be customised to suit the audience.

The student initially inputs a plan for the project. Once a plan has been created the student then selects appropriate resources to perform the work to this plan. The simulation can then be advanced by the student. The student can choose the rate of simulation (daily, weekly, fortnightly or four-weekly), or this can be set by the game umpire. Feedback on simulated progress is given and the student can choose to continue the simulation or take management action. Figs. 1 and 2 show elements of the Muck Game interface.

A number of simulated events such as resource availability, weather and accidents can influence project progress and students must be aware of these events and take appropriate control action to ensure progress follows the current project plan. In some instances this will involve re-planning the project due to a poor current plan or an inability to work to a plan due to events.

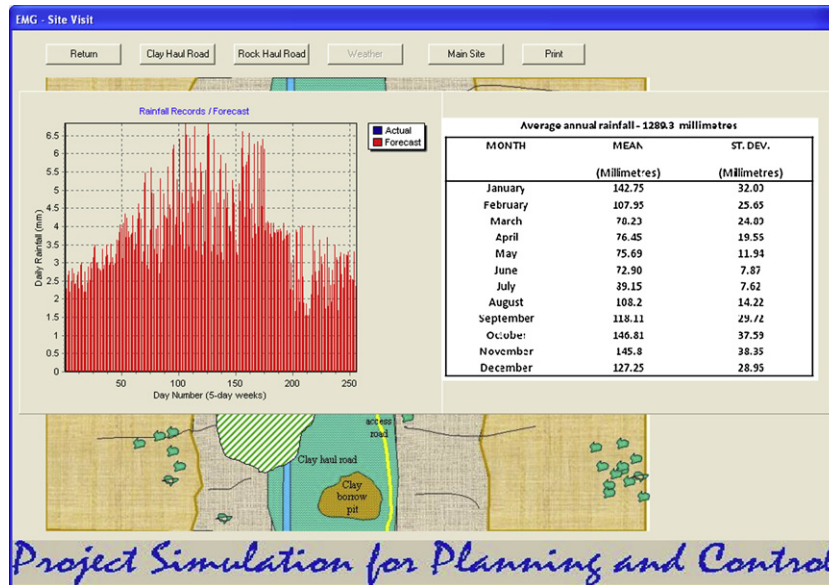**Fig. 1.** Screenshot showing form for selection of plant equipment.

Fig. 2. Muck game screenshot showing rainfall and site data.

3.2. The canal game

The Canal game was developed to test a hypothesis regarding the utility of the Muck game as a teaching tool. The hypothesis was that the use of the Muck game was imparting some knowledge of construction management skills and methods to the students and not just teaching them to play the game. The Canal game tests this by requiring the students to apply the skills learnt in the Muck game in a similar yet different simulated environment.

Screenshots from the Canal game are shown in Figs. 3 and 4. The user interface and general structure of the game is almost identical to the Muck game. In fact the Canal game could reasonably be described as a variant of the Muck game rather than a completely separate game. The key difference between the Canal and Muck games is in the nature of the construction projects they simulate.

The Canal game requires the player to excavate and line with clay 7 km of canal within 150 weeks. It is a much larger scale project than that simulated in the Muck game. In addition the canal construction project requires the player to excavate through a hill for a significant portion of the 7 km length. This gives the project a non-linear aspect requiring the player to adjust their resource levels and/or planning to reflect the vast differences in production levels required in different stages of the project. This non-linearity of the project can be seen in the cross-sectional profile for the project shown in Fig. 5.

The game is played in an identical manner to the Muck game with players creating a plan, assigning resources and advancing the simulation. However, the differences in the nature of the project lead to the game being played in a different way. The large amount of earth
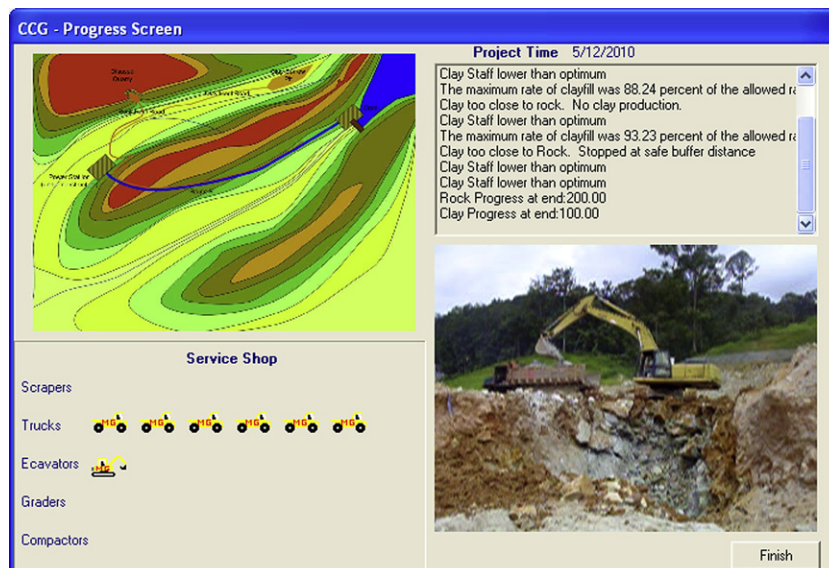

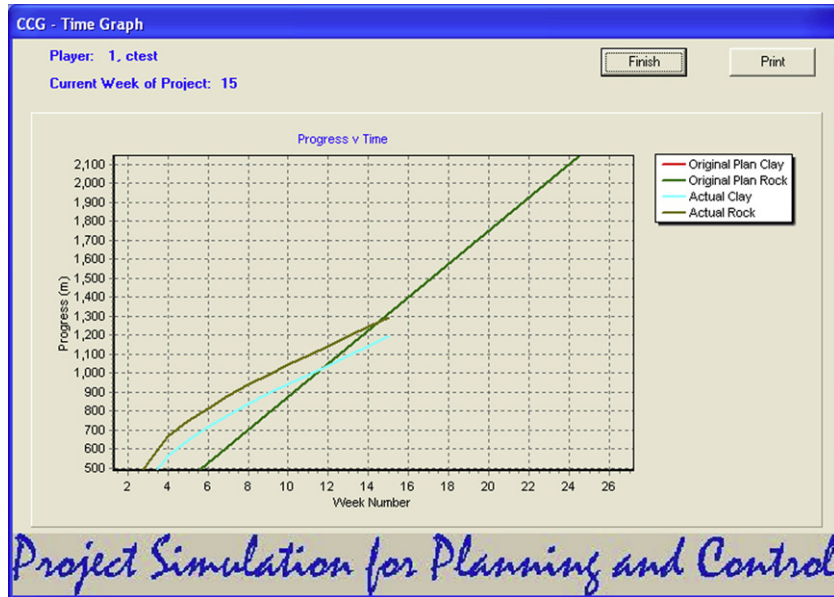**Fig. 3.** Canal game screenshot showing game progress.

Fig. 4. Reports screen from the Canal Game.

to be excavated early in the project combined with changed climate conditions forces the player to consider different types of plant equipment to utilise if they are to be successful in completing the project within budget.

3.3. The muck and canal game umpire (MCG umpire) tool

The MCG Umpire tool is a software application developed for the purpose of managing the operation of the Muck and Canal games and tracking student progress and data. It also enables the use of the games across a local network and is used to set up security and generate a set of players based on the needs of the teaching. The number of runs of the games for each student can be specified along with some of the settings for the projects.

A major function of the tool is the ability to monitor student progress and generate both standard and customised charts of their progress. Charts can be generated to compare performance of players or to compare a number of project parameters for an individual player.

The MCG Umpire also enables the use of an in-game messaging system whereby the players and umpire can communicate. This was a necessary addition to allow the players to run the games unsupervised. Players can choose to send a message to either *head office* or the
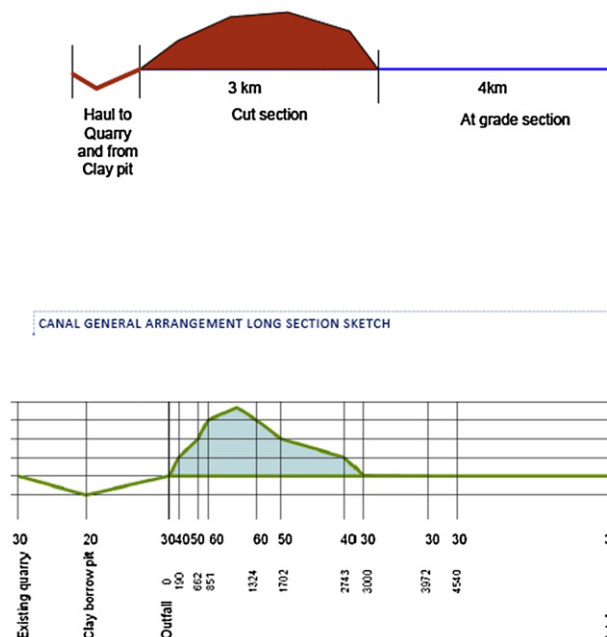

Fig. 5. Sketch and profiles for the Canal project scenario.

umpire. Messages to *head office* are concerned with the simulated project and allow the player to highlight any queries or problems they are having completing the project. Message to the *umpire* regard technical issues in using the games such as any bugs encountered or difficulties of running the games.

3.4. Modifications to the games and umpire tool to increase engagement and reflection

Some modifications to the two simulation games and the MCG Umpire are required in order to introduce the changes to the learning experience outlined in Section 2.2. The major elements of software development required are:

- Choice of project scenarios and difficulty – This fundamental change to the operation of the simulation games will allow students to choose from a range of project settings to allow more able students to increase the challenge posed by the games whilst still allowing less able students the opportunity to practice in a less demanding simulated scenario. This will increase the student's engagement with the material by reducing frustration and boredom. This modification is currently in development and will be implemented in the next academic year.
- In-game feedback on peer group performance – A smart messaging ability has been added to the MCG Umpire allowing students to assess progress in terms of their peers. This has been completed and tested with existing student data. This functionality will be implemented with the next intake of students. The ability to view their performance against their peer group will help students to reflect upon their own performance.
- Extended data monitoring and student tracking functions – Additional data has been added to the MCG Umpire's data logging functions. This will enable teaching staff to more clearly identify those students who appear to be struggling to achieve the learning outcomes during the teaching module.

4. Results and discussion

Results and feedback from using the simulation games during the ACPM module is detailed in depth in a doctoral thesis recently submitted by one of the authors (Long, 2010). Results from earlier trials and selected data from the first three years of the ACPM module have also been published by the authors (Al-Jibouri & Mawdesley, 2001; Gribble et al., 2006; Long et al., 2009) and will not be repeated in full here.

A brief summary of results from the ACPM module are provided in Section 4.1. Preliminary findings from the ongoing work extending the ACPM module, as described in Section 2.2, are given in Section 4.2

4.1. ACPM results to date

Table 1 shows mean averages and standard deviations for a selection of performance measures from the Muck game for all students who have taken the module. Results are broken down by run number to show the improvement to student performance through repeated iterations of the game. Fig. 6 shows this improvement in terms of overall project profitability illustrating the wide range of profit in early runs of the game.

Note that the time spent is measured in minutes; project duration is in simulated days. The maximum and final score measures are an aggregate measure of performance against plan where low values represent good performance and high values indicate wide divergence from planned performance.

It can be seen from Table 1 that only around half of the students reach the 4th run of the game. This could be due to a number of factors including a lack of time, boredom, frustration or simply that they have achieved a satisfactory level of performance. The changes to the module outlined in Section 2.2 are aimed at increasing student engagement and should lead to a higher percentage of games played by the

Table 1
Statistical measures for all players of the Muck Game on the ACPM teaching module to date.

| Measure	Statistic	Run			
		1st	2nd	3rd	4th
Number of players	Started	132	115	96	64
	Finished	61	69	69	40
	%Finish	46.21	60.00	71.88	62.5
Time spent	Mean	345.40	283.78	310.45	199.51
	St. Dev.	282.51	246.93	360.84	204.50
Project duration	Mean	157.56	157.39	144.15	109.14
	St. Dev.	85.04	71.24	58.60	70.27
Number of plans made	Mean	4.83	4.03	3.02	2.73
	St. Dev.	3.38	2.94	2.39	2.79
Overall profit	Mean	−2,009,470	−1,665,695	−603,072	−276,699
	St. Dev.	3,861,021	4026,033	1,164,731	916,865
Maximum score	Mean	10,727	4419	4758	1774
	St. Dev.	35.460	10,044	12,758	2914
Final score	Mean	1312	880	460	290
	St. Dev.	2912	4514	774	497
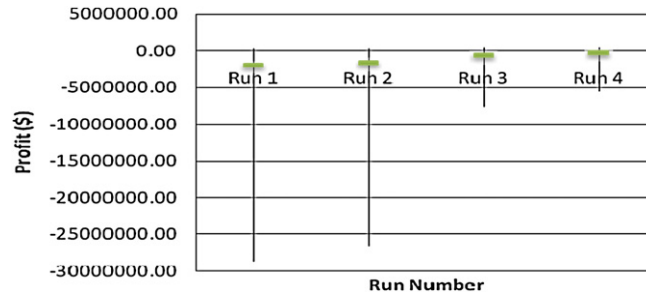
Fig. 6. Graph showing profit range for the four runs of the Muck Game.

students. It also seems evident from Table 1 and Fig. 6 that many students struggle with their early runs of the game and may benefit from the changes proposed.

Fig. 7 shows progress against calendar date for a range of typical students from the initial year of the ACPM module. It is clearly evident that there is a clustering of progression around 20/03/06. This behaviour is repeated in all years and is likely to due to the coursework submission date being around that period (Long, 2010). The introduction of the additional coursework element of a project diary to run throughout the teaching period should alleviate this behaviour and spread student progression across the teaching period. It is hoped that this will encourage greater reflection by the students on the learning experience.

4.2. Preliminary results from ACPM module revisions

As stated in Section 2.2, a number of prototype changes were introduced to the ACPM module in academic year 2008/2009 to test their effectiveness. Results from each of these modifications to the teaching will now be detailed and discussed.

4.2.1. Group presentations

Students were invited to present their progress at the simulation games in groups of 3–4 during one of the teaching sessions. This was not a mandatory requirement (though it will be in future) and students were allowed to form their own groups. In total, 15 students took part in the presentations and those not presenting their work attended the presentations, with the exception of one student who was unable to attend the class.

Feedback from this exercise from the students was very positive with attendees and presenters finding it a useful learning experience. It was noted that student performance at the games showed significant signs of improvement in the weeks following the presentations. This is thought to be due to the presentations by the more successful groups highlighting methods for improved performance.

Obviously it is not possible to prove that any improved performance may not have occurred without the presentations. However, a number of students interviewed after the presentations indicated that presentations by other groups showed them that their own performance could be improved and led them to attempt alternate strategies.

4.2.2. Pre and post teaching questionnaires

Results from the questionnaire based exercise show changes to student responses after the teaching module with a definite trend for more detailed and insightful replies. It is only possible to provide a brief example here, shown in Table 2. The first three examples in the table are from one student and the other three from a different student.
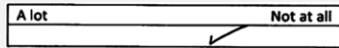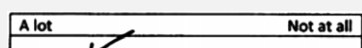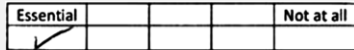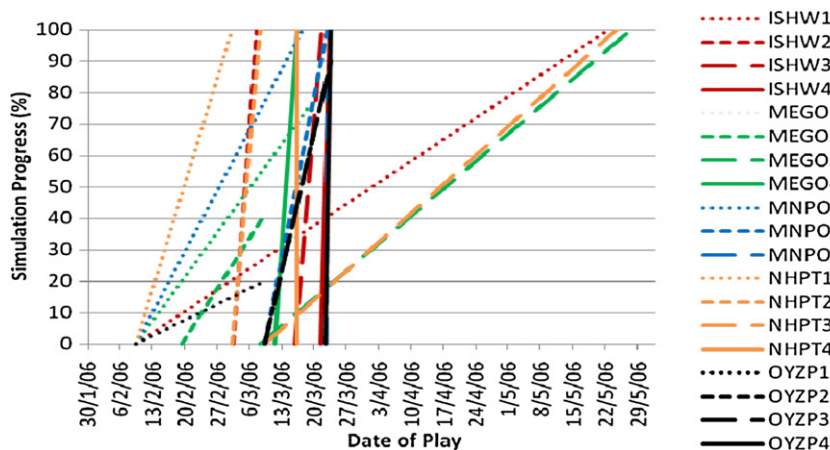

Fig. 7. Chart showing game progress against date for a typical set of students on the ACPM module.

Table 2
Selection of changes to student response identified through pre- and post- teaching questionnaires.

Question	Pre-module answer	Post-module answer
What information do you need to control a project?	How well plant is operating	Progress and plan – to see how close you are
What are the main obstacles to the successful completion of an earthmoving project?	Breakdowns of equipment, Bad planning, Too little information	Weather, Too little information, Inaccuracies in information, Site Layout
Is the experience gained on one project of any use on another, and if so how? Considerable = 1, Not At All = 5	Value 3/5 "depends on the first project"	Value 2/5 "Know how some things affect others i.e. bad weather makes haul roads deteriorate"
Does it matter if you are ahead of schedule on a project? Please give your reasons	A lot _____ Not at all Good, but need to look at why? Safety risks, etc.	A lot _____ Not at all Something is wrong with the plan
Is re-planning just a necessary evil?	Rarely	Never
How important is it to have very accurate data about all aspects of a project before planning?	Essential [✓][ ][ ][ ] Not at all	Essential [ ][✓][ ][ ] Not at all

4.2.3. Focus group revision exercises

Three capable students were chosen to act as group leaders and form groups of 6–8 members for this exercise. Two focus group sessions were held; one focussing on project planning; one focussing on project control issues. After a brief introduction to define the requirements of the exercise groups were left to discuss each topic and produce a presentation of key points and their relationship between the topic and the examination questions to be answered. Teaching staff observed the focus groups during the exercise and clarified certain points where necessary.

At the end of each session, each group presented their findings to the whole class and the teaching staff. Teaching staff then summarised the findings and highlighted aspects of the discussion of principal interest.

Student feedback on the sessions was positive and the presentations produced by the groups were a useful starting point for revision. The group based discussion definitely increased student involvement in the revision process compared to the traditional revision classes held in previous years.

Timetable limitation constrained the time available for the exercise. This problem could be alleviated in future years through earlier formation of the focus groups enabling them to hold initial meetings outside of the timetabled sessions to prepare their initial ideas.

5. Conclusions

The aim of the work described in this paper was to improve the learning experience offered by the existing ACPM module by the inclusion of additional teaching and assessment elements and through modifications to the simulation games. A number of conclusions can be made at this stage in relation to this aim:

- Group based presentations seemed both a popular and useful exercise. Led to increased engagement due to the competitive nature of some students. For other students frustrated by their performance it provided incentive that improvements can be achieved. However, it could also lead to plagiarism of the strategies adopted by the more successful groups. The stochastic elements of the simulation games should lessen this problem as a particular strategy will not produce identical results on repeated attempts.
- The limitations of the original self-directed approach to learning for some types of student seem to be somewhat mitigated by the changes to the learning adopted initially. This improvement should be more marked in the future full implementation of the changes outlined.
- The introduction of scalable difficulty and a range of simulated project scenarios should increase engagement and enable students to face a suitably challenging learning experience. Student feedback from interviews has indicated that this change to the simulation games would be welcomed by both the most and the least able students taking the module.
- The use of pre- and post- module questionnaires can highlight learning occurring during the module and should, in conjunction with the existing structures for student monitoring and assessment, enable the quantification of student learning during the ACPM module.

It should ne noted that the project described in this paper is a work in progress, and as such, any conclusions drawn are not final. However, initial findings show great potential for an improved learning experience for those students less suited to the fully self-directed learning experience that formed the ACPM module in previous years.

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