Research-Based Computer Games to Train Civil Engineering Students to Be Lifelong Learners

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INTRODUCTION

In spite of vast efforts to adopt available information technology in higher education teaching and learning, the truth is that most of university students and academic staff make only limited use of communication technology. Selwyne [1] concluded that there is a growing need for the education community to account for the distinct 'digital disconnect' between the enthusiastic rhetoric and rather more mundane reality of university information and communication technology use. Recent advances in computer science and multimedia as well as optimistic effects of multifaceted modes of education on student learning have encouraged teachers to look at adopting new technologies to improve students' learning experience. Chang et al. [2] have suggested that digital games can be powerful informal learning environments encouraging active and critical learning, supplementing traditional teaching methods. It is well proved that through game playing, students can build up their cognitive-recognition architecture and gain satisfaction as well as a sense of achievement. Among many available strategies, gaming has been proven to be a tool that effectively enhances teaching and learning. For example, Randel et al. [3] stated that games that have curiosity-causing and challenging characteristics could have positive effects on learning, such as increasing students' internalisation of classroom knowledge. Because games are challenging, instructors can engage their students in either competitive or cooperative ways. Chang et al. [2] concluded that challenges, competition, cooperation, and authentic tasks are

the required components in an effective game in university subjects to improve the students' learning process.

Michelle Weise in October 17, 2014, wrote an article in Harvard Business Review. She believes "something is clearly wrong when only 11% of business leaders, compared to 96% of chief academic officers, believe that graduates have the requisite skills for the workforce. It's therefore unlikely that business leaders are following closely what's going on in higher education" [4]. In-line with the above mentioned point, Gorovo [5] recently published an article in Campus Review underlining the lack of digital skills among university students. According to Gorovo [5], higher education leaders are expected to provide forward-thinking solutions to meet the needs of educators and students. Gorovo [5] emphasised that "Nationwide, as well as across the globe, colleges and universities are awakening to an urgent and widening issue: multiple digital skills gaps affecting their students and faculty with consequences reaching far beyond campuses. Key among these challenges is a lack of preparation for students entering the workforce, requiring instruction in both hard and soft skills, along with a new kind of digital literacy that far exceeds job-specific training". Fostering digital skills in teaching and learning may lead to a future required competency as university graduates enter the 21st century workplace.

Game based learning is one of the effective approaches that can make the digital skills gaps smaller and provide engaging learning experiences for students [6,7]. Appropriate and well-designed games can highly motivate students and provide ideal learning environments to achieve specific learning goals. An experiential gaming model was suggested by Kiili [6], as shown in Figure 1. The main purpose of the model was to link game-play with practical learning in order to facilitate flow experience.

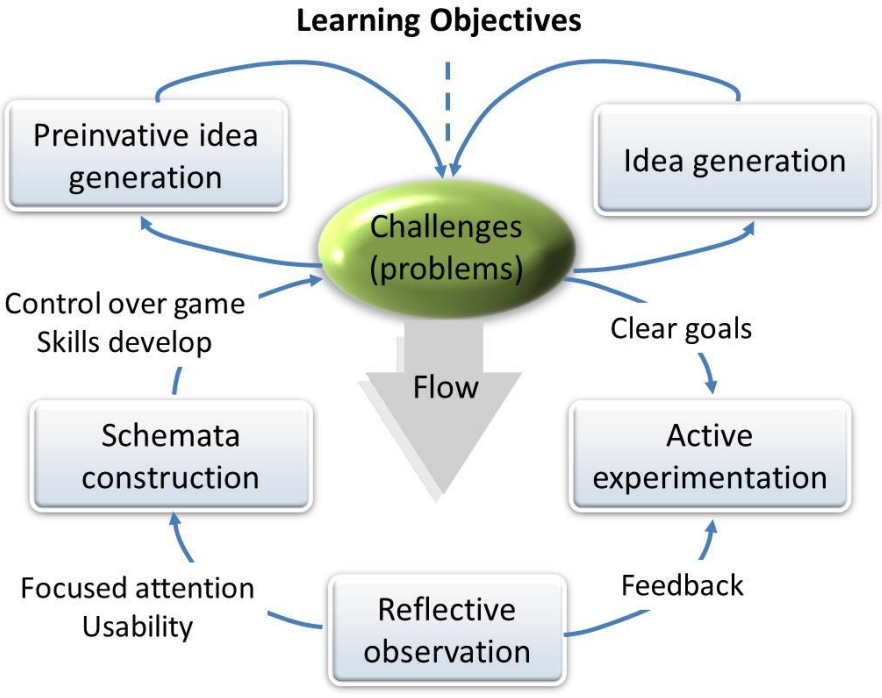

Figure 1. Experiential gaming model (modified after [6])

Only a few engineering subjects in the undergraduate level try to give the opportunity to students to experience different modes of learning and at the same time encourage them to conduct disciplinary research. The game can serve as a teaching aid to increase the instructional effectiveness in Civil Engineering course. In particular, students need to be trained to think outside the box through novel or innovative thinking to minimise the construction cost, while ensuring the safety of future structures. By allowing students to use multifaceted modes of learning, and giving the required guidance to students to improve their learning experience, students are encouraged to be self-motivated, and continue to build skills and knowledge throughout the life. In this project, the research team would like to provide alternative learning method, through research-based computers games, while involving students in disciplinary research in two major subjects of Civil Engineering sharing similar principals (Soil Behaviour and Geotechnical Engineering) supplementing traditional textbook and classroom based learning.

1 RESEARCH METHODOLOGY

This study targeted Civil Engineering students at mid stages of their undergraduate studies. It is believed that Civil Engineering students in their second year and above have acquired the fundamental knowledge (e.g. statics, mechanics of solids and fluids) and skills which are the basic requirements for the engineering game. It should be noted that the proposed game module at this study was not an alternative to lecturer's application of class presentation, but was used as a supplementary material.

First a survey was conducted among the students in Soil Behaviour subject regarding online computer game usage and level of students' expertise. This subject has two components including Engineering Geology and Soil Mechanics. The number of students enrolling in this subject is about 160. Approximately half of the students participated in the proposed activity. The survey results (85 students participated) indicated that 54% of students consider themselves as professional/advanced user of some sort of computer games (see Figure 2) and 62% of students stated that they played computer games (mainly online games) in the last 30 days (see Figure 3). We developed a geotechnical engineering computer game called "Back to Bedrock", using PLAXIS software as a learning and assessment task. This task provided an alternative learning method, through research-based computer games, while involving students in disciplinary research in Soil Behaviour subject supplementing traditional textbook and classroom based learning.

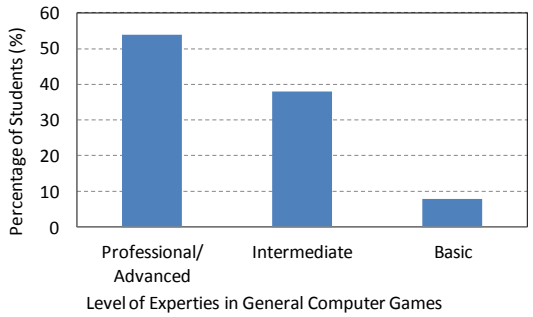

Figure 2. Survey results about how expert students think they are with computer games

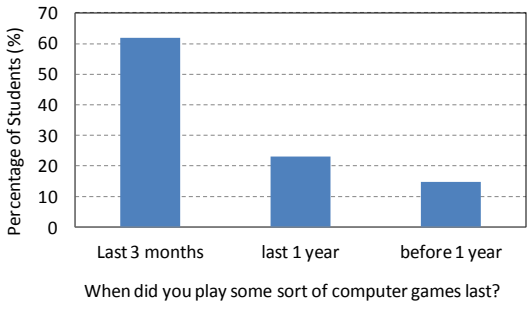

Figure 3. Survey results about when was the last time students played some sort of computer games

In the beginning of the game, 10 multiple-choice questions related to the basics of soil mechanics were asked from the user, and the user could only proceed to the main game menu by answering all questions correctly. “Back to Bedrock” game has two modes (a) Laboratory Experiment, and (b) Earth Structures. The “Laboratory Experiment” mode includes 4 major soil tests, including:

- Soil Permeability Test,
- Flow Net Test,
- Consolidation Test, and
- Triaxial Shear Test.

The main aim of this mode of the game is setting up the required tests to measure the various given soil parameters. Students needed to conduct research on library databases and other available sources to find the optimum setup. The final solution of the user could be compared with the optimum solution calculated by the analytical solutions at the end.

The “Earth Structures” mode includes design of 6 major infrastructure including Earth Dams, Underground Tunnels, Deep Excavation, Embankments/Slopes, Raft Foundations, and High-rise Buildings on Soft Soil, as shown in Figure 4. For example when students selected the Earth Dam design topic, they had 6 weeks to play with the developed code to design a 70-m high dam, being stable and cost effective.

It is clearly explained to students that there are many criteria to be taken into consideration to design a superior earth structure. Some key measures are: the cost of structure, the elapsed time of construction, short term and long term stability of the structure, maintainability (the ease and speed with which a structure can be restored to operational status after a failure occurs), constructability (the ease and efficiency with which structures can be built), long service life of the structure, less carbon foot print by reducing energy use, the innovative and convenient shape and function (architectural aspects), less environmental impact, and sustainability over the entire life cycle of the earth structure. For the sake of simplicity, in the proposed game associated with earth structures design, only the first three criteria have been applied to give scores to students (the players). The “Back to Bedrock” system could automatically calculate the cumulative cost, the construction time, and the factor of safety at the completion of each game. The system rates a player’s overall performance by calculating the cumulative costs (the lower cumulative cost reflects the better performance), the construction time (the shorter the better), and the level of safety (the expected factor of safety should be met). A billboard was designed online, enabling users to know the status of other competitors and it could also be used as an indicator to encourage deeper learning. In addition, the game announcement provided a continuous display of some statements to remind the users about the operational methods and some technical points. The main menu provided seven functions, including material usage, cost so far, calculator, technical database, message board, billboard and help. This provided an alternative learning method, through research-based computer games, while involving students in disciplinary research in a major subject of Civil Engineering sharing (Soil Behaviour) supplementing traditional textbook and classroom based learning.

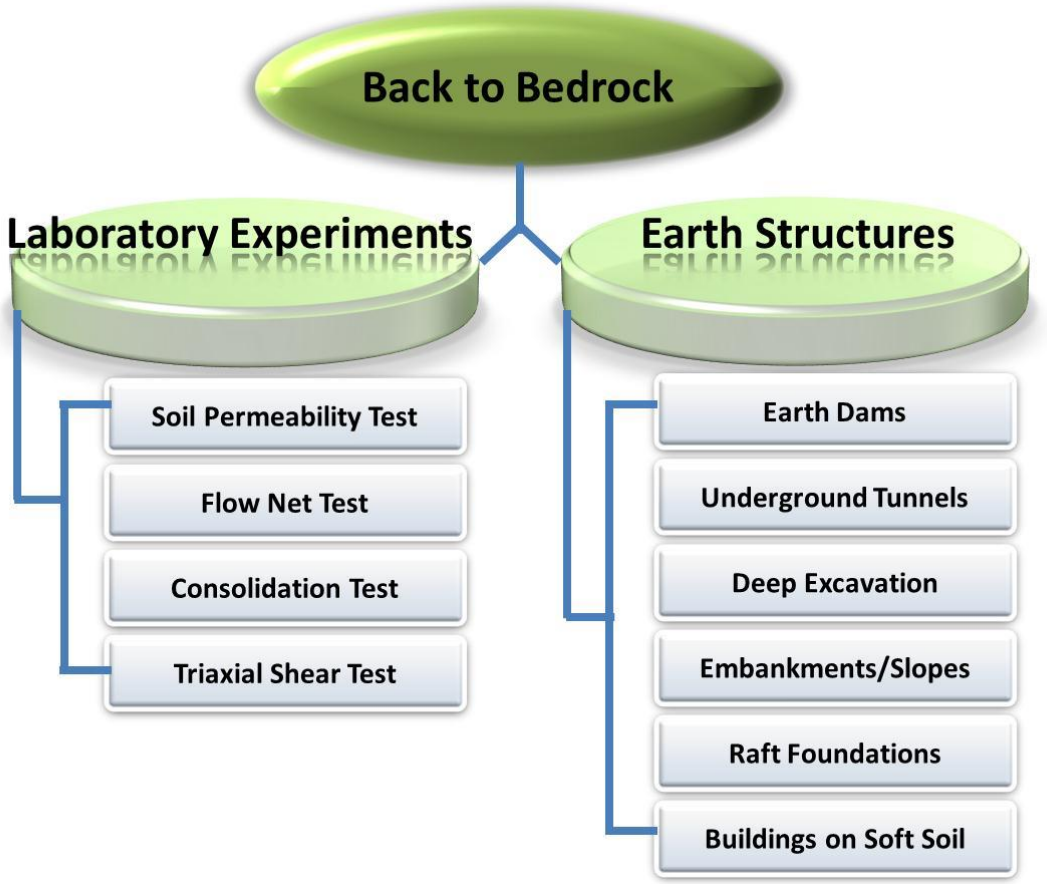

Figure 4. Components of Back to Bedrock game

2 RESULTS AND DISCUSSION

According to the feedback received from students, this mode of learning and assessment provides enjoyable and competitive learning environment using the computer game, in addition to traditional classroom learning and teaching within the four walls of the university. A couple of samples are presented below from the anonymous online Students' Feedback Surveys, regarding the application of "Back to Bedrock" computer game assessment task helping with student learning experience:

- *"In particular, Back to bedrock competition is my favourite part in my soil study. I am able to use PLAXIS to design and simulate the soil in different conditions. It is a terrific idea to adopt this sort of tasks because they inspire me to explore deeper. For instance, I didn't understand the friction angle when I assigned the properties of soil, then I researched that and understood a series of topics like consolidation. For me, computer game based assessment task keep me more engaged. However, traditional assignments were also a vital part for my study, because it provides me a foundation and basic knowledge which allow me to apply in the computer based tasks" Survey No: 77855, 48330-SPR-U-S-LEC1-01.*

- *"I really enjoyed the structure and the concepts covered in Soil Behaviour subject. The Back to Bedrock game assignment was helpful in helping me to apply the learning I had made in real world situations". Survey No: 73586, 48330-AUT-U-S-LEC1-01*

In the tutorial classes, the lecturers/tutors explained the efficient approaches to conduct critical review of articles related to each game modulus (i.e. earth dams, excavation, and slope stability) and how find papers helping with their initial design. The main aim of this research inspired computer game was to develop design skills for solving geotechnical problems through enjoyable mode of learning. From week 6, tutors have been allocating some time at the end of class to help the students with the required programming and learning PLAXIS software and give feedback on students' progress and design as required and well before the final submission. It is believed that students can gain extensive experience by discussing their research, while getting immediate and specific feedback on their progress.

Before starting to build their computer model, students needed to conduct research on UTS library database and other available sources to find the optimum setup. This can motivate students to learn disciplinary research skills, and get used to adopting research inspired learning in many parts of their course. In the presentation session organised, all the participants presented their works and ways they tweaked the program and used literature leading to their optimum design. Students had a chance to comments on each other's work and share their experience. Authors experience shows that the traditional grading process in which the lecturer scores the class quizzes, projects, exams and assignments may result in conflict between the lecturer and the student, or the students may try to only write what the lecturer wants them to remember or demonstrate, rather than truly utilizing the opportunity to learn in depth. Each student received three scoring sheets to assess three projects and comment on "Effective use of the PLAXIS software package for modelling", "Brainstorming and Optioneering Process", "Detailed Design and Construction Procedures", "Time Management" and "Capability to Answer Questions". The outcome of this peer-assessment, which was specific, descriptive and focused of the major research project and presentation, stayed anonymous and a copy of available assessments (including the lecturer's assessment) was provided to students as feedback to improve or modify their learning in the future. This project also assisted to train top quality Civil Engineering graduates with "lifelong learning capabilities, including the values, the communication, information and technological literacies and the capacities for judgement" underpinning one of the major graduate attributes.

It should be noted that Soil Behaviour subject has a separate research project task and it was attempted to compare effectiveness of the research project and computer game-based assignment and most of the participating students believed that if both of these tasks are combined then they can spend more quality time to complete the task while improving their geotechnical engineering skills. Looking at the final exam results, it was very evident that performance of students participated in Back to Bedrock Computer game, were well above the others (on average 25% higher mark than others). Following is a suggestion from one of the students combining Back to Bedrock computer game with research project work and his view of the outcomes:

- *“I think if back to bedrock computer game is introduced as an project work , students can learn more about geotechnical design tool and can be more innovative while think in design aspect as well as the reality, they will find the subject more interesting as they will feel that they are like junior professional and can have fun while learning and checking their theoretical knowledge with actually what is happening in real condition .” Survey No: 77855, 48330-SPR-U-S-LEC1-01.*

In order to get feedback from students, several interviews were carried out. Students were asked to highlight the ‘best features’ of using games in their learning, with a particular reference to the “Back to Bedrock” computer game. Most of them (over 60%) stated ‘it was fun’ in their responses. Furthermore, a large group of interviewees explained that because it was fun they became more motivated to learn Soil Behaviour subject.

3 CONCLUSIONS

The primary intention of this paper was to present how a well-designed game can facilitate teaching soil mechanics concepts and enhance students learning effectively. A geotechnical engineering computer game was developed as a learning tool and assessment task. This game called “Back to Bedrock” has two components, including laboratory experiments for finding the best set of soil properties; and earth structures design based on an advanced commercially available software, PLAXIS. PhD students/tutors were involved in this activity explaining the professional methods to conduct critical literature review of materials related to each game modulus and how to find papers helping with the initial design. In addition, tutors helped students to quickly learn PLAXIS software and how to use the program to estimate the construction cost, as well as the factor of safety.“Back to Bedrock” game has two modes (i) Laboratory Experiment, and (ii) Earth Structures allowing students to progress from small scale lab modelling to large scale field simulation. An online billboard enabled students to know the status of other competitors while it could also be used as an indicator to encourage deeper learning. Student survey results indicated that computer game based assessment task kept students more engaged, while the traditional assignments were also a vital part for their studies, as it provides a foundation and basic knowledge which allow students to apply in the computer based tasks.

The proposed activity stimulated the students to improve their skill of learning in a way that was enjoyable to them. The participated students did not realise that they were learning many aspects of soil testing and design of earth structures, because they had plenty of fun. After completion of the game some students clearly expressed that they liked the “Back-to-Bedrock” game, because it was not only fun but also interesting; and they learnt new concepts and innovative methodologies.

References

[1] Selwyne, N. (2007). The use of computer technology in university teaching and learning: a critical perspective, Journal of Computer Assisted Learning, 23, 83–94.

[2] Chang, Y.C., Peng, H.Y. and Chao, H.C. (2010). Examining the effects of learning motivation and of course design in an instructional simulation game, *Interactive Learning Envi*.,18(4), 319–339.

[3] Randel, J.M., Morris, B.A., Wetzel, C.D., & Whitehill, B.V. (1992). The effectiveness of games for educational purpose: A review of recent research. Simulation and Gaming, 23(3), 261–275.

[4] Weise, M. (2014). The Real Revolution in Online Education Isn't MOOCs, Published on 17 October in Education Section, *Harvard Business Review*, Accessed on 6 February 2015 from: www.hbr.org/2014/10/the-real-revolution-in-online-education-isnt-moocs/

[5] Grovo (2015). How the Digital Skills Gap is Failing Higher Education and How to Close It, Published in Campus Review on 14 February. Grovo free whitepaper can be downloaded from http://resources.grovo.com/acq-highered-dsg-whitepaper-desktop/

[6] Kiili, K. (2005). Digital Game-based Learning: Towards an Experiential Gaming Model, Internet and Higher Education, Elsevier Inc., 8, 13 – 24.

[7] Gee, J.P. (2003). What Video Games Have to Teach Us about Learning and Literacy, New York: Palgrave Macmillan, (A list of Gee's principles is available online: http://mason.gmu.edu/~lsmithg/jamespaulgee2).