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# Innovative eLearning: Technology Shaping Contemporary Problem Based Learning: A Cross-Case Analysis

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**Abstract**

*Preparing students to be critical thinkers and effective communicators is essential in today's multinational and technologically sophisticated environment. New electronic technologies provide opportunities for creating learning environments that extend the possibilities of 'old' but still essential technologies: books, blackboards, and linear, one-way communication media. Such technologies contribute to engagement and meaningful learning in the higher education sector. Greater understanding in educational psychology and the effectiveness of educational interventions has motivated the development of various student-centred pedagogies (e.g. Problem-Based Learning (PBL)) addressing perceived shortcomings of traditional didactic instruction. PBL as a pedagogy promotes meaningful learning due largely to its power to stimulate critical, reflective and creative thinking.*

*Can teaching staff, then, adopt technology-based approaches to create multi-disciplinary interactive PBL environments that enhance learning and excite students, inspiring them to take ownership of their own education? This paper presents a cross-case analysis of four cases that explore how classroom-based learning activities have been transferred to online formats in universities to improve critical thinking, problem-solving skills, and other learning attributes across a range of disciplines.*

**Keywords**

Problem-based learning, Critical thinking, Problem solving, Self-directed learning, eSimulation

## Introduction

Educators looking for new ways to engage their students frequently use information and communication technology (ICT) in ways that develop their students' problem-solving skills and critical thinking. In doing this, they typically look for ICT that goes beyond a didactic, or "drill and skill", approach to offer more than a typical off-the-shelf program that tailors the technology to their students' e-learning needs in a do-it-yourself manner.

The emergence of communication technologies has seen computers proliferate in homes, schools and workplaces. Access to a rapidly growing pool of information is becoming easier and cheaper, and the amount of discipline-specific information and educational tools available has grown enormously. In this environment of abundant information, today's graduates need to be self-directed and possess lifelong learning skills. They need to be critical thinkers and analytical problem solvers, graduate attributes that are highly valued by prospective employers (de la Harpe & David 2012; Jones 2013; Karantzas et al. 2013).

Problem-based learning (PBL), a student-centred pedagogy, has recently taken on greater importance in many university courses (Boud & Falchikov 2006; Dalsgaarda & Godska 2007; Sadlo 2014; McLoughlin & Luca 2002; Richardson 2005). PBL is an instructional method of active learning based on the investigation of real-world scenarios that fosters deep long-term learning (Parkinson & St. George, 2003). With its historical origins in the late 1960s at the medical school at McMaster University' in Canada (Lee & Kwan 1997), the PBL approach has, until recently, prospered mainly in medical and professional schools. PBL is both a pedagogical approach and a curriculum-design methodology that concurrently develops higher-order thinking and disciplinary knowledge, engages students in active role play as problem-solvers (practitioners), provides a deeper, richer learning experience and confronts students with real-world situations.

Learning is an active process (Michael & Modell 2003), and the educational strategy of PBL, which is itself an active learning process, is suggested to be superior to traditional methods, because its "learn by doing" paradigm makes problems relevant, and increases students' cognitive engagement, knowledge acquisition, motivation and self-directed learning (Vernon & Blake 1993; Berkson 1993; Kiernan, Murrell & Relf 2008; Biley & Smith 1998; Harding 2002; Hoffman et al. 2006; Thomas 1997).

PBL asks students to identify contextualised problems, investigate these problems and implement meaningful solutions. This method develops a student's critical thinking and promotes creative skills. Motivation is increased as students transfer knowledge to new situations. Teachers adopt the role of facilitators of learning, guiding the learning process and promoting an environment of inquiry. The pedagogical value of problem-based learning activities has led to increased use of this approach in many university courses (Norton et al. 2012).

Given that problem-solving has emerged as an important graduate attribute and PBL as a student-centred pedagogy that facilitates this learning, what might be the role of technology in meeting the needs of learners through PBL? Technology-driven approaches to education are increasingly being used by innovative teachers seeking new ways to engage their students and to enhance their learning and understanding (Peck & Dorricott 1994; Ertmer, Gopalakrishnan & Ross 2000). More pedagogically sound instructional innovations, such as the problem-based and enquiry-based learning pedagogies, promise better learning outcomes than previous didactic approaches to teaching (Kilroy 2003; Mykytyn et al. 2008; Watson & West 1996; White et al. 2004). Faced with a plethora of technology offerings and the need to create dynamic and meaningful learning experiences for students whilst integrating interdisciplinary knowledge, educators are trying to identify opportunities to best develop these graduate attributes in a way that lets students exercise their problem-solving and creative skills in relevant technological and theoretical contexts.

Many educational courses and materials, both traditional and online, provide students with basic knowledge and principles about a specific discipline. However, in most cases, they fail to provide the content in terms of complex, real-world problem-solving (Blackburn 2011). Problem-solving skills are highly valued by prospective employers, but in coursework programs the opportunities to develop this attribute can be limited.

PBL fits in well with technology-rich learning environments that are designed to put the focus not on the software, but on the learning experience. This paper reviews how an e-learning authoring tool called Scenario Based Learning Interactive (SBLi) has been implemented to developed PBL materials that challenge students to learn through engagement in real-world problems.

## Scenario Based Learning Interactive

Scenario Based Learning Interactive (SBLi) is an easy-to-use, multi-disciplinary e-learning tool for creating self-paced learning activities. SBLi was developed at the University of Queensland, Australia, and has its pedagogical origins in problem-based learning (PBL) and situational learning theory. SBLi is original in that it has been specifically developed as an e-learning technology to give teachers, lecturers and others working in training or education an easy approach to developing intuitive, easy-to-use, affordable, online problem-based learning experiences for learners of all ages across a variety of disciplines (Blackburn 2011; Jinks et al. 2011). Successful uptake of the tool and its efficacy for learning have been well established (Breakey, Levin, Miller & Hentges 2008; Gossman et al. 2007; Stewart, Brown, & Weatherstone 2009). The approach encourages student-centred learning rather than teacher-directed instruction.

The online interactive PBL simulations (called scenarios) provide a systematic way for students to look at issues, collect data, analyse information, draw conclusions and report results. Working through scenarios requires students to identify and analyse key issues in theoretical and real-world situations. Blackburn (2011) argues that one of the strengths of SBLi is the DIY aspect of creating scenarios, easily incorporating media such as images, audio, video, tests and other multimedia; plus the ability to monitor student progress and their understanding of subject matter, quickly identifying students' learning strengths and weaknesses through instant online feedback. Whilst not an "intelligent" system, SBLi uses dynamic pathways that take into account multiple variables that provide different outcomes depending on user input. This important distinction means that it is not just a simple decision tree; instead, various outputs are possible depending on what the user does, changing the scenario's final consequence or ending.

## The Case for Web-Based, Real-World Problem-Solving

University teachers are under increasing pressure to use educational technologies in ways that will place less emphasis on surface and rote learning, memorisation and cramming for examinations, and more emphasis on the development of real-world, transferable skills such as critical thinking and understanding collaborative problem-solving in authentic real-world contexts (Blackburn 2011; Ramsden 1992). Herrington, Reeves and Oliver (2004) argue that deeper learning will be achieved with online simulations in which authentic tasks or problems become the focus of the learning environment. Authentic tasks, based on realistic simulations and scenarios where students are immersed in problem-solving, have been shown to have many benefits to learners, not least the applicability of knowledge and skills in workplace contexts, and the development of student learning skills (Lebow & Wagner 1994; Herrington, Reeves & Oliver 2006; Hung & Khine 2006; Hendy & Hadgraft 2002, Gossman et al. 2007).

As Herrington et al. (2006) have shown, PBL and situational-learning approaches to online learning do much more than deliver information, because they foster synergies between the learner, the task and the technology. Immersive, authentic, problem-based learning environments enable students to complete realistic tasks, by taking on realistic roles and engaging in realistic behaviours. SBLi PBL scenarios have been designed to give students mastery over key concepts and the ability to reflect on what they are learning. Reflection contributes significantly to learning (Moon 2000).

Herrington, Reeves and Oliver (2004) reason that there is a need for software that more suitably guides educators to a range of innovative online strategies, reflecting contemporary constructivist philosophies and advances in learning theories. Student outcomes are also improved as PBL improves the student learning initiative (Martí, Gil & Julià 2006) and enhances learning, thinking and communication among learners (Tarmizia et al. 2010).

## Methodology

This paper applies a multi-case design (Yin 1994) allowing for cross-case analysis and the investigation of the phenomenon of interest in diverse settings. The choice of case studies as a research design corresponds to the objective of studying PBL software implementation in real-world contexts. A maximum-variation sampling strategy was employed in case-study selection, as this facilitates selecting cases that exhibit important common patterns that cut across variations (Shakir 2002). This selection methodology aims at selecting cases demonstrating diversity in terms of the dependent variable or a predicted outcome linked to the case, documents diverse variations and identifies common patterns encountered in the case (Patton 2002; Guba & Lincoln 1989; Mahoney & Goertz 2004).

A sample of four cases have been selected as a satisfactory number for a literal replication, as recommended by Yin (1994, pp.46, 50). Multiple cases are suggested to increase the methodological rigor of the study and enable the successful generation of theory (Eisenhardt 1989; Miles & Huberman 1994; Yin 1994). The case-selection strategy involved addressing the issue of maximum variation across the different cases within technology-enhanced classroom environments. Although selecting cases that are different can sometimes be constituted as a problem, this characteristic has the potential to increase the strength of the results (Patton 1990, pp.172). The aim of this research, therefore, is to report on emerging patterns that cut across the four cases, however different they may be.

*Objectives*

The aim of this research is to study educational settings where online PBL simulations created in the SBLi suite of tools are used; in particular, how the technology is implemented. The purpose is to learn how teaching staff can adopt technology-based approaches to create multi-disciplinary interactive PBL environments that lead to a shift in student thinking, decision-making, problem-solving and/or critical thinking. Also of interest is how technology can emphasise the reflective nature of PBL, whic focuses on both the act (process) and consequence (outcome) of learning.

### *Research question generated by objectives*

Arising from the previously stated objectives, the following research question has guided the study:

> *Can PBL contribute or be transferred to a technology-based approach to serve multidisciplines in enhancing learning?*

To answer the research question, four case studies were examined that explored how PBL technology has been employed in various educational environments and disciplines.

### *Research design*

Case data were collected from three universities: the University of Queensland (Australia), Massey University (New Zealand) and the University of Manchester (United Kingdom). Each organisation was selected based on its SBLi experience and the willingness of the relevant people to participate in the study. Unique to these cases was the opportunity to look at very different applications in varied university disciplines.

Primary data sources for this research were semi-structured lecturer interviews, telephone interviews, email correspondence and published works. Course instructors were interviewed to gain insight into the underlying decisions and thought processes about pedagogy used in teaching the courses. These interviews occurred in the semester after the courses ended.

Cross-case analysis enabled comparisons across the different cases. By viewing the different PBL technology implementations in multiple contexts we are able to highlight similarities and differences, and develop arguments for explaining them.

To gather meaningful feedback on the suitability of SBLi as a tool for fostering critical thinking and problem-solving, students were asked to complete a questionnaire at the end of their semester. This questionnaire was modelled on those used by Man-Ling et al. (2011) and Robertson (2004) during their surveys on e-learner satisfaction; on student evaluations of teaching; and on the questionnaire-design methodology illustrated by Rowley (2014). Students answered using a standard five-point Likert scale. The questionnaire, administered at the end of the course, included questions that evaluated the student’s opinions about the appropriateness of the scenarios, the tool’s ability to foster critical reasoning, technical aspects and real-world representation.

## Integrating PBL Scenarios into University Courses

A number of schools, universities, agencies and organisations are using SBLi globally. The following four case studies demonstrate how SBLi is being applied in a variety of educational settings across diverse disciplines.

### *Case One: An interactive e-learning and story-based method for teaching statistics*

An experienced University of Queensland lecturer recognised that students in large business and economics undergraduate courses had difficulty with basic statistics and its concepts. A major difficulty for students enrolled in statistics courses is that it is exceptionally difficult for students to catch up if they fall behind, resulting in the course being widely regarded as extremely challenging.

To address this issue, the lecturer devised a story-based teaching method. He used a set of illustrations (pictorial icons) to deliver abstract mathematical concepts in an engaging manner using fictitious scenarios and simple stories. The combination SBLi software with a non-traditional, story-based teaching method achieved positive student outcomes. SBLi was the chosen technology to convert this story-based teaching method into e-simulations. A series of fully interactive PBL scenarios were developed that enabled students to make choices and interact with real-world technical issues.

These stories integrated theory and solved particular statistical problems, rather than simply applying formulae, as is done in a typical statistics course. In other words, demonstrating everyday applications by building linkages between mathematical formulae and real-world applications was key. Photographic and other multimedia materials enhanced this teaching method, assisting in capturing student interest. Existing computer-managed quizzes were embedded with prerequisites that presented a variety of statistical events to challenge students and structure their learning coherently.

Each scenario was aimed at specific lecture topics, with an emphasis on inferential statistics (e.g. normal distribution, confidence intervals, hypothesis testing, etc.). Each scenario built on the theory and learning from the previous one. Therefore, students needed to practice and complete all previous scenarios to apply their newly gained knowledge in the subsequent scenarios. The aim was to help alleviate the discouraging cumulative effects students can experience if they fall behind. Multiple-choice quizzes and short-answer questions both evaluated and reviewed student performance, as well as reinforcing learning outcomes.

This approach increased students' pass rates from approximately 65% to 88% over the last four semesters. Approximately 750 students were enrolled in the undergraduate statistics course during the first year of implementation (2010), and approximately 850 students were enrolled in 2013.

### *Case Two: Deconstruction of intellectual property in a plasmid*

In teaching intellectual-property components of biotechnology courses, this SBLi scenario challenged second-year and postgraduate (master's, graduate diploma and graduate certificate) students to play the role of a R&D scientist in a small, fictitious biotechnology company. The company specialises in the expression of protein molecules using recombinant DNA technology and transfection of mammalian cells.

The scenario was created to develop technical and intellectual-property knowledge in a scientific context that students are highly likely to encounter in their careers in biotechnology. Students are presented with a multifaceted task that requires an active choice of task, plus the acquisition and application of knowledge, which is a graduate attribute highly valued by prospective employers. The implementation of SBLi aimed to increase the opportunities for students to develop and exercise their problem-solving and creative skills in a relevant technological context, by using a novel, technology-embedded, task-based approach to intellectual-property teaching.

In the scenario, the CEO of this fictitious firm instructs the R&D scientist (the student) to come up with a potential protein molecule and choose a plasmid to use for expression of that protein in mammalian cells. The purpose of this scenario is to enable students to apply principles of intellectual property in a biotechnology context, encourage them to think across disciplinary boundaries and allow them to apply these concepts in a problem-solving mode. The tasks that students must undertake in completing this scenario include reading and researching the function of each of the components shown on a plasmid map, choosing one of the plasmids and justifying their choice based on the type of protein they want to express, performing a web search and a supplier catalogue search to see if any of the components they have selected are covered by current patents, listing all the relevant patents (together with priority date, filing date and countries designated), listing the important claims of the patent that affect the sale of the protein they wish to produce, deciding in which country or countries they will manufacture their protein, determining how many licenses they need to purchase to express a protein from their plasmid, making manufacturing and marketing decisions based on intellectual property considerations and listing some methods (technical or strategic) by which they might minimise the number of licenses they need before they can commercially use their chosen plasmid.

This real-world simulation encourages students to take responsibility for their own learning and develop critical-thinking skills and professional attitudes. In investigating options, students visit several virtual locations including the CEO's office, a patent attorney, a marketing department, a production department, a library to research patents, and an R&D team to discuss a protein product before making a written application for the protein they have chosen along with their rationale for their choice.

The results of student evaluation questionnaires for rating the course improved from 4.2 (out of 5) to 4.4 in the first year this scenario was used, and to 4.7 in the second. Informal student verbal feedback has been positive, although this has not been formally recorded.

### *Case Three: NZ small-animal medicine and nutrition assessment*

In a global first, the Institute of Veterinary, Animal and Biomedical Sciences at Massey University, New Zealand, implemented a computer-based "virtual veterinary hospital" to use clinical PBL scenarios for the final-year examination. Previous paper-based exams had been considered boring, uninspiring and inappropriate in that they didn't capture the skill sets students developed in their final year: diagnostic problem-solving and assimilation of knowledge. Therefore, an assessment format was sought that would capture diagnostic problem-solving in a holistic approach to the patient.

The final year for veterinary students is lecture-free. Students perform clinical rotations in surgery, anaesthesia, medicine, epidemiology and theriogenology of animals; health and management of production animals; diagnostic procedures including imaging, necropsies and laboratory testing; and diagnostic reasoning. SBLi was the chosen technology, as PBL scenarios can accurately present a case study whilst providing the student the freedom to make decisions. For example, a student presented with an animal with a limp is free to decide to perform a brain biopsy (N. Cave, pers. comm., 25 February 2013). PBL scenarios were constructed to simulate as close to complete diagnostic and therapeutic freedom as is practical for the final-year exam. Students were presented with a case, and were then free to obtain a clinical history; perform a physical examination; request whatever clinical test they saw fit; collect blood, urine and other tissues; perform imaging; anaesthetise; perform surgery; and dispense medication. Real prices were attached to each step, and every decision and action was recorded by the server. Conventional questions, such as those regarding the interpretation of clinical pathology, radiological interpretation or planning of anaesthesia, were inserted at key points.

Approximately 100 students in 2009, 2010 and 2011 who were completing their final examination as part of a five-year program were presented with three clinical case scenarios as part of their three-hour examination. Students were assessed on two criteria. First, they received points for correctly answering questions buried in the simulation. These questions were only “found” if the students took a correct diagnostic path; for example, if they requested a particular medical test. Questions might ask the student to interpret a test result, explain why they chose a particular treatment or describe what verbal instructions they would give to an owner. They would not find the question if they did not perform that particular test or procedure, thus missing out on marks. Second, students were marked on the diagnostic pathway. That is, the XML logs were used to determine the students’ logical steps through the simulation. Those who took additional and useless side trips on their diagnostic/therapeutic path were penalised.

Comparing each student’s performance in the PBL-based examination with their performance the previous year in their final written companion-animal clinical-studies examination found that the correlation between students’ marks in two separate written examinations within the same subject area was much stronger than the correlation between the same students’ marks in the PBL scenarios and written exams. These findings support the validity of this examination format.

Eighty percent of students surveyed on whether the PBL-based exam used realistic clinical scenarios that a veterinary graduate could expect to face strongly agreed. Moreover 70% strongly agreed that the PBL-based examination format was the most effective method of testing clinical reasoning, and 60% strongly agreed that it was a more suitable assessment method than the conventional paper-based exam.

### *Case Four: Chocolate monsters*

The School of Life Sciences at the University of Manchester has developed a series of five PBL scenarios that forms the laboratory component of an otherwise lecture-based genetic-analysis subject to support an undergraduate course in genetics. In this scenario, students role-play the part of a genetics researcher and perform simulated experiments on an imaginary model organism, the chocolate monster. Each scenario incorporates a series of experiments linked by a common concept, the aim of which is to re-introduce Mendelian genetics by giving students a problem to solve on a new imaginary species. The goal is to help students to concentrate on the processes behind their analysis, rather than focusing on a specific species. Thus, students are not able to guess the experimental outcome of the laboratory experiment based on the model organism used, and instead must apply the concepts learned during the course to their decision-making process.

Throughout this series of scenarios students play the role of a genetics researcher, and perform simulated experiments to reinforce concepts taught in lectures. Quiz questions are included in each scenario along with support materials, and user logs track the students’ decision path, which shows the sequence in which each location was visited, what items were viewed or collected and what actions were performed. Reviewing these logs enables educators to assess the student's understanding of the scenario's content and concepts.

Breakey et al. (2008) argue that many courses are enhanced with additional laboratory work, which is often cost-prohibitive, time-consuming, or too lengthy to satisfactorily allow students to reinforce concepts taught in lectures. Additionally, students who are not used to handling agents such as hazardous chemicals often used in laboratory experiments pose a further safety consideration. Thus, research and data analysis and interpretation in a virtual laboratory before moving onto the next series of experiments permits students to move through the steps involved in genetics experiments without the cost, time or safety constraints of traditional laboratory exercises. It

To gather meaningful feedback on the suitability of PBL scenarios as a laboratory-simulation tool, students were asked to complete a questionnaire. The results from the survey indicate that 78% of students agreed or strongly agreed that feedback on incorrect answers was useful, with 60% agreeing or strongly agreeing that the online PBL was a useful addition to the course.

## Cross-Case Analysis

We now reflect on the cross-case analysis, bringing together what was learned from all four case studies; this technique is described by Mathison (2004) as both a way of aggregating across cases and the means for making generalisations. In this cross-case comparison, Miles and Huberman's (2003) method was applied, where qualitative data are first significantly reduced (data reduction), then organised into different representations such as diagrams or matrices (data display), from which conclusions are drawn and verified during the last stage (conclusion and verification).

To prepare the cross-case analysis, a data matrix of topics was used to present real-world role plays, decision-making occurrences and student problem-solving (per case). Thus, each case was condensed in a form that permitted a systematic visualisation and comparison of all the cases at once. Data from interviews was entered in a table with lecturer perspectives in columns and cases in rows. Then, lecturer perspectives were summarised per case to allow for scanning across the four cases for commonalities and differences per variable (Miles & Huberman 1994). The cross-case analysis and synthesis permitted the identification and elaboration of several themes of general interest in the consideration of whether problem-based learning software can contribute or be transferred to a technology-based approach to serve multidisciplines in enhancing learning. Some of these themes emerged by working through the within-case reports, others through looking across cases.

After analysing each case study, the author read through the results of each case several times, noting differences and similarities between them. In addition, exemplifying examples were noted where they appeared in any of the case studies. The result is a cross-case matrix (Table 1) that demonstrates that PBL can be supported when delivered online through SBLi-developed multidisciplinary scenarios. These concepts are based on the within-case analyses of the four cases, as it was possible to compare the four cases and to discern patterns or themes. The purpose of the study was neither comparative nor evaluative, but rather to inform others how PBL scenarios have been implemented to improve critical thinking, problem-solving skills and other learning attributes across a range of university-level disciplines.

| | ***SBLi scenarios*** | ***Case 1*** | ***Case 2*** | ***Case 3*** | ***Case 4*** |
|---|---|---|---|---|---|
| ***Activities/Techniques*** | incorporates role-play activities | ✓ | ✓ | ✓ | ✓ |
| | fosters critical thinking | ✓ | ✓ | ✓ | ✓ |
| | presents real-world representations | ✓ | ✓ | ✓ | ✓ |
| | involves student problem-solving | ✓ | ✓ | ✓ | ✓ |

| | | | | | |
|---|---|---|---|---|---|
| | is interactive (students perform actions) | ✓ | ✓ | ✓ | ✓ |
| | structures the learning process (framed learning environments) | ✓ | ✓ | ✓ | ✓ |
| | incorporates assessment | ✓ | ✓ | ✓ | ✓ |
| | changes dynamically (depending on student actions) | ✓ | | ✓ | ✓ |
| | employs collaboration/peer assistance | | | | ✓ |
| | encourages student-centred learning | ✓ | ✓ | ✓ | ✓ |
| | lecturers author e-learning content themselves | ✓ | ✓ | ✓ | ✓ |
| | simulates experiments | | | | ✓ |
| | students identify and analyse key issues | ✓ | ✓ | ✓ | ✓ |
| | simulates real-world situations | ✓ | ✓ | ✓ | ✓ |
| | provides for resource-sharing | | | ✓ | |
| | requires students to provide decision-making rationale | | ✓ | | ✓ |

**Table 1: Visual representation of cross-case analysis (factors identified to demonstrate that PBL can be supported when delivered online through SBLi-developed multidisciplinary scenarios)**

## Discussion

The case studies illustrate how thoughtfully designed PBL activities can help students develop the understanding and skills needed for success in university and beyond. Commonalities exist across the four cases presented in this paper in terms of how the technology-based approach promotes the reflective nature of problem-solving and student critical thinking. In all cases students were presented with scenarios based on real-world concepts where they acted out professional functions in role plays. They were required to think critically, solve problems and be responsible for their learning decisions as professionals. Commonly the cases demonstrate that student-focused approaches that encourage self-directed learning successfully promote students' reflective thinking and stimulate higher-order cognitive skills.

The literature reveals that PBL supports students as self-directed learners and provides them with a more pragmatic representation of the issues and challenges of professional life (Blumberg & Michael 1992; Dunlap 2005; Malan, Ndlovu & Engelbrecht 2004; Sofie et al. 2008). Role-playing activities in PBL scenarios appear to stimulate scientific inquiry or problem-solving skills where the student recognises, recalls, analyses, reflects, applies, creates, understands and evaluates (Adams & Mabusela 2013; McLean, Brazil & Johnson 2014; Whitehair & O'Reilly 2010). Jonassen (2012) argues that story construction in the form of scenarios and mental simulations can be used to aid decision-making. In examining students' perceptions and motivation to engage in authentic tasks, Lubin and Ge (2012, p.264) suggest that "…the authenticity of problem-solving tasks may serve as a strong motivator to help students see value and relevance and to help them determine if they want to set goals and make investment to those learning tasks". Students, then, who are engaged in learning environments emphasising self-directedness are motivated by undertaking authentic activities.

The PBL exercises outlined in the cases above embed a degree of self-directed learning and guide exploration in numerous directions. These scenarios have the advantage of involving students in activities that provide immediate feedback and reinforce an integration of skills, motivating students to perform to increased levels of rigor, and thus preparing them to become effective practitioners when they enter the workforce. In this way the PBL scenarios foster critical thinking, where students develop approaches and strategies enabling them to frame, set and solve problems across a variety of learning contexts.

Overall student feedback to PBL scenarios has been very positive, with many students commenting on the realism and even the enjoyment of the learning experience. Some students from Case Three commented that they wanted more of this type of assessment and that it didn't feel like an exam, it felt more like a mix between a video and a game. Below is some feedback from these students:

*"I really think you're onto something good here. Rather than simply regurgitate facts onto paper this made us think!"*

*"It's more interactive. It's easy to tune out during Lectopia."*

*"The scenario thing is awesome! Good work – it really does help clarify the content of the course."*

*"In all, these were incredibly helpful study tools, and while I took penalty time to do the scenarios, I tried to make the most of it with added information, which I think will pay off in the final."*

*"I'm just writing to let you know that the Learning Scenarios are fantastic, and are a great help with understanding the course material. I think they are an even better study tool than having Lectopia available. Thanks a lot!"*

*"I really liked this exam, I felt that although I studied as I normally would, I focussed more on my diagnostic pathway which I do believe has helped prepare me for work better than perhaps a written exam would have. This exam was most like the real world which is where we're going!"*

*"I think it is a brilliant way to test our knowledge, in fact, all the other exams should be done this way, especially large animal orals, the stupid things we say [when] sat in front of 2 senior lecturers is unbelievable."*

*"I really enjoyed this exam, felt like a real clinician, and it was a good challenge. I really think this is the method final years should be examined. I know that you have put in much time and effort into this computer-based exam and I think you did a really good job, and I thank you for that."*

From the lecturer's perspective, this is a novel and exciting development in the assessment of clinical competency in final-year veterinary students. "The technology doesn't get in the way; students are immediately in touch with the clinical problem because it's so intuitive. [SBLi is] the only tool that comes close to capturing that experience. There is no question about going back to a paper-based assessment. SBLi delivers a unique experience that I have never experienced in any other university" (N. Cave, Senior Lecturer, Massey University, pers. comm. 25 February 2013).

The student perspectives and experiences that emerge from this study highlight that students are engaged by the PBL simulations. The cases demonstrate that students have transcended rote memory as an indicator of learning and now demonstrate an appreciation for conceptual thinking. This methodology appears to help move student understanding from merely knowledge and comprehension to the application of their knowledge, and even to analysis. Flint and Stewart (2010) report on a student survey showing that students enjoyed SBLi exercises, felt the exercises fulfilled the aims and objectives of the lesson, generally felt they improved their knowledge when using a SBLi virtual laboratory, and considered the interface intuitive and easy to use. However, they argued that there was room for improvement. It is clear that students perform better in and feel more engaged in classes that use PBL scenarios; whether this improvement is caused by the SBLi scenarios themselves is not yet clear, but the end result is often more-satisfied, more-engaged, higher-performing students.

Before rushing to uptake SBLi scenarios, one should consider Norris and Soloway's (2011) pertinent question: "Where are the digitally based curriculum materials to come from?" Administrators cannot expect teachers to generate curriculum materials. The lack of available materials can pose a barrier to technology uptake. Free open-education resources (OER) are a partial answer. Massive Open Online Courses (MOOCs) offer freely available content, but often lack the interactivity and problem-based learning structure provided by SBLi scenarios. The sharing of scenarios by educational institutions has already begun. With this model, if 10 participating institutions each create 10 scenarios, a bank of 100 scenarios, which may need little to no modification, would be available to share. SBLi scenarios can be used in their current form, modified to fit different teaching goals and disciplines or personalised for different cohorts of students. Whilst still in its infancy, the concept of sharing PBL scenarios has already been implemented in the UK as part of a £5million Open Educational Resources program funded by the UK Government's Joint Information Systems Committee (JISC), where universities are able to freely download scenarios as an open resource, modify and deploy scenarios and track student progress. A similar initiative, Project EnRole, is reported by Wills et al. (2009); this is a repository of sharable, reusable role-play materials. Wills et al.'s (2009) key findings are that a good practice repository cannot be built without simultaneously building a community of practice, and that the role of connector/broker is essential for community development.

## Summary

Multimedia technologies are becoming increasingly popular in educational settings, motivating students and providing educators with the flexibility to present their curriculum innovatively. The growth of new technologies has affected education, with e-learning initiatives emerging as commonplace. Education is constantly undergoing a changing role due to these influences as educational institutions introduce these technologies and face the need to produce graduates with the problem-solving skills that make them highly valued by prospective employers. Education psychology simultaneously has explored how students retain knowledge and apply it to situations outside the classroom, leading to the development of various student-centred pedagogies, such as PBL. Integrating technology and pedagogy into effective technology-enriched learning environments promises to meet the needs and expectations of modern learners and the demands of industry seeking particular graduate attributes. For many educators working at the "coal face" the issue is how to adapt to the new paradigm.

This study examined four cases that demonstrate how teaching staff have adopted innovative technology-based approaches to create interactive online PBL teaching resources and implement them into existing courses that challenge students to learn through engagement in real-world problems and role-playing. These resources allow students to interact with complex and realistic problems designed within a framework of PBL methodology, which is shown in the literature to deepen student learning outcomes and promote critical thinking, problem-solving and decision-making. The cases suggest that students who often play out professional roles in these scenarios exercise critical thinking and problem-solving skills. Anecdotal reports indicate that student reception and interest in SBLi-supported courses is very enthusiastic; hopefully these courses will inspire them to take ownership of their own education and be accountable for their learning decisions.

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