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Practitioner Reflections on Engineering Students' Engagement with e-Learning

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ABSTRACT

This paper reports on an investigation of student engagement with e-learning, using practitioner reflection as a lens. Five e-learning practitioners each provided a case study from their teaching, which was the focus of practitioners' reflective accounts. Each of the practitioners had used e-learning as a way of promoting both learning and engagement in their classrooms, and while the

contexts in which they worked were varied, there were some emergent similarities in their experiences. The practitioners' reflections show that e-learning is used as a tool to promote various types of engagement from engineering students; indeed, students' engagement in some cases evolved beyond that which the practitioners had intended or anticipated. While the intended outcomes were certainly achieved, other emergent changes in student engagement were reported by the practitioners.

Keywords: e-learning, student engagement, reflective practice

INTRODUCTION

E-learning has been defined as "a collection of learning methods using digital technologies, which enable, distribute and enhance learning"[1]. A recent analysis by Beddoes, Borrego & Jesiek [2] found that research on e-learning in engineering education has tended to emphasize specific interventions, coupled with assessment as necessary. At a time when information technologies are not only becoming ubiquitous in learning and teaching practices, but also tend to lead our pedagogical conversations and scholarship, it is important to revisit the reasons for integrating them into learning environments. In this paper, we are doing so through the lens of practitioners' reflections on student engagement. Some questions that were examined include: What are the benefits of implementing an e-learning tool? What does student engagement look like when e-learning tools are implemented? What are observed unintended or negative outcomes? Does e-learning engagement look like old-school engagement, or is it a new and different animal?

In terms of engagement, research on college student development "shows that the time and energy students devote to *educationally purposeful activities* is the single best predictor of their learning and personal development" [3]. Student engagement differs from mere involvement; while students can be involved without being engaged, engagement speaks to the accrual of heightened outcomes [4]. Given this knowledge, learning experiences should be developed in accordance with practices that encourage students to put forth more effort (which includes asking questions, working with other students on projects inside or outside of class, discussing ideas from class, reading outside of class, and using information technology appropriately). These student efforts, in turn, will result in greater gains in such areas as critical thinking, problem solving, effective communication, and responsible citizenship [3, 5]. As Kuh, et. al. explain, "one line of inquiry that promises to increase our understanding and ability to improve student success is the research showing the positive links between student engagement in educationally purposeful activities and such desired outcomes as higher grades and higher first-to-second year persistence and graduation rates" [5]. Further, as Harper & Quaye [4] detail, educationally purposeful engagement produces gains, benefits, and outcomes in cognitive and intellectual skills development, college adjustment, moral and ethical development, practical competence and skills transferability, the accrual of social capital, and psychosocial development . It is important for us as practitioners and researchers to realize that even the most skillfully designed materials are not effective if they do not engage students.

This raises the question: What might student engagement in e-learning and other environments look like? In their review of pedagogies of engagement Smith, Shephard, Johnson & Johnson [6] reflect on principles and guidelines that should be considered. The concept, "pedagogies of engagement", was originally coined by Edgerton in a white paper that explained "Learning 'about' things does not enable students to acquire the abilities and understanding they will need for the twenty-first century" [ibid]. Smith, et. al. [ibid] also go on to discuss Gamson & Chickering's *The Seven Principles for Good Practice in Undergraduate Education,* guidelines that have not only been widely accepted, circulated, and cited, but also adapted to varying contexts. Of the seven principles at least three are directly related to pedagogies of engagement (student-faculty contact, cooperation among students, and active learning) [ibid]. Finally, they go on to discuss the importance of student engagement based on Pascarella and Terenzini's summary of twenty years' of research on the impact college has on student development:

> …a substantial amount of evidence indicates that there are *instructional and programmatic interventions* that not only increase a student's active engagement in learning and academic work but also enhance knowledge acquisition and some dimensions of both cognitive and psychosocial change [ibid].

The focus on the importance of student engagement, both as a concept and a measure of importance, has continued to gain supporters at all levels in higher education. Since 2001 the National Survey of Student Engagement (NSSE) [7] has administered surveys that are completed at large numbers of U.S. colleges and universities where institutional leaders seek further information about students' experiences, including engagement. NSSE was designed to "assess the extent to which students are engaged in empirically derived good educational practices and what they gain from their college experience" [8]. NSSE centers on five benchmarks of effective educational practice. Four of the five benchmarks are relevant to the e-learning context of this research including: level of academic challenge; active and collaborative learning; student-faculty interaction; and enriching educational experiences [7].

Against the backdrop of this growing body of work relating to student engagement, this paper focuses on current learning and teaching practices in engineering education. In particular the paper will explore how student engagement takes on additional qualities when considered from an e-learning perspective. The examples presented will also investigate why and how e-learning activities have been designed in terms of student engagement. The teaching practices reported in this paper have been contributed by a team of engineering faculty, who shared practitioner insights into student engagement relating to areas such as:

- Deepening student learning through the work-play nexus using video games when learning dynamic systems and control;
- Encouraging both faculty-driven and learner-centered experiential learning using simulator software in electrical engineering;
- Facilitating the development of generic graduate attributes using online roleplay simulations;
- Using e-learning tools that are both portable and provide instant responses and feedback, while incorporating scaffolded examples; and
- Strengthening student reflection and engagement using internet controlled, remote laboratory equipment.

In practical terms, the examples of e-learning reported here all represent blended learning, where aspects of online learning have been integrated in the curriculum with offline or face-to-face learning. In addition, several of the e-learning initiatives describe an approach to student learning and engagement that harnesses what Dede has termed "the power of immersion" [9] in learning technologies such as manipulating a simulated Porsche 996 around a sharp turn, controlling laboratory equipment in another location, or arguing a case in a roleplay involving an online environmental inquiry. In addition, some examples emphasize enhanced communication and student access, which enable "learning anywhere, anytime" [10]. Across the board, by providing this snap-shot of current practices through these practitioner reflections, we hope to raise the conversation about e-learning and student engagement practices in engineering education to the next level, a level where we are not working in isolation but rather coming together to learn from one another.

RESEARCH CONTEXT

The authors were first brought together at a meeting of the Australasian Association for Engineering Education (AaeE) to participate in a National Science Foundation-funded workshop on e-learning. The goal of this workshop was to form collaborative partnerships to explore different aspects of e-learning. Through a process of structured dialogue at the workshop, several themes related to e-learning were elicited, with our team forming from the participants who gravitated towards student engagement as a theme.

Our collaborative team is comprised of five academic faculty members who teach in undergraduate engineering programs, and two academic developers. The team has five members from Australia and two members from the US, representing five universities in total.

As the workshop progressed and our collaborative team took shape, it became clear that while we all had very different contexts for e-learning, we were all using e-learning to overcome similar challenges in our teaching. Our students were being exposed to vastly different forms of e-learning. However we were identifying generalizable similarities in the ways in which we as practitioners had approached the development and implementation of our students' e-learning experiences. These similarities prompted the use of practitioner reflections as a tool for analyzing student engagement in e-learning.

Initial discussion at the workshop gave some insight into the positive and negative influences on student engagement in e-learning in engineering education. Once we dispersed, our collaboration progressed via email, a wiki space, internet calls, and local teleconferencing. While the team proceeded with a deliberately collaborative and participatory approach, due to logistic necessity two team members shared leadership roles.

METHOD

Theoretical Framework

While research on student engagement to date has varied from case studies of individual interventions and classes to large-scale student surveys, this project focuses on the perspective of teaching practitioners. We situate this project within the theoretical framework of reflective practice developed by Schön [11]. In reflective practice, professional knowledge is not seen as arising only from sources of knowledge that are external to the practitioner (as in textbooks or professional manuals), but is also seen to develop from within via reflection on one's own practice. Specifically, reflective practice refers to "thoughtfully considering one's own experiences in applying knowledge to practice" [12], which may also be assisted by coaching from professionals in the area. A reflective practice approach is based on the view that through experiencing and reflecting on their practice, practitioners accrue valuable knowledge. In this project, academic faculty are reflecting on their professional teaching practice.

Schön [11] introduced the twin concepts of reflection-in-action (which is tacit learning that occurs in the moment, such as when teaching staff interact with students), and reflection-on-action (which is learning that occurs through deliberate reflection after an event, such as through reflective writing after class has finished). The focus of this project is on reflection-on-action, where practitioners are reflecting on their professional teaching experiences in e-learning. While the limitations of the reflective practice framework have been explored in detail elsewhere (for example Usher et al [13]), it is nevertheless a useful and widely adopted framework.

Reflection is more than merely observation or description. While definitions vary, we have adopted the following developed by Moon:

> Reflection is a form of mental processing—like a form of thinking—that we may use to fulfil a purpose or achieve some anticipated outcome... Reflection is applied to relatively complicated, ill-structured ideas for which there is not an obvious solution and is largely based on the further processing of knowledge and understanding that we already possess.[14]

Method of Practitioners' Reflective Accounts

Within the framework of reflective practice, we have adopted practitioners' reflective accounts as our central method. To this end, our main data source was practitioners' reflective writings—borrowing from an emphasis on reflective professional practice in methods such as action research [15]. In qualitative approaches to research, reflective methods for generating data have been gaining widening acceptance (for multiple examples see Denzin and Lincoln [16]). We have chosen practitioner reflections because they provide rich and useful insights not traditionally reported in sections of the literature. While there is necessarily individual variation between practitioners in this project, the value and strength of this approach lies in its reflective and subjectivist aspects. This method enabled us to explore a shared question: What can we learn through practitioner reflections on the positive and negative influences on student engagement in e-learning in engineering education?

As a way to structure individual reflections in this project, we initiated reflections with prompting questions. As Race argues, "The most efficient way of helping people both to reflect *and* to evidence their reflection can be to provide them with questions as devices to help them to focus their thinking, and direct their thinking to those areas of work where reflection can pay highest dividends" [Race's italics] [17].

In terms of process, we first developed a project plan, then using recursive cycles we developed an overarching set of prompting questions that covered the broad themes: positive/negative influences on student engagement; planning to support student engagement; professional learning regarding engagement; and characteristics of student engagement in e-learning. These reflections related to specific implementations of e-learning activities, which are presented below (see Case Designs and Contexts). A second trigger for data were the academic developers, who took on the role of "critical friend" [18] to the teaching faculty—in the action research tradition of asking questions and encouraging dialogue to support reflection. Our final source of data included the artifacts generated during the collaboration, including e-mails, e-conversations and wiki texts.

Procedure

Data for this study were collected and analyzed over a six-month period. The analysis consisted of detailed readings of practitioners' reflections relating to e-learning and student engagement. Analysis was conducted by the two academic developers who approached the task separately to build in trustworthiness through cross-checking and peer review [19]; trustworthiness is a term that represents credibility, dependability and conformability in qualitative research [20]. Coding was conducted manually by color-coding passages using a word-processing package. The two academic developers read independently for common themes within and across reflections relating to prompting questions. First, themes closely related to the prompted questions were examined, followed by sub-themes within the main themes that emerged beyond the prompting questions. A central assumption in our method is that valuable knowledge is conveyed in the specific wording of practitioners' reflections; therefore, the fidelity of practitioners' voices was maintained by using verbatim quotations in reporting, and through practitioners co-authoring attributed sections of the paper.

All practitioners were involved in member checking after results were first drafted, which is where members of a study review a draft to check and give feedback on aspects such as the accuracy, fairness and completeness of reporting [19]. This also assisted to establish communicative validity [21]. At this point practitioners were also able to feed into the discussion section of the paper.

The validity for this research lies in the dependability of our study design (reflective writing texts and project artifacts); the authenticity of our study design (reflections of our own professional viewpoints, and member checking), and of course, the triangulation of the multiple data sources [19]. The validity of socially constructed research, such as this study, is embedded in the credibility, transferability, dependability, and confirmability of a study [ibid].

CASE DESIGNS AND CONTEXTS

In this section we present the context of case studies from which we pooled practitioner reflections on student engagement in e-learning. Following are the contexts and descriptions of five e-learning tools that have been used and shown to be effective when it comes to engaging students.

Video Game-Based Dynamic Systems and Control

Practitioner: Brianno Coller

One of the most difficult courses in the undergraduate mechanical engineering curriculum at Northern Illinois University is Dynamic Systems and Control. Students find the Laplace-domain mathematics very unnatural and confusing. The pace at which new theoretical material is piled on top of a shaky foundation can be overwhelming.

In 2008, the course was redesigned; new laboratory assignments, homework assignments, and other learning activities were built around a video game called *EduTorcs*. The game is a car and bicycle driving/racing game that has much of the look and feel of commercially successful games such as *Need for Speed* and *Gran Turismo*. However, students do not "play" the game like a traditional video game. They do not spend countless hours, joystick in hand, honing their eye-hand coordination and driving skills. Instead, students drive their cars and bikes by writing control algorithms in C++. They model the vehicles' dynamics then design and implement feedback controllers that are (hopefully) sufficiently robust to handle system nonlinearities and measurement errors. The driving algorithms get dynamically linked to the game at run time. Students can get immediate feedback as to whether their algorithms successfully navigate a Porsche around a sharp turn at 150 mph, or whether they cause the sports car to crash spectacularly. A screen-shot of the game is shown in Figure 1.

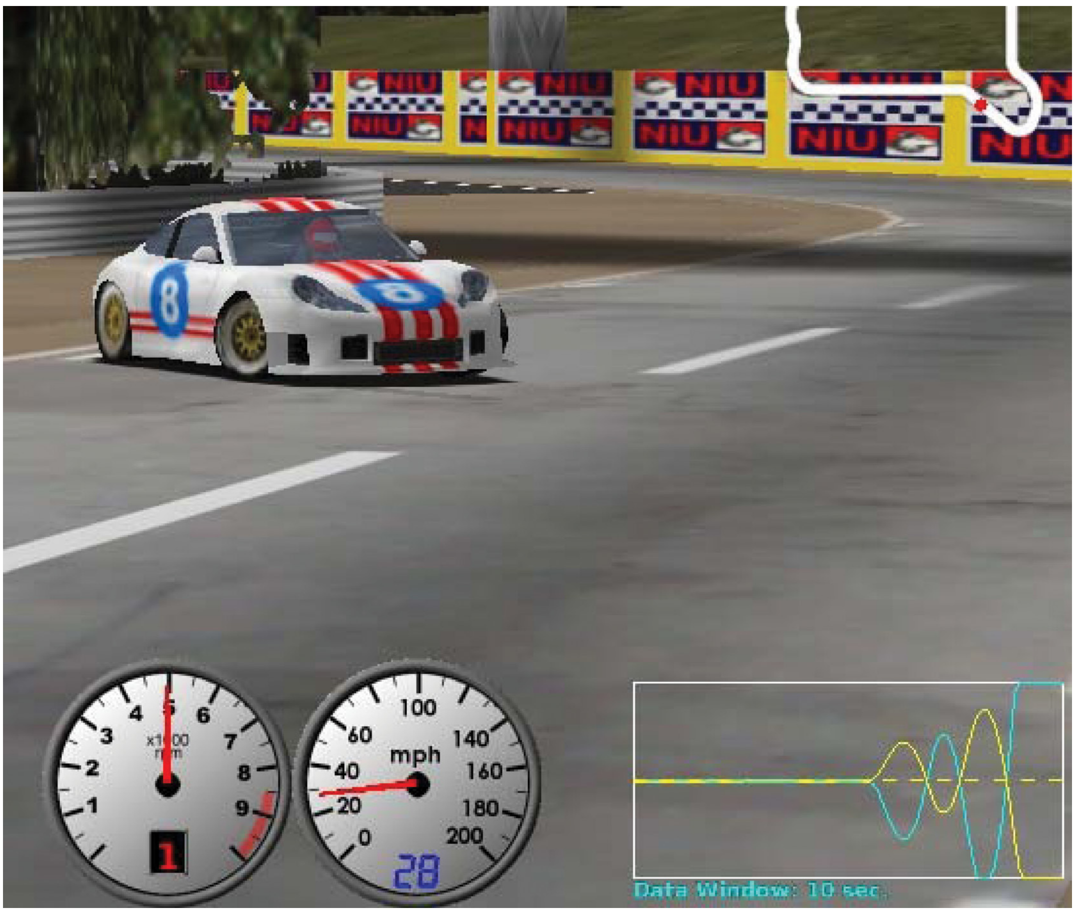

Figure 1. Images from EduTorcs.

The game-based dynamic systems and control course covered the same content as the original course without the game. The rationale for introducing the game was to give students a reason to want to learn the material. Narrowly focused, over-simplified homework problems that one typically finds in textbooks bear little resemblance to actual engineering practice, whereas the challenges embedded in the game require authentic engineering problem-solving skills. Students learning with the game have to think and act like engineers. On concept tests, students who learned with the video game scored significantly better than students who took the course from the same instructor in 2007, before the game was introduced [22].

Use of Simulator Software for Experiential Learning in Electrical/Electronic Engineering

Practitioner: George Banky

Since 2008, at Swinburne University of Technology, each undergraduate engineering student who is enrolled in the first-year electronic systems course had to purchase a student edition of the commercially available electrical/electronic circuit simulation software, *NI Multisim 10* (http://www.ni.com/multisim/). The feature that makes this computer application useful in this context is the user-interface that enables the students to wire up, on their computer screens, any electronic/electrical circuit using the included simulations of both ideal and commercially available real electronic/electrical components—just as they could have completed such tasks in a bricks-and-mortar laboratory. Further, with the use of the appropriate simulated real test instruments, student-focused experimentation is possible on these circuits—the resultant activity facilitating deeper levels of learning in line with Ramsden's [23] proposition that in order to achieve this students must interact with the content in ways that enhances their understanding—by being 'immersed' through simulations, for example.

Additionally, student ownership of a copy of the software facilitated any-time access to a tool that enabled his/her verification of assignment solutions, laboratory preliminary submissions and tutorial and textbook exercises with a corresponding simulation. In this way the development of both critical thinking and analytical skills, which are required in professional practice, were encouraged. This software was also installed in a number of computer laboratories for on-campus use. The students were scheduled into these laboratories for their weekly tutorials, rather than into classrooms as has been the practice in the past. This gave the tutor the ability to introduce communal "troubleshooting" exercises, where the students were asked to predict and then confirm with an appropriate simulation the possible reason for an ill-behaving circuit whose correct operation was discussed earlier in that session.

The use of simulators dates back to the Roman Empire [24], and in this context their use directly targets the visual, kinesthetic and tactile learner [25]. While there are some

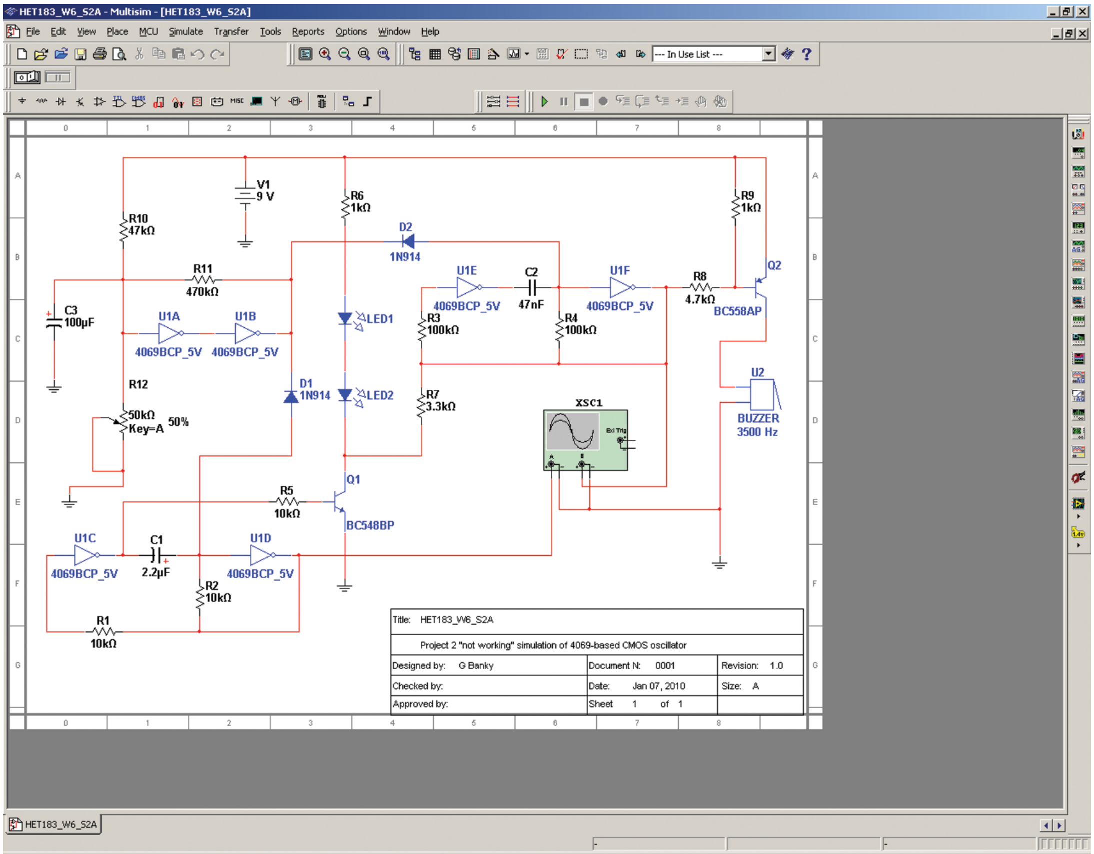

Figure 2. Typical desktop of a troubleshooting session using NI Multisim10.

disadvantages in using software simulators for physical artifacts, such as electronic circuit components (in that these are not able to be physically handled, resulting in the loss of some elements of conscious and subconscious learning) [24] the opportunity to troubleshoot ill-behaving circuitry, which lead to deeper understanding, proved to be more than sufficient compensation. Finally, making the simulator software easily available to the learners supports both academic-driven and learner-centered experiential learning, thereby encouraging student engagement that leads to deep levels of understanding resulting in the student attaining highly desirable tertiary attributes [23, 26-28].

Post-event participant surveys conducted in 2009 confirmed the intervention's effectiveness, as fewer than 10% of them found that their exposure to troubleshooting exercises and/or their use of the simulator software did not improve their understanding of content.

Use of Online Roleplay Simulations for Developing Generic Graduate Attributes

Practitioner: Holger Maier

The Mekong eSim (http://www.adelaide.edu.au/situationallearning/mekong/) is an online roleplay simulation hosted at the University of Adelaide. It is aimed at second year civil, environmental and mining engineering students but generally also includes students from disciplines such as geography and Asian studies. The purpose of the eSim is to develop a range of generic skills and attributes that have been recognized as being important by professional bodies responsible for the accreditation of engineering degree programs, but are generally difficult to develop in a traditional classroom setting, including an understanding of the concept of sustainability, the ability to communicate and function in teams, and an understanding of social, cultural, global and environmental responsibilities of engineers [29, 30].

Roleplays that are centered on realistic, controversial engineering projects are an excellent means of engaging students in the development of graduate attributes that are generally considered "soft" and "non-core" by engineering students [29, 30]. Staging roleplays online has a number of advantages, including increased opportunities for reflection and analysis, improved access to realistic

Figure 3. Mekong TV news releases provide prompts for roleplay discussion.

sources of information and the ability to cater for geographically distributed participants, possibly from different disciplines and/or countries, further increasing student engagement.

As part of the Mekong eSim online roleplay simulation, between 60 and 108 students adopt the roles of stakeholders and respond to proposed development issues in the Mekong River basin of South-East Asia. Through research and interaction with other roles, participants build a case as to whether a proposed development should proceed or not, which they present and defend during an on-line public inquiry. The public inquiry is chaired by a role representing the potential funding body for the project that makes a decision as to whether the project should proceed, based in the arguments presented during the public inquiry. Students then step outside their roles as part of a de-briefing phase, during which an understanding of the generic processes that occurred is gained.

Using Java Applets with Computer Aided Teaching in Geotechnical Engineering (CATIGE)

Practitioner: Mark Jaksa

One example of attempting to deepen the engagement of undergraduate civil engineering students as they undertake geotechnical engineering experiments in the laboratory involves using

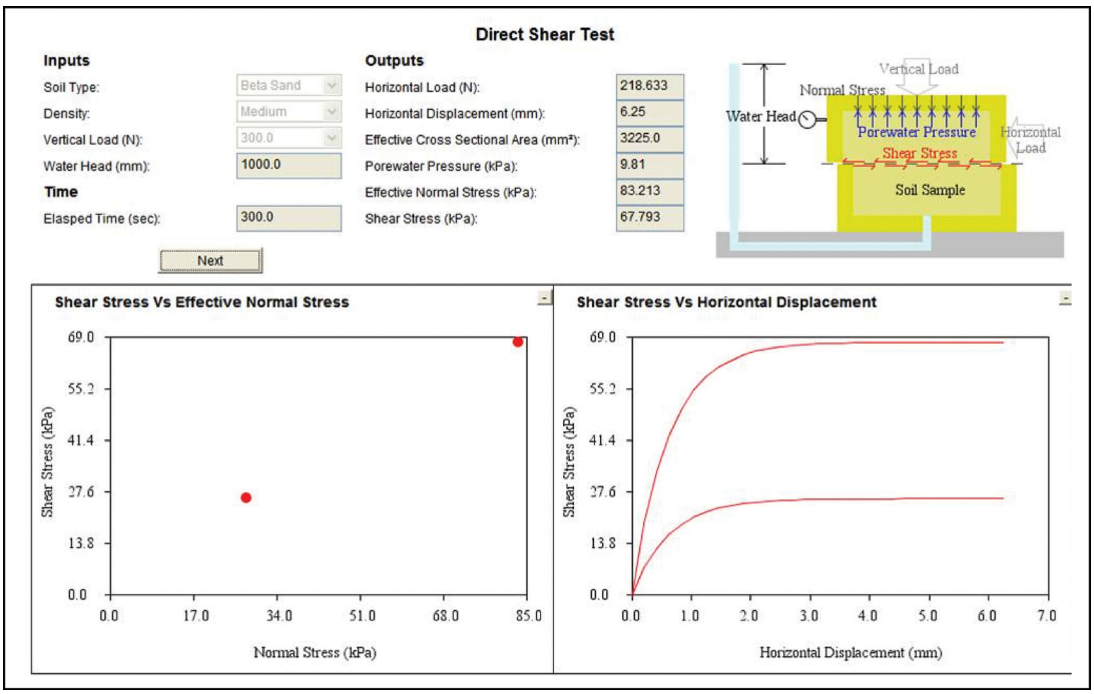

Figure 4. Computer Aided Teaching in Geotechnical Engineering—direct shear test.

emerging technologies at the University of Adelaide. The measurement of soil behavior generally involves experiments which can take several hours to perform, and as a result, are generally not particularly engaging from a student's perspective, and sometimes, such as in the case of the triaxial test, involve complex and expensive equipment which requires specialized technical support.

Over the last decade or so, educators have attempted to address these factors by developing e-learning tools. One such example is the PC-based *CATIGE* (Computer Aided Teaching in Geotechnical Engineering) Suite (http://www.ecms.adelaide.edu.au/civeng/staff/mjaksa01), which was originally developed in DOS by Priest et al. [31] and subsequently enhanced and ported to Windows by Jaksa et al. [32]. The software is currently used at 38 universities and six companies. The design philosophy of the *CATIGE* Suite, which relates to soil types, is discussed by Jaksa et al. [33]. The suite consists of 15 separate programs including: Mohr's circle; triaxial test, vertical effective stress calculation; and a Geotechnical engineering unit converter. Recently, eight of the programs have been further developed as Java applets by Jaksa and Kuo [34].

CATIGE is used in lectures to assist with the understanding of fundamental geotechnical engineering principles, in practical classes to enhance student engagement and reinforce key learning outcomes, and as a private study resource. By means of the software and scaffolded examples, students are able to examine the variables that influence soil behavior, using a medium which is both portable and provides instant responses and feedback. In other words, students engage with the learning object not only because it is more modernized in its use of computer technology than other laboratories but also because it is more responsive than laboratory equipment. As a result, students are further engaged and deeper learning is achieved more efficiently.

Remote and Virtual Laboratories

Practitioner: Euan Lindsay

In 2002 and 2003, the University of Melbourne introduced alternative access modes to a third year data acquisition laboratory class for engineering students. In this class students are required to calibrate a piezoelectric accelerometer using a Doppler laser. (See Figure 5a.) Students were randomly allocated to one of three modes—a traditional face-to-face laboratory experience, an internet-based remote control mode, and a fully virtual simulation of the experiment [35].

Alternative access modes offer great potential for flexible delivery of laboratory classes; colleagues and I conducted a study that was intended to measure the effect of these different approaches to engaging with the laboratory equipment [36]. Remote and virtual access inherently change the nature of the students' engagement by combining physical separation with a technology mediated interface [ibid.]. This combination of factors should have an impact upon the way in which students learn; this study was intended to determine if this impact was educationally significant.

Figure 5a. Remote laboratory.

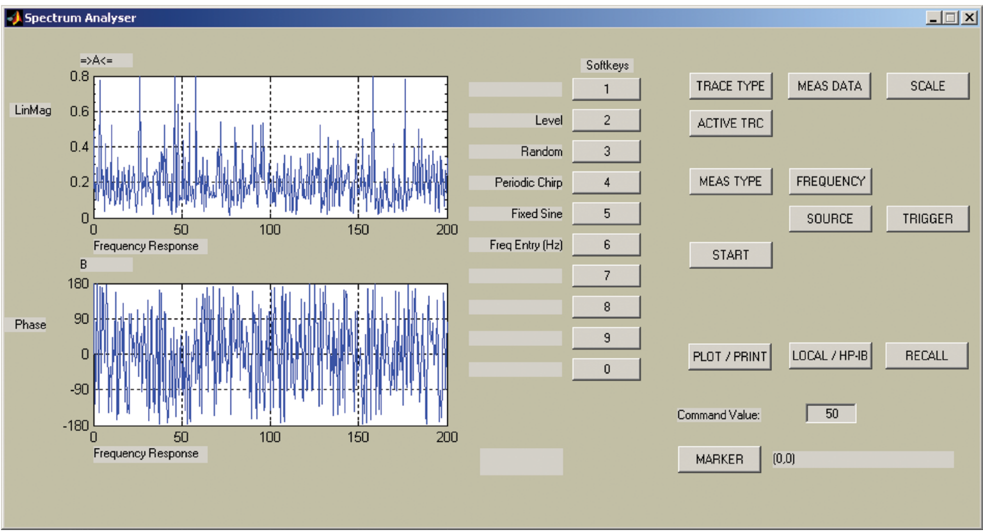

Figure 5b. Remote laboratory's remote control interface.

Changing the way in which students engage with the laboratory changed not just how they learned, but also what they thought they learned. The students in the remote mode were more reflective in their practice; they thought about their data as they gathered it, rather than simply writing down numbers. They also proved better at dealing with unexpected results.

Perhaps more striking than the changed learning outcomes were the changes in students' perceptions of their learning outcomes in the remote and virtual access modes. Students in different modes reported differences in their perceptions of the objectives of the class; the groups thought that they were meant to learn different things, depending upon the mode they had used to control the equipment [35].

RESULTS

This results section draws on the practitioners' reflections on student engagement and e-learning. It includes themes that were collected as a result of prompts for reflection, and sub-themes that emerged from within these main themes.

The academic faculty who collaborated on this paper shared a motivation when developing and introducing e-learning activities. Their motivation was to improve on the traditional teaching and learning approaches that they perceived were impeding learning and student engagement. As one collaborator, Coller explained: "One of the most difficult courses to teach is Dynamic Systems and Control. It is highly mathematical and theoretical, so it spooks students. The difficult material, though, is worth the effort to learn. It's so cool. But you wouldn't know it by working through the problems in the textbook or by laboratory assignments." To us, this is at the heart of engaging students. It speaks to authentic contexts, relating the material to students, accessibility, and motivation.

As a research group, we easily settled on the concept of student engagement as a focal point for discussing e-learning tools. As educators, we held tacit understandings of the key importance of engagement, even before we engaged with the literature in this area. As Coller explained early in his reflections on his own experience as a student:

> I think that many, if not most, of us professors long for students who treat the subjects we teach with the same degree of fascination and seriousness that we once had… or think we had. [However] There were classes that I did not regard as particularly important, relevant, or interesting. Why? I didn't see the relevance or purpose of many of the courses… As a professor I have always put a lot of effort into making my courses appear important, relevant and interesting. Sometimes I do better than others.

Our five practitioners had each chosen e-learning as a way to encourage student engagement with their course materials. What became clear in our analysis was that – at least from the practitioner perspective – this change had indeed occurred.

The results section presents both anticipated and unanticipated themes that emerged from the data. The results are arranged by the four overarching themes (affordances and constraints of the e-learning tools, lessons learned, e-learning engagement differences, and advice from the practitioners) with additional major subthemes included.

Observed Affordances and Constraints of the e-learning Tools

Practitioners' reflections showed that e-learning can potentially enable students to expand and deepen their engagement through the affordances of intellectual experimentation, deepened authenticity, improved accessibility, and increased opportunities for feedback.

Intellectual Experimentation

Several practitioners reflected on the intellectual experimentation and cognitive engagement that they observed in students' e-learning, some of which had been intended in the learning design, and some of which were unexpected. For example, Jaksa had intended to deepen student engagement by providing soil-test simulations that provide a quick response. He reflected on students' behavior in comparison to traditional soil-testing laboratories, saying:

> It was clear that they were far more engaged with the material and the resources. There was a great eagerness to explore the 'cause and effect.' In other words, what happens when I adjust this parameter? How does it affect soil behavior? Contrasting this with the traditional laboratory setting where soil behavior is usually measured extremely slowly, students often disengage from the material and from learning.

Another practitioner's reflections pointed to students' intellectual experimentation with an e-learning tool in a way that was neither intended in the learning design nor required for credit. As Banky explained, "One observed positive influence was the initiative taken by some students to use the software to check their calculations even though they were not asked for this, nor was it a requirement for assessment. Such actions are rare for transitioning first-year students at many institutions." This reflection on student initiative and cognitive engagement speaks to the flexibility of e-learning tools to be harnessed in multiple ways to enhance student engagement, some of which may be unintended. In this case, the unintended usage was perceived as a positive initiative because it was in line with intended learning outcomes. However, at times, students approached e-learning tools from a perspective that is not in tune with learning outcomes. In this vein, Jaksa reflected that "Sometimes, too, the students will 'fool around' with the software, trying to identify inputs that may cause the program to crash." Jaksa's assessment focused on the tool: "In these cases, the tool fails as effective instrument." Clearly, where an e-learning tool is caused not to function, it not only ceases to be a useful tool to support other students' learning, but it also requires urgent attention from the teaching practitioner responsible.

However, these reflections open up questions around the engagement with e-learning tools and simulations specifically. To the extent that exploration or 'fooling around' is the point of e-simulations, there is an argument that if students are trying to 'break' the e-simulation, then they are engaged with it. Students very rarely engage with real laboratory equipment with the malicious intention to break it; something in the e-learning environment must be changing the nature of that engagement. One possible explanation is that students feel anonymous online, and as such are free of the consequences of any malicious behavior. A second possible explanation is that they do not believe there will be consequences. Interfering with an e-simulation is unlikely to result in the same financial cost as breaking laboratory equipment; it may be that the students do not see their actions as malicious at all.

Whatever the specific factors, malicious experimentation with e-simulations suggests aspects that attract students to engage with e-learning tools and activities that can inform e-learning design. Namely, activities that enable students to experience a sense of agency and powerfulness; activities that allow a sense of fun or even playfulness; and activities that encourage social connections, both during the e-learning activity and after the fact. However, it may be that no matter how thorough and creative our design of e-learning activities, we may not be able to design out of certain undergraduate students the desire to experience rites of passage through illicit transgression.

To round out this section on intellectual experimentation, we need to include a cautionary tale for those considering implementing an e-learning tool, which could be categorized as anti-intellectual experimentation. Both Banky and Coller reported that students sometimes used e-learning tools to avoid cognitive engagement with the learning material. For example, Banky reflected, "A noticeable negative influence was some students' clear reliance on using the simulator to obtain numerical answers, and perhaps 'work backwards', in lieu of attempting a mathematical analysis of the problem(s) encountered."

That students' intellectual experimentation can be both fostered through learning design, and also emerge spontaneously, points to the flexibility of e-learning tools to be harnessed in multiple fashions to potentially enhance student engagement. Spontaneously malicious student behavior provides a further catalyst for reflection.

Deepened Authenticity

The deepened authenticity of activities afforded by the e-learning tools was also a positive aspect reflected on by the majority of the practitioners. For example, Coller explained in terms of both learning design and interface:

> Although the cars and bikes in the game are virtual, the process of designing controllers for the simulated vehicles is realistic. By combining an engineering-quality physical simulation with video game-like challenges and a video game-like interface, the hope was that students would see a purpose for the theory and have intrinsic motivation to learn it.

Other practitioners designed authenticity into the nature of students' interactions with peers. For example, Maier's role playing activities were designed so "role anonymity could be maintained, making the experience more authentic for students" since knowledge of role-players' identities remained concealed.

Authentic learning environments make it easier for students to transfer and apply their learning; however there is an underlying risk that the focus of the activity might shift from promoting learning to preserving authenticity. While making a mistake may be a valuable learning opportunity, in a rigorously authentic environment the consequences of that mistake may deny the student that learning. Alternatively, an awareness of such risk enabled practitioners such as Coller to incorporate safe experimentation into their learning design. In addition, Coller reinforced this approach by using debriefings to support students to think critically and deeply about the learning activity

Improved Accessibility

Various practitioners also reflected on the affordances and constraints of accessibility. The first order affordance of improved accessibility is that more students can gain access to a learning activity. As Lindsay explained about the use of remote laboratories, "In a traditional face-to-face class, not everyone gets to'drive'—students often work in a group where one will be controlling the equipment, one taking down results, and the others either looking over their shoulders or perhaps not even paying attention. The individual nature of most remote laboratories means that each and every student actively engages with the learning experience." Similarly, as with Maier's Mekong e-Sim:

> The use of the online environment also enabled students from different geographical regions and disciplinary backgrounds to share the same interactive space....by using an online environment, more realistic resources could be provided (e.g. multimedia), making it easier for students to be motivated and immersed in their role.

However, as Maier's reflection implies, accessibility coupled with thoughtful learning design and additional affordances can elevate student activity from merely 'doing' or being 'involved' to active engagement. This qualitative shift to strengthened engagement may be accompanied by access to peers, real-world complexities and heightened authenticity—and underpinned by learning design that provides a sufficiently extended period of time for engagement. As Maier reflected:

> It was great to see students appreciate the complexity and multi-faceted nature of engineering projects. They were able to experience first-hand that sustainability means different things to different people, that there is no single solution to complex engineering problems and the degree to which engineering problems can impact on different aspects of society.

Conversely, student accessibility is constrained in situations where technology fails. As Jaksa explained, "Probably the most significant aspect of disengagement with [the e-learning tools] is when the computer resources fail…students having to adapt to the nuances of the computer server in order to run the resource and the server or computer program inadvertently crashing or operating extremely slowly because of demand on computing resources." Issues with access, as occasionally experienced with the use of the remote laboratories, were also observed. As Lindsay explained, "Remote laboratories without adequate audio visual feedback block student engagement. They can't visualize what's going on, and as a result the dominant factor in their experience becomes what they cannot do, rather than the things that they can."

On a more individualized-level for accessibility, Jaksa reported on e-learning tool software design issues, a common pitfall for e-learning tools and environments: "if the software is poorly designed, students can struggle to navigate the programs and spend more effort on learning how to use the program rather than learning the material embedded within the tool."

Increased Opportunities for Feedback

As several of the practitioners pointed out, an added benefit of integrating e-learning tools over traditional classroom exercises is the immediacy of feedback provided to students. The role of feedback in the instructional process in an integral and essential one [37–39]. As class sizes increase, and concepts and content become more complex and/or compact, feedback becomes ever more important. In general, instructional feedback provides students with information that either confirms what they already know or changes their existing knowledge and beliefs [38]. Higgins, Hartley, and Skelton [40] note that feedback that is meaningful, of high quality, and timely helps students become cognitively engaged in the content under study, as well as in the learning environment in which they are studying; when designed and implemented effectively it can also improve and accelerate learning [41]. As mentioned previously by Coller, students using the *EduTorcs* video game and exercises can get immediate feedback as to whether their algorithms successfully navigate a Porsche around a sharp turn at 150 mph, or whether they cause the sports car to crash spectacularly. Similarly, Jaksa's applet example provides students with instant responses and feedback following their examination of variables which influence soil behavior. These examples are in sharp contrast to traditional exercises.

However, we would also like to communicate that the feedback process can be improved in other forms through e-learning opportunities as well. For example, in Lindsay's remote and virtual laboratories example, the fact that students are each afforded the opportunity to "drive" the experiment or experience enables them to receive more individualized feedback; whereas in traditional classes they would tend to be grouped together as a result of lack of equipment for all. The observed affordances and constraints of e-learning for student engagement led us to broader reflections on lessons learned.

Lessons Learned

Our practitioners reflected on lessons learned, and shared insights into how they refined e-learning activities over time with a focus on student engagement. The main sub-themes that emerged as lessons learned included: scaffolding the learning experience, carefully calibrating the focus of assessment tasks, and building in contact between faculty members and students.

For example, Jaksa reflected on the need for scaffolding, "[There is a need] for well structured examples which enable students to more readily grasp the key learning outcomes. Without scaffolding, students can bumble along with the software—more like playing with it, rather than it being an effective learning tool." Maier, in his reflection, talked specifically about some of the scaffolding approaches that were initiated for the Mekong e-Sim as a means to increase student engagement:

> The Mekong eSim has been run each year since 2001 and over this time, a number of changes have been made in order to increase student engagement. This was partly in response to student feedback, partly in response to observations made by teachers and partly as a result of the time it takes to develop some of the resources. Even though the Mekong eSim runs over 6 weeks, events happen very quickly and there is a very steep initial learning curve. Consequently, it is vital that students engage early so that they do not fall behind. However, given the extended timeframe and the reliance on students to take the initiative to log into the system, some students did not engage in the first few days. In order to address this, a number of online quizzes were developed that were due in the first few days and required students to log into the online system to complete.

Maier also discussed learning materials including a student handbook, which allowed students to increase their ease of use of the tool and "facilitated development of a better understanding of what was required, particularly during the early stages of the eSim." Also, on the advice of previous students, multimedia content was incorporated such as video recordings of news events.

As with any educational intervention, both formal and informal assessment is suggested. Through this approach the practitioners were able to verify the impact of their e-learning tools. For example, when Coller implemented the video game-based Dynamic Systems & Control course, he observed students using the tool, but the outcomes, such as low performing scores on exams, were still an issue. As he explained:

> When I offered the video game-based Dynamic Systems & Control course for the first time, I recall that students were not performing well on exams. They were meeting the challenges within the game. However, they were not meeting the learning objectives of the course (on average). When I looked more closely, I discovered that students were investing a lot of time and effort in the game. However, they were not playing the game as I had intended. In order to pass challenges within the game many of the students tried to solve the problems through some kind of intelligent trial and error rather than by learning and applying the theory. These students would take the cognitively easy route even if it meant spending more time, overall, on homework assignments.

Once the problem was identified he moved forward to remedy the situation:

> By trial and error on my own part, I found that certain types of homework problems seemed to work better. Rather than have students meet quantitative criteria, it seemed to me that students seemed more engaged in a quality learning experience when there were qualitative goals (e.g. figure out how to write an algorithm to balance a bike).

Both Lindsay and Coller reported that they had improved the implementation of their e-learning tools for student engagement by becoming more involved personally with the students during the process. Lindsay states: "The main thing I have done differently is to hybridize the learning experience. While students may operate the equipment remotely, it is still helpful to orient them to the equipment in a face-to-face fashion, so that they know that it is real, and it exists." While Coller discussed a more ongoing approach for his tool:

> In 2009, I taught the game-based Dynamic Systems & Control course a second time. This time, I had more qualitative, tinkering-based challenges within the game…but I had students meet in small groups and with me to discuss the assignment. In these meetings, I pressed students to think deeply about the assignment….I would provide a partial list of questions that I would ask during our session. These questions were usually fairly deep and required considerable thought. I made them go back and find answers to new questions. In addition to the game, I constructed a meta-game consisting of social interactions to question, explain, and write about what is going on in the game.

One interesting commonality between the three lessons learned is that all these practitioners have been engaged in improving student engagement by refining the design of e-learning activities over time.

Is e-Learning Engagement Different to Student Engagement in other Modes of Learning?

As a way for us to better understand what student engagement can and does look like in e-learning environments, practitioners reflected on whether e-learning engagement is different to student engagement in other modes of learning. Banky's reflection brings to light an important point that brings us back to learning in a more general paradigm. He discussed the point that all activities, regardless of mode, need to be integrated and integral to the coursework. Similarly, Maier discussed how "student engagement in e-learning is similar to that in other modes of learning. I think the key is to motivate students by providing relevant context. If students can see that the learning activity is relevant to their development as an engineer, they are much more likely to be engaged." Lindsay, in his reflections, described his perception that "the technology is just a mechanism for the students to engage; it won't actually do the engagement for them." All the practitioners see context, relevance and modes as essential to student engagement regardless of the environment. However, most of the practitioners also pointed to what they consider obvious advantages of engaging students with e-learning tools. As Lindsay continued:

> Engagement in e-learning is inherently different to different modes because it incorporates technology-mediated interfaces. The students' experience is made up of the elements that the interface provides; in effect it acts as a filter upon their learning. Good interfaces will not filter out important elements, and indeed may instead act as amplifiers to improve student learning. But they are an additional element that the non-mediated experience does not have. Just as students behave differently when watching live concerts than they do listening to their iPods, they bring inherently different paradigms to the e-learning environment.

Jaksa discussed the advantages he sees for engaging students with e-learning tools:

> With regard to geotechnical engineering, e-learning has a great advantage over learning derived from experiments. Computer simulations can provide the solutions to many separate tests in a matter of seconds, as opposed to results from experiments that may take several days or weeks to produce. Hence, deeper learning can result from e-learning as one can examine deeper relationships between various parameters.

Similarly, Maier reflected on the strength of learning that gives students the ability and freedom to explore content through the use of e-learning tools, especially independent of time and location, which also allow for a more universal engagement, a point Lindsay also referred to on several occasions.

Advice from the Practitioners

The practitioners also reflected on what advice they would provide to other instructors and educators considering the need for, use of, and implementation or design of e-learning tools for their courses. Practitioners' reflective advice covered the sub-themes of the intention of the educational intervention, appropriately designing the e-learning tool, allowing sufficient time for implementation, and ensuring that pedagogy drives the technology.

Coller and Lindsay advised that the first step would be to consider the reasoning behind considering such an educational intervention. For example, as Lindsay explained in terms of the remote laboratories as the educational intervention or tool:

> I always begin with the question "what do you want the students to learn?" One of the biggest pitfalls in developing remote laboratories is that people try to take an existing face-to-face laboratory and make an online version. It is an understandable approach, but it is an approach that takes with it all the assumptions and baggage that were built in to account for how students engage with the equipment in the face-to-face mode. There is no real reason to take this more-constrained design into a space where you actually have more flexibility in ways that students can engage. A laboratory is just a pathway to learning outcomes; there is no reason why the remote laboratory needs to be just the best facsimile of the face-to-face pathway.

Coller, going back to the lesson he has learned through the use of his e-learning tool, expressed the need to be able to identify the purposes of the various parts and activities related to the tool: "What aspect of the intervention is responsible for the learning gains? Is it the game, or is it the active social structure [collaborative activities] built around the game? In my opinion, it is the combination of the two that makes it work."

Jaksa's advice reminds us to consider the importance of tool design. As he explained:

> The look and feel of [e-learning tool] resources is essential. Today's students are more engaged with e-learning tools that look modern and realistic. In relation to simulating laboratory experiments, the more they look like the real laboratory apparatus and soil looks and behaves like real soil, the more engaging the e-learning tool will be. Navigation

of the tool also needs to be self-intuitive so that students put more effort into learning the material rather than learning how to use the program.

Maier's advice stems from his experiences, but his perspective is one that every member of the research team also shared. He counseled those interested in developing such tools to take the time necessary to build an effective and efficient tool that will in fact be engaging, "Focus on the core activities in the first year, with a plan of adding "extra" features, such as multimedia content, in subsequent years. If the task seems too big at the beginning, you will never get started. Also, it is vitally important to seek student feedback and to use this to improve the eSim in subsequent years."

And a final note from Coller is one that the research team as a whole embraces—that thoughtful pedagogy, rather than technology, is the appropriate driver for introducing e-learning tools. His cautionary words remind us that it is how technology is used that engages students both behaviorally and cognitively: "I think it's critical that the new instructor NOT think of the [tool] as a self-contained silver bullet. The instructor must be willing to build up the meta-game [tool and activities]. Obviously, one would need very dedicated instructors....this can be viewed as a barrier to adoption...[or] it can be viewed as a beneficial feature."

DISCUSSION

The purpose of this research was to share successful examples of e-learning tools in an effort to increase student engagement. By reviewing the lessons learned by expert practitioners, faculty considering similar activities will have a better understanding of design issues, the need for continual evaluation, and the nature of student engagement with e-learning. Moreover, student engagement has been highlighted as an important feature, as students who are more engaged in educationally purposeful activities demonstrate greater gains in such areas as critical thinking, problem solving, and effective communication [3, 5].

In the literature on student engagement one term continues to appear: "educationally purposeful". The results presented in this paper show that it is insufficient to design an educational activity and hope it will be effective. The practitioners' reflections shared that the intent, and not only in the design but also in the evaluation and redesign, of such activities was what drove the successful implementation of these particular activities.

It is significant to note that while the original focus of the research was on e-learning, all of the successful scenarios in fact represent blended learning environments. Staey & Gerbic [42] discuss how successful blended learning environments (combined virtual and physical environments) should be based on an understanding of the strengths and weaknesses of each environment as well as the appropriateness of choice to the learners involved. None of the scenarios presented in this paper represent stand-alone activities. Each has been designed to be embedded within the broader curriculum, and was implemented only after careful consideration of how to engage students to think more deeply about the content. The practitioners chose these methods to engage their students in a way that was not currently available or feasible in traditional face-to-face experiences.

An emerging theme from the results shows us that effective learning design, assisted by the affordances of e-learning, can foster authentic learning which in turn increases student engagement by enhancing academic challenge. The practitioners repeatedly discussed the importance of authenticity as a means to relate to students "real world" environments, which increased engagement through motivation. Authentic learning is not just a means of providing relevant examples; the research and our reflections tell us that there is a need for authentic contexts to be "all-embracing, to provide the purpose and the motivation for learning" [43]. Authentic learning designs provide authentic contexts that "reflect the way knowledge will be used in real-life, provide authentic tasks, support collaborative construction of knowledge, and provide coaching and scaffolding" [ibid.]. Correspondingly, this approach "may require more effort than standard academic instructional methods such as lectures and discussions" [ibid.].

Another emerging theme reported in the results was accessibility. All of the practitioners felt that accessibility was increased as a result of implementing the e-learning tools. Generally accessibility refers to a particular population or context, however as discussed here it is much broader. By implementing e-learning tools students were able not only to engage with the materials at their convenience, but each individual was able to "drive" the experience as they did so. Moreover, students were able to engage beyond the materials and work with peers, some from differing geographical regions, and others with peers not so far away in distance but a world away in terms of disciplinary backgrounds.

However, the experts also reflected on the downside of the cost of providing accessible tools in some cases. Good e-learning still needs to be good technology; without a reliable implementation it will be ineffective. As with the integration of any technology or educational intervention, unforeseen problems can occur, and some problems were intervention-driven while others were student-driven. Hopefully the findings here can serve as guidance for others during the planning process.

This study has introduced a framework for examining student engagement and applied a method not commonly seen in Engineering Education, namely practitioner reflection. Specifically the framework for examining student engagement in e-learning includes:

- Positive and negative influences on student engagement in e-learning
- Planning to support student engagement in e-learning
- Professional learning (by faculty members) regarding engagement in e-learning
- Characteristics of student engagement in e-learning

While this framework has been used for student engagement in e-learning, it could be applied to student engagement in additional areas.

In addition, this study uses the method of practitioner reflection. We cannot claim to be the first research team to use first-person practitioner reflections in the higher education literature; however, this method is most commonly used by single researchers or small research teams [44, 45]. Our approach to first-person practitioner reflections, where five practitioners pool their reflections and are also attributed co-authors, represents a novel approach in Engineering Education.

CONCLUSION

Engineering Education practitioners are using e-learning to shape the ways in which their students engage with the learning process. The practitioner reflections presented here show that practitioners' experiences were in some cases more successful than they had intended with students' engagement evolving in ways other than was originally proposed. With proper design and support, e-learning can be a successful learning tool; however, its consequent impact on the nature of student engagement cannot be disregarded.

The practitioners in this study had used e-learning as a way of promoting both learning and engagement in their classrooms, and while the contexts in which they work were varied, there were some emergent similarities in their experiences. It was clear from their reflections that they saw e-learning as a means to increase student engagement. The practitioners further reported the need to scaffold the introduction of e-learning in their courses through proper course design, revisions of assessment, and supplementary materials to support the e-learning activity.

The scenarios presented by the practitioners showed that e-learning was being used to engage students differently. Different tasks and challenges were explored, with e-learning providing learning opportunities that would have been otherwise impossible. With a deliberate choice to explore different learning goals, several practitioners observed that student engagement appears different in e-learning; however, not all of these differences were predicted consequences of the learning design.

The practitioners reported that e-learning allowed them to increase students' intellectual experimentation, to provide deepened authenticity and to improve accessibility to their learning materials. For the most part, these were in keeping with their planned objectives; however, each of these aspects of e-learning also provided unintended consequences. E-learning allowed (or perhaps even encouraged) students to experiment in ways that would be considered malicious if done in a physical classroom; the increased authenticity of some simulations can distract students from the purpose of learning; and the assumption of accessibility can cause resentment when access fails.

Future directions for research are suggested by both the research method and the framework for examining student engagement. The research method of practitioner reflection could be used to address additional research questions with a focus on practitioners. It would be particularly interesting to apply to the method in practitioner teams—such as teaching teams, or design teams. The framework for examining student engagement in e-learning also suggests directions for future study. There is scope to extend this framework—for example by add additional measures of student engagement, such as the measures in the National Survey of Student Engagement [7]. The study could be replicated with existing framework and method applied in engineering education institutions in cultural settings other than Australia and the United States. The study could be supplemented by additional methods of data collection for triangulation. In particular, the research team is interested in a parallel study that would also collect student reflections on engagement with e-learning.

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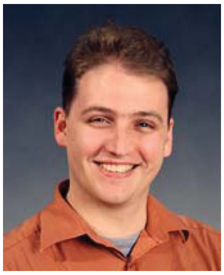

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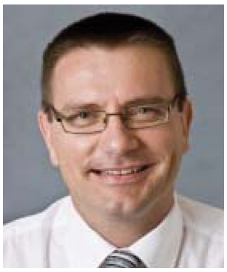

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