Re-conceiving "Intelligence" in Learning Management Systems: Tuning Learning to Theory

Lynette SCHAVERIEN
Faculty of Education, University of Technology, Sydney,
PO Box 222, Lindfield, NSW 2070 Australia

Abstract. In recent years, educational developers have begun to focus on the design of Learning Management Systems, in an effort to support e-learning in many different disciplines, contexts and fields of practice. These general-purpose systems have sought to enable a range of learner interactions with textual and audio-visual material - through reading, listening and viewing, pursuing a variety of set tasks and participating in discussions (synchronous and asynchronous). As well, developers have addressed the challenge of providing so-called "intelligent" support of such activities and of supplying information to educators about learners' progression through them. However, though such Learning Management Systems sometimes provide interesting learning opportunities, they are rarely underpinned by a powerful, explanatorily coherent theory of learning. Consequently, whilst learners are routinely channelled through a range of e-learning activities, much significant learning is more likely to occur by chance than by design.
I assert, in this paper, that a powerful new learning theory is now available, drawing on recent insights into neuroscience, evolutionary epistemology and self-organising, dynamic systems. From our preliminary research testing, this learning theory appears particularly helpful, not only in making sense of the learning that occurs in e-learning systems, but also in the challenging task of supplying design parameters for the development of such systems. I describe, in operation and evolution here, two examples of Learning Management Systems, designed in response to two different educational scenarios and for two different sets of learning purposes; and I argue that each presents a case in point of how "intelligent" Learning Management Systems might be reconceived: as systems designed so as to be "educationally intelligent" - soundly based on a viable theory of learning.

Introduction

A plethora of so-called models and theories has characterised the discipline of education in recent decades. At some times and in some places, behaviourism has held sway, at other times, cognitive science. Of late, there has been broad acceptance that learning is active rather than passive, constructive rather than transmissive. However, despite this intellectual sea change and the spur it has received from the use of brain imaging technologies, no further particular conceptual enlightenment has occurred for educators, who continue to work at arguably the most challenging but least understood frontier – that is, until the work of Edelman [1], [2] and Plotkin [3], [4], [5].

1. A (Biologically Based) Generative Theory of Learning: Making Sense of e-Learning and of e-Learning Design

Conceiving the task of explaining the mind as the completion of Darwin's program, Edelman argued that knowledge gaining is an adaptation in its own right, hedging the chances of our species' survival. So, genetic inheritance occurs through random genetic variation, followed by selection of successful variants, on their value. Similarly, on this view, learning can be explained as a selectionist process, too – occurring by generating ideas, testing them on their value and keeping those that survive the tests. In fact, cultures gain knowledge in this way as well – by conjecture and refutation, as Popper (1968) was quick to recognise [6]. So, in effect, as Plotkin described, the generate-test-regenerate heuristic is apparent at three nested levels: the genetic level, within organisms (in brains and immune systems) and in cultures, constituting a powerful, unifying explanation of learning.

We have already written extensively [7] on the three central characteristics of this theory of learning:

- that it is driven by learners' values,
- that it is antithetical to transmission, proceeding as it does by learners' generating and testing of ideas on their value, and
- that idiosyncratic and epigenetic developmental pathways are to be expected, given individual learners' and learning communities' distinctive lineages and lives.

As well, we have laid out implications, for technology-and-science education, of adopting this generative theory [8]; and we have begun to anticipate the worth of this generative learning theory as a basis for e-learning design: first, with respect to a particular e-learning system for teacher education [9] and then, more generally, across a family of e-learning systems designed to assist learners with fundamental discipline concepts challenging to learn and teach [10]. Most recently, we have described the operation of these and other e-learning systems with a range of learners and learning communities, as (successful) tests of this biologically based generative learning theory itself [11], [12]. Now, in this paper, I use this research as a foundation for developing an alternative way of thinking about what it means to build "intelligent" Learning Management Systems – Learning Management Systems that are explicitly in tune with (this) explanatorily powerful learning theory.

2. Two Learning Management Systems: Designing for Generative Learning

In recent years, in our e-learning research and development group, we have confronted several scenarios that have necessitated building e-learning environments to respond to significant educational challenges. I describe two contrasting scenarios here and the e-learning systems we designed to address each.

The first educational challenge was the long-acknowledged difficulty of inspiring confidence and competence in large numbers of K-6 science and technology teachers. Certainly, resource-intensive, often one-to-one, classroom-based and mentor-supported approaches proved successful [13]. However, these strategies could not easily be scaled up, suggesting that subtle, innovative teaching approaches based on sophisticated, new views of learning might well elude significant numbers of teachers. A web-delivered, e-learning system, The Generative Virtual Classroom, was conceived to respond to this challenge, prototyped and research-tested. As a boutique e-learning environment, it was designed principally for initial teacher education (though it can be used by experienced teachers, parents and others), to assist learners to identify, clarify, deepen and extend their views of

learning. For prospective teachers, such intellectual work is crucial in order to form a basis for their professional practice.

The second educational challenge, by contrast, was a relatively recent one, but no less daunting for its newness: to develop an e-learning system in which professionals from corporate, community and education sectors could grow, in authentic ways, those fundamental but emergent ideas they would need to contribute strongly to e-learning research and development within their organizations. A suite of postgraduate courses (a Master of Arts/Science in e-Learning, a Graduate Diploma and a Graduate Certificate in e-Learning) was developed, based in the Education Faculty and taught collaboratively with the Institute for Interactive Media and Learning, and its first cohorts of students were accepted in 2001. These courses were delivered wholly by way of a customised Blackboard platform, with two supporting face-to-face weekend workshop days per subject per semester.

Both Learning Management Systems were designed on a model of learning directly derived from the biologically based generative theory of learning already described. Broadly speaking, the generate-test-regenerate heuristic that underpins that theory can be expressed as six acts of natural learning: exploring, designing, making, operating, explaining and understanding [8]. Though boundaries between the g, t and r elements of this heuristic are somewhat blurred, in essence,

- exploring and designing are generative of ideas,
- designing, making and operating constitute tests of those ideas on their value for learners, and
- explaining and understanding represent ways of regenerating surviving ideas for the next testing cycle.

In our design of the two Learning Management Systems described here, we attempted to hedge the likelihood that learners would engage in these six acts of natural learning, considered a basis of generatively principled e-learning design [10].

Learners in the Generative Virtual Classroom (GVC) found themselves located in a pair of nested virtual classrooms for teacher education in technology-and-science: an elementary and a tertiary one. They could choose to view and review exemplary learning and teaching events at their leisure, as if they were witnesses to these events in a virtual elementary classroom. Supported by a browser-based platform, they could make general observations about these events, share their views about events with others in the virtual tertiary classroom through a threaded e-mail discussion group and record ideas, in a searchable community database, about particular, salient aspects of these children's learning. In their visits to the GVC, learners could use this database both as a source of ideas about learning and to track their own development of ideas over time. As well, whenever they chose to do so, they could access pre-recorded narrative commentaries in which learning events are interpreted according to a generative view of learning. Students were encouraged to entertain these commentaries as another plausible view, examining the criteria on which they agreed or disagreed with this perspective; and they could access related materials on the World Wide Web.

Students in our postgraduate e-learning courses began by completing a series of four core e-learning subjects: e-Learning Experiences, Models and Theories 1 (EMT1) and 2 (EMT2), e-Learning Technologies and e-Learning Design. Typically, as part-time students, they enrolled in the first pair of subjects during their first semester, and the second in their subsequent semester. I illustrate the character of the e-learning system in which they found themselves by describing in brief the first pair of subjects here, as students experienced them during the first offering of these subjects. In EMT1, students grouped themselves, as far as was possible, according to their e-learning interests. Each group was required to immerse itself in one e-learning environment, gaining deep insights into it as e-learners and

discussing with each other the perspectives they gained. They were asked to prepare a joint report of their conclusions for presentation to the class group at the second weekend block day. EMT2 students also grouped themselves on the basis of their interests in particular e-learning environments, but in this subject, they were asked to compare and contrast two e-learning environments so as to identify the learning theories underpinning these environments, referring where necessary to descriptions of key learning models and theories. The work of these small groups was supported by teaching academics, assigned as mentors, and by general and specific whole-class conversations online. In addition, students were required to document their own formation of a personal model/theory of learning over the course of their study, in the form of a chronicle for assessment. Their chronicles included shifts they noticed in their views of learning and e-learning, connections with workplace issues or professional or personal interests, and conversations with nominated critical friends (generally, but not always, in their workplaces). Students were asked to collaborate to compile a short annotated list of interesting e-learning sites and sources so as to contextualise their work in these subjects, and prepare for development work later in the course.

So, both Learning Management Systems were designed broadly to support learners' generation and testing of ideas – through hedging the likelihood that they would explore, design, make, operate, explain and understand - in a variety of ways.

3. Supporting Generative Learning

Once these designs became operational with e-learners and e-learning communities, it was clear that they were effective in supporting generative learning in both Learning Management Systems. I now describe, in brief, the evidence on which this conclusion is based.

3.1 The Generative Virtual Classroom (GVC)

In addition to formative trials of components of the Generative Virtual Classroom, the development of its first browser-based version proceeded in parallel with three research studies. In all three studies, naturalistic case study methods were used to research learning. Such approaches drew on learners' contributions to this environment over time (in the GVC's accumulating community database and e-mails to other students), diaries or other student records (including teaching-related plans and resources where appropriate), conversations between students and the researcher at salient points and observations of students' teaching where possible. These modes of inquiry tracked the evolution of students' ideas about learning (if it occurred), detailing how such evolution might occur and the diversity that is possible in development.

First, an experienced early educator (Swati) became a participating member of the GVC development team, and chronicled her ideas about learning as development proceeded [14]. She tracked the development of her views of learning from a noticeable tentativeness (evident, to her, in her desire to align what she saw of learning with others' descriptions or categorisations of it) to an increasing ability to describe learning for herself, in her own terms, and to recognise it when it occurred. She began to make sense of the children's learning in those digitised video excerpts that would form the core of the Generative Virtual Classroom; and she drew on what she saw of the learning of other members of the project team. Interestingly, Swati notes that she was slowest to focus on and identify the characteristics of her own learning within the project team. However,

when this occurred, she felt she had evolved a fully integrated and educationally powerful view of learning, one that supplied her with words to describe learning and criteria by which to recognise it. The events in her account appeared to be consistent with and well explained by the particular (generative) theory of learning being designed in to this learning environment.

Once a robust enough Version 2 of the Generative Virtual Classroom was available, a second study subjected it to sustained investigation. A teacher education (Honours) student (Megan) undertook an eight-month case study of what happened to her views of learning as she worked there [15]. In documenting the development of her thinking, Megan discerned three phases. The first phase (of just over two months' duration) was spent in detailed but comparatively superficial and tentative exploration of the video excerpts. While she made detailed journal records, Megan did not feel confident enough to enter any of her views in the community database. Nor did she feel that she could make any sense of the commentaries provided about these learning events. However, this initial phase provoked in her an urgent desire to pursue her curiosity about learning. This she did in a second phase (of four months' duration). This second phase was marked by a period of six weeks in which she did not visit the GVC at all. Instead, Megan pursued her own ideas about learning, thinking and brain function, away from it. She noticeably gained in confidence in recording her thoughts and feelings, drawing on her everyday life experiences to test her ideas. By the end of this second phase, Megan felt drawn to return to the GVC in a final phase (of just over one month's duration). Her account of her thinking during this third phase provides evidence that she had formed a deeper, subtler appreciation of the learning events depicted in the GVC and that she was able to articulate her thinking about them more clearly than in the initial period of her study. She appeared to be able to bring to bear her own insights (from the second phase of her study) so as to make more profound sense of the children's learning. Furthermore, choosing to analyse her own learning under the very same headings she had used to explore the children's learning in the GVC's community database, Megan demonstrated that she recognised certain similarities between the children's and her own learning there. Summarising detailed evidence, Megan claimed the GVC had allowed her to describe learning accurately and boldly. Now able to move her thoughts about learning around, in words, she could identify significant changes in her knowledge state over the course of her investigation, just as Swati could. In particular, she could discern the limits of her understanding of learning. In precisely the same terms in which one of the children in the primary virtual classroom had crystallised his knowledge and his ignorance of electricity[1], Megan concluded,

> Whilst by the end of my study I could describe and identify learning when it occurred, there were still things I wanted to know about it. Recognising that I am still unsure of what happens inside the brain when a person learns, a more critical question for me now would be, 'What is learning in itself?'([15] p. 109)

Megan's most enduring idea was the development of an urgent and, in some ways, even childlike fascination with the very basis of teaching: learning. Ironically, this fascination, though central to the professional practice of teaching, had not been provoked before in her four-year teacher education degree.

These two early research investigations prepared the ground for a third study in which teacher education students on practicum became learners in the web-delivered GVC over an intensive three-week period. Their developing views of learning were tracked through their contributions to the GVC and through connections they made with it in their day-to-day practice teaching. Essentially, this third study investigated teacher education students'

[1] At the end of the research study of technology-and-science learning in which we collected the video excerpts used in the GVC, Daniel confided to us that though he knew what electricity did, he did not feel he understood what it was in itself.

learning to teach in a complex, hybrid e-learning environment in schools during a scheduled teaching practicum. The findings of this case study affirm the effectiveness of the GVC's design for developing these students' understanding of learning [12].

3.2 The Postgraduate e-Learning Courses

Over their semester of study, students in these postgraduate e-learning courses engineered diverse modes of working within their groups. They recorded the results of such work in their presentations, their chronicles and their evaluations of each subject, providing rich research evidence for a range of learning outcomes. I begin by making some general observations before turning to consider a specific case.

From the outset, contributions to whole-class online discussion forums were prolific and generally of significant length and conceptual depth. General class discussions covered a broad range of concerns in both EMT1 and EMT2. Students differed in their responses (both positive and negative) to learning and teaching events, affirming that the course appeared to privilege and to nurture diversity, even though it was not a uniformly comfortable learning experience for all. We were able to make the following observations (of many):

- When they contributed, most students used general class discussions freely and generously to recommend sources, to refer to others' views and to make comments that would amplify and test others' ideas, creating a conversational flavour to these online exchanges from the outset.
- There was a significant and sustained emphasis on the discussion of learning theories. Most students appeared to perceive the fundamental importance of learning theory in providing a basis for design and a way of thinking about e-learning environments in operation. Many students began to make critical connections between these two, implying that consistency or integrity might be important discriminators when judging an e-learning environment of worth for learning. Many students acknowledged that their theories of learning were shifting; and in their writings, they attributed such shifts to aspects of the design of the e-learning courses.
- There was a range of feelings about online community work. Many students (including some of the most conscientious and incisive) expressed a real apprehension about contributing online. They described the process as nerve-wracking, requiring great courage and ability to subdue feelings of low self-worth or ability, fear that their views might be ridiculed or that they might regret having expressed a particular view at some later date. (In fact, the community appeared to be generally supportive. There were few, if any instances, which we detected, of gratuitous, destructive criticism.)
- Several strong friendships were formed, students utilising informal discussion forums (both synchronous and asynchronous) to enjoy each other's company – often late at night over a glass of red wine. Face-to-face workshops suggested it had become an easy community in many ways. Students shared a set of in-jokes (for example, particular lecturers' and students' styles or patterns of response), and knew each other's names, faces, interests and backgrounds (despite having interacted largely online).
- Many students expressed, explicitly, the view that the course had provided them with one of the most powerful learning experiences of their lives, even though many admitted that it had had high levels of challenge for them. Significantly, many students noted that facets of their developing views of learning appeared to

be emerging by deep thinking about how they were learning in this course; and many attributed the course's potency to the influence of community.

Against this background, the work of a particular small group of students during their EMT2 "compare and contrast" assignment is of interest. This group chose to consider the Generative Virtual Classroom and a well-known, general-purpose, commercial learning management system. They decided to organise and conduct almost all their work for collaborative presentation of their report online (apart from one face-to-face meeting prior to the second weekend block presentation). Significantly, individuals in this group admitted to having refined a much clearer position on learning that they could use with discernment in considering diverse e-learning environments. As well, these students used their view of learning to make explicit the function of particular parts of their work over the semester in their presentation to the class community. For example, they had begun to refine for themselves a generative theory of learning, conceiving of learning as iterative cycles of generating ideas and testing them on value, keeping those that survive their tests. Furthermore, they could use it to distinguish between the "generate" and the "test" phases of their work. They explained to the class that they used different technological tools for these different purposes: virtual chat at a planned time each week to generate ideas, and asynchronous online discussion to test them, periodically weaving those of the group's contributions that were relevant to the particular, critical task at hand.

At the end of the semester, some of these students acknowledged the power of their learning experience and expressed interest in reporting their work in the form of a journal publication. Having initially suggested such a course of action, I offered some guidance, advising them to collate all electronic records of their work over the semester to review as a first step. Four of the students met for a virtual chat each week throughout the semester break in order to try to make some sense of their experience and to distil its critical incidents. Over a number of such chats, they assembled evidence by which they might gauge their learning outcomes. Such evidence charted, amongst other things, group members' developing powers of educational critique and growing appreciation of the roles of community.

Subsequently, three of these students used the Semester 2 core e-learning subjects, e-Learning Technology and e-Learning Design, explicitly as vehicles by which to refine their ideas about generative learning even further, sensing the power of this particular theory for e-learning application. They maintained their interest in publishing some of their work and pursued that goal through mentored individual study projects and in their capstone e-Learning Research and Development Project for credit towards their Masters degree. One result of their work, a fully refereed paper [10], was presented at the Australasian Society for Computers in Learning in Tertiary Education, making an original contribution to research in e-learning design; and another publication detailing their use of this approach in a corporate training context is currently in preparation.

4. Towards Intelligent Learning Management Systems

This close scrutiny of the learning that occurs in these e-learning environments reveals that these are contexts in which it is no longer possible to anticipate a finite set of learner thoughts, ideas or behaviours. Even if it were, it would then be challenging to gauge, in isolation from the future trajectory of learners' thinking or behaviour, the worth of such a step. Very often, in corporate, community and education sectors, we are educating so as to hedge highly imaginative, but still obviously rigorous and life-enhancing learning outcomes. Furthermore, we are doing so in emergent and poorly defined knowledge domains.

In such circumstances, it can lack integrity to try to inculcate what we might consider, a priori, to be an acceptable set of taught responses. In any case, learners appear to sense this lack of integrity, for tuning learner behaviours narrowly in situ, by what has been called "intelligent" tutoring, is often unsuccessful.

However, all is not lost. Once we have a theory we can use to set design parameters for Learning Management Systems and by which we can recognise learning when it occurs, we have the wherewithal to operationalise a new view of "intelligent" Learning Management Systems. A Learning Management System can be considered "intelligent" if it hedges the chances that learning will occur – here, that learners will explore, design, make, operate, explain and understand; that they will generate ideas, test them on their value and keep the ones that survive their tests.

How then might we tune Learning Management Systems so that they become more intelligent? Such improvement can only occur by examining the learning that occurs in operating these systems and making alterations in subsequent generation systems, to try to increase the likelihood that the next cohorts of learners will engage with learning behaviours that prior ones avoided. In both the Generative Virtual Classroom and the postgraduate e-learning courses, extensive scrutiny has been undertaken of the learning that has occurred, in terms of the behaviours that constitute (generative) learning, and adjustments have been made.

Version 4 of the Generative Virtual Classroom (2003) removes the option of a personal on-screen notepad for general thoughts and observations, incorporating it into the searchable community database, to try to provoke even more sustained and comprehensive use of this database to mediate learning in the community. We assumed that if learners wished to make private jottings, these could be made offline. Furthermore, learners indicated an urgent desire for more sustained offline access to video excerpts to support and deepen their thinking. In response, an offline option is being incorporated with access to video and audio excerpts but not to the community database. Data from the research studies described here also indicated that whilst this Learning Management System was clearly effective in provoking most learners to draw connections between their own learning and the learning of the students in the virtual primary classroom, some learners did not make strong sense of the characteristic features of a generative view of learning. On-screen help is being incorporated to hedge the likelihood that learners will give deeper consideration to ideas related to generating and testing on value in this environment – the students', their community's and their own.

After careful examination of the work of the 2001 and 2002 cohorts of EMT2 in the postgraduate e-learning courses, I have reconfigured the 2003 EMT2 subject so as to try to make it even more likely that students will engage in broad-ranging, theoretically rich conversations (in whole class and small groups online) about a small set of e-learning environments for immersion, comparison and contrast. Certainly, learners considered the 2001 and 2002 offerings educationally powerful, in particular, for their fluid and evocative use of e-learning media to teach about e-learning. However, the work of the small group described here, after the taught subject had concluded, convinced me that if learners' own experiences were to become the wherewithal for learners' development of new views of learning, it was crucial to build opportunities, within the subject itself, for them to gather evidence, more easily and more tangibly, of the progression of their ideas over time. This led me to re-conceive the subject as two concurrent and related educational strands. In the first strand, learners immerse themselves in diverse e-learning environments, culminating in the GVC. In the second strand, learners read a series of suggested references so as to familiarise themselves with educational models and theories in historical order, from behaviourist to cognitive sciences and thence to biologically based generative ideas. These readings are designed to provoke them to identify characteristics of these different views of

learning in the e-learning environments with which they are engaging. As well, they are designed to lead them, in small interest groups, to regenerate one of the e-learning environments they studied early in the subject, in tune with the ways they now conceive of learning. At the time of writing, 12 weeks into semester, it is clear from students' learning journals and from small group presentations of these regenerated e-learning environments, that most students admit to significant shifts in their ways of thinking about learning and can cite specific evidence of how and when this happened for them in their semester's learning journey. Concurrently with this redesign, teaching academics have also redesigned EMT1. Students note helpful overlap between the two subjects and this overlap has been the source of some interesting online conversations. So, this preliminary analysis of the current cohort's learning suggests that these subjects' reconfiguration has been successful.

In both these Learning Management Systems, learners are being provided with rich and varied opportunities to generate ideas, test them on their value and keep those that survive their value tests. In the GVC, for example, a learner can test ideas about classroom events s/he observes by comparing and contrasting what s/he thinks with what others in the community believe, as entered in the community database – or by listening to and thinking about the pre-recorded generative view. In EMT2, for example, having expressed a view of learning by working in an e-learning environment early in the subject, a learner can directly compare that view with her/his views expressed later in the subject, whilst regenerating the e-learning environment with class colleagues. In both these cases (and in many others), learners will have generated a model or theory and are now testing it. This might well constitute regeneration in its own right: the model or theory might already have been modified in an earlier testing cycle. Alternatively, this testing might lead to further modification and thence to further testing cycles. Whatever the case, such activity is easily and powerfully characterised in terms of the six acts of natural learning. One such description would see it as operationalising a view (particularly if it leads to careful comparison of the relative merits of different views) and driving towards explanatory coherence and eventual understanding. Clearly, both Learning Management Systems appear to hedge the likelihood that (biologically based generative) learning will occur, rendering them "intelligent" in this author's view.

What, then, must be done to reconceive intelligent Learning Management Systems as those with a high measure of consistency with a powerful learning model/theory and what implications might such a reconception have? Of course, a learning model/theory with explanatory coherence for education first needs to be chosen. Educational research has failed to yield a powerful and coherent explanatory 'theory' of learning, spawning instead a variety of 'approaches' [16]; and the absence of such a theory threatens to obstruct progress in education generally, as well as in e-learning. On the evidence currently available, we have argued in detail (for example, [8] and [9]) that a generative view is the strongest choice for education, and that such a view positions our discipline centrally in a growing community of interdisciplinary scholars. Furthermore, a generative view of learning has supplied us with a sound starting point for the crucial and challenging work, now required and which we have already begun in our e-learning research and development group, of identifying what constitutes learning in particular knowledge domains. Such work will pioneer ways of thinking about learning different topics and disciplines in terms of the key ideas that learners might fruitfully explore, what they might design, make and operate on that basis (not only tangible models they might construct, but theories or thought experiments they might propose and test), what varied explanations they might speculatively raise or understandings they might seek to gain. At this point, we can only glimpse the implications that such a reconception might have. However, it holds out the promise of taking us past simplistic, behaviourist notions of learning as mastery of inert bodies of knowledge and offering an alternative for learners to slavishly tracking

instructionist practices. Early European builders of cathedrals enabled the development of an engineering science. Brain imaging techniques spawned the neurosciences. It is not too grand a hope that the development of intelligent Learning Management Systems, tuned to enhance learning, will deliver a science of learning.

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Associate Professor Lynette Schaverien (Lynette.Schaverien@uts.edu.au) teaches in the Faculty of Education at the University of Technology, Sydney. She currently leads two sizeable Australian Research Council Linkage Projects in e-learning research and development: GENESIS (Generating e-learning systems in schools) in collaboration with Professor Shirley Alexander and three school partners, and DESCANT (Science and Technology) (Developing e-learning systems to celebrate and nurture teaching) in collaboration with the NSW DET. She is Program Director of the postgraduate e-learning program and an active member of the UTS e-Learning Research Group.