ascilite 2011
CHANGING DEMANDS, changing directions.
Wrest Point | Hobart Tasmania Australia | 4–7 December 2011

Mix and match : m/e-learning and engineering curriculum

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This paper describes how and why various technologies – mobile devices and web services combined with tools available in online learning management systems – are being used to support individual, team and situated learning in one university's engineering programs. The tools include mobile devices for peer marking, online peer review and marking tools, online tools to support team formation and collaboration and online tools for individual learning. Games and simulations are also being introduced. All of these are helping to develop the curricula in ways that enhance graduate attributes such as design problem solving, critical thinking, teamwork and communication skills, and in some cases they are also saving staff time. By mapping and analysing in technology use in relation to different theoretical perspectives on learning, we are able to suggest what might be the next steps in an integrated action research approach to developing the use of learning technologies.

Keywords:e-learning; m-learning; engineering education; team learning; situated learning; distributed cognition.

The undergraduate engineering context

The context for this study is the Faculty of Engineering Faculty of the University of New South Wales (UNSW) in Sydney, the largest Engineering Faculty in Australia with around 9000 students. Many classes have several hundred students. Most of the teaching academics are required to prioritise research output, and at the same time respond to demands from accreditation bodies and industry for a curriculum that develops communication and teamwork skills, critical thinking skills and engineering design problem solving skills.

Internationally, there are moves to include more design project work in undergraduate engineering curricula (Campbell et al., 2009). This is a continuing challenge in a discipline that also requires students to have a thorough grounding in basic concepts (Goldsmith, Reidsema, Campbell, Hadgraft, & Levy, 2009). The Australian Learning & Teaching Council has been funding a number of national projects that address one or both of these. In this context, curriculum development initiatives reflect the same tensions between theory and practice, and the need to balance individual learning with team project work. There are two aspects of this tension – the student learning experience and the teacher workload. Our efforts have been aiming to improve the former without increasing the latter.

The paper is an account of our experience of using and developing a range of technologies to solve particular educational challenges, as presented to us by the teachers we work with. We map the educational needs against the tools that are proving useful in addressing these needs – as suggested by Laurillard (2008), and we use both individual and social learning theory to analyse these maps. In this context, the educational needs are those of the teachers as well as those of the students, because both form essential parts of the academic educational system.

Our approach is practice-based educational research, in that we observe and analyse emergent practice within one discipline context. Only a few of the examples described have been evaluated for learning effectiveness independently of the routine (and confidential) institutional course and teacher evaluations. Our aim here is to examine how the disciplinary curriculum development priorities in engineering have been influencing academics' choice of learning technologies, in relation to the types of learning required and the teaching work involved.

Educational theories

A broad range of educational theories is needed to make sense of the numerous learning activities that build engineering graduate attributes. We categorise them here under three headings: individual learning, social learning and situated learning, because these correspond to the complementary requirements for discipline concepts and theory, teamwork and communication skills, and critical thinking in a professional context. This approach provides different lenses through which we can make sense of the complex system that constitutes disciplinary learning and teaching.

Individual learning

Several learning models focus on the individual cognitive construction process, through which each student will learn to articulate or use knowledge explicitly. In an academic context, where individuals have to demonstrate conceptual understanding in a discipline to gain a degree, and especially in Engineering Science, the individual perspective fits many of the formal learning processes. Some theories focus on the supports and filters needed to present activities and information to learners using learning technologies. For example, scaffolding can be built into the design of a learning activity to help students build the skills they need in stages (McLoughlin, 2002; Winnips & McLoughlin, 2001). Cognitive load must be managed, to enable the learner to absorb and process information effectively (Sweller, 2008).

Threshold concepts within disciplines are ideas that lead to a qualitative and irreversible change in understanding, which then shapes subsequent learning and behaviour (Meyer & Land, 2006). Threshold concepts integrate and transform previous knowledge and may sometimes even lead to a transformation in the learner's worldviews and sense of identity. They are also troublesome to learn, because the learner can initially find them alien and counter-intuitive, or simply incoherent because of their complexity. In undergraduate engineering, there has been particular concern about high failure rates in engineering mechanics, related to problems with threshold concepts (Prusty & Russell, 2011). This leads to additional demands on teacher workloads, and on the whole teaching system, because students then require additional tuition to allow them to progress.

The conversational model of learning with technology (Laurillard, 2002) brings the teacher into the picture, by framing the learning activities and technologies as mechanisms and media for the exchange of conceptual knowledge between learner and teacher. Environments and activities for experiential learning complement discursive activities such as lectures, tutorials and written examinations. The underlying assumption in this model is that the student primarily is acquiring concepts that the teacher has already mastered, although there may also be some learning with and from peers (Figure 1). In Engineering Science, this model is valid way of thinking about learning. There is an established body of knowledge, relatively uncontested, that students need to acquire in order to work with the physical world. If they cannot reliably calculate forces on a bridge or within a car engine, their engineering designs will fail, unless of course someone else, or something else, can do the calculations for them.

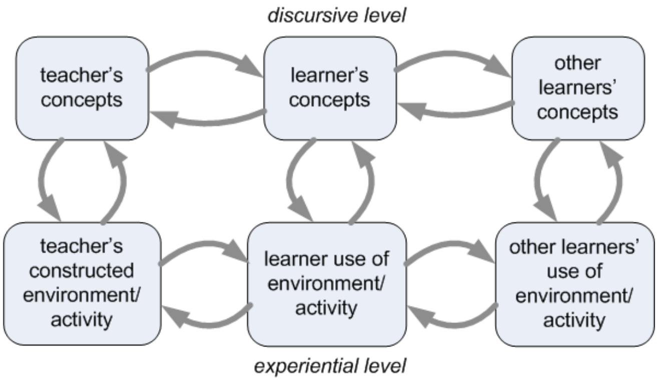

Figure 1. The conversational model of learning (based on Figure 1 in Laurillard, 2008)

Social learning

Social learning theories focus on how people learn in and from a social context, and a number of writers apply the idea of social constructivism to online learning (Huang, 2002; Kim & Baylor, 2006; McLoughlin, 2002). There is also a view that knowledge not only is socially constructed in the individual, but exists beyond individuals. Distributed cognition views knowledge as embodied in patterns of teamwork, organizational processes or systems, and in the technologies that support shared activity (Salomon & Almog, 1998). Computer technology provides cognitive tools that the learner can use individually or in groups to construct their own representation of knowledge, for example by doing calculations that help them transcend the limits of memory or problem solving (Jonassen & Reeves, 1996). Viewing learning as a distributed cognitive process is particularly relevant for engineering students, because their discipline's knowledge is embodied in artefacts and techniques.

Salmon's (2000) 5-step e-moderating model provides a practical framework for facilitating social learning online, by showing how learner progress from needing support for basic access, information exchange and socialisation, to interacting online with peers to construct new knowledge, eventually becoming independent developers of new knowledge. In engineering, students often work together on team projects that are supported by online communication tools, so they will often be required to progress to the higher levels of this model.

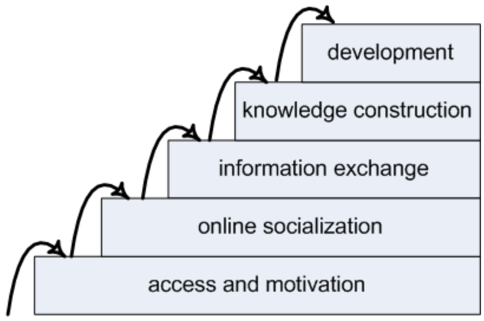

Figure 2. The 5-step e-moderating model (adapted from Salmon, 2011)

Situated learning

Situated learning theory focuses on learning in a real-work context (Boud & Solomon, 2000). This underlies the idea of communities of practice (Wenger, 1991; Wenger, 1998), a concept often referred to but which may be hard to achieve in practice (Eraut, 2002). Many engineering degree programs, like ours, include a work-based component. However, there is also a need to provide realistically complex experiences in which students can integrate the various cognitive and social aspects of their learning in as authentic a context as is possible in the academic environment. Project work tackling real world problems is more engaging and motivating, and helps to build graduate attributes such as the ability to engage with the ethical and social dimensions of engineering.

Theories in action

It is extremely unlikely that engineering academics are consciously thinking in terms of all these theories when they design learning activities. Although many are familiar with some educational models, this is not the focus of their attention while they are teaching, and perhaps cannot be, in 'the heat of the classroom' (Atkinson & Claxton, 2000).Their expertise is as discipline-based teachers and not as educational researchers (Borrego, 2007). The majority of the practitioners are simply seeking pragmatic solutions for a particular class or context, and will not be carrying out broader educational evaluations of the general effectiveness of the technologies for learning.

As pointed out by Schön (1987), reflective practice in higher education may require stepping outside the context of professional practice in order to reflect effectively. Eraut (2000) refers to this as 'deliberative learning'. Laurillard (2008) argues for a research-style approach to innovation with learning technologies, and for identifying generic learning designs or patterns. In analysing our own Faculty's learning technology developments, we hope to provide some insight into how this might work in one disciplinary context. Therefore, rather than focusing our study on particular projects that are explicitly set up as research, we provide a contextual overview of a range of initiatives, many of which are practice-based.

We are aiming to find out how the requirements for curriculum-level learning outcomes in engineering are being supported and enhanced by different types of educational technology in terms of:

- Individual learning
- Social and team learning
- Situated learning
- Teaching work.

Methods

Here we are presenting and analysing a context-specific case study of developing uses of educational technology within an Engineering faculty. We have gathered the information as participants in the process – as part of our role in providing educational development support. In this role, we are able to take an overview that forms part of continuing educational action research, in which we are combining the principles of reflective practice, as defined by Schön (1987) with a reflexive approach to information gathering and analysis. Reflexivity in research, as described by Alvesson & Sköldberg (2000), implies that we continually question the underlying assumptions in our research methodology and data collection methods.

As a starting point for the action research, we have compiled short pragmatic descriptions of educational technology uses in our Faculty, outlining the types of learning activity they are used for, and the function of these activities in relation to the required graduate attributes, as expressed by the teachers involved. This is the first cycle of continuing action research that aims to develop a better theoretical framework for selecting educational technologies to support disciplinary curriculum development priorities, as suggested by Laurillard (2008). At this stage, our focus is on the teacher intentions in adopting the technologies.

We have grouped the technology applications into three categories:

- mobile devices (e.g. phones, laptops, iPods, iPads)
- online tools (both within and outside institutional online learning management systems)
- virtual contexts (e.g. VR, online games, simulations and role plays).

The mobile and online technologies, although they are often used together, have in our case mostly been used for classroom and online activities respectively. Both involve technologies that are widely available to staff and students in universities. The 'virtual contexts' category is described separately because the role of the technology is not just as a medium for teachers and students to communicate, and to exchange and develop ideas. The technology provides environments in which learners temporarily engage with a different reality or take on a different identity. Also, some (but not all) of the examples use specialised software and hardware.

We have mapped the various projects, activities or techniques in these categories onto the educational theories outlined above. Also, as a first step in identifying the costs and benefits from the teaching perspective (Laurillard, 2007), we include in the mapping some consideration of efficiency gains. The aim of mapping in this way is to begin building a deeper and more systemic model of how learning technologies can support practical curriculum development in engineering.

Technology applications

The following is the grouped list of the types of learning activity that various technologies are supporting.

Mobile devices

The Faculty has 100 iPods. These have been used with an external web polling service for classroom voting and peer marking.

We have also developed a mobile marking application that provides marking rubrics for iPod, iPad or iPhone linked to a web server. We have built a simple web application that allows the teacher to build a scoring rubric on items, activities or groups.
classroom voting
The aim of classroom voting is to make lectures more interactive, by asking the students for their views or to answer specific questions about the topic being discussed, anonymously. The responses are displayed live using the external web service rather than specialised local software and hardware (often called 'clickers'). The advantage of using this method is that students can also use their mobile phones or their laptops. So our own iPods only need to be issued for those that have no web-enabled device with them. For encouraging a more socially interactive form of learning in lectures, an effective strategy is to ask students to answer in teams of four, on the assumption that at least one in four will be carrying a mobile device.

peer marking
We have also used the web polling service to record and monitor live peer feedback in student 'bearpit' presentations on their team projects in a 4th year Mechanical Engineering Design course. The mobile marking application for iPods and iPads has been used for peer marking of poster presentations.
practical classes

The Educational Technology team are working on a mobile application that allows students to answer questions while they do practical work in a lab or other site where they are observing. The software can deliver videos along with questions or instructions on what to observe in a lab or on a site visit.

teacher marking
Our iPod/iPad application can eliminate tedious paper-based marking of student presentations, posters and project work by allowing the markers to enter scores on an iPod application that presents the marking criteria and standards. The application can also display images for reference during marking. Scores are automatically sent to the server and compiled in real time. It has been used for:

- 4th year thesis competition marking

- research poster marking
- an undergraduate project competition in 1st year Mechanical Engineering.

The Faculty of Medicine are interested in using the same application for oral examinations (vivas) and for use in hospitals and remote locations.

One School in our Faculty has bought all members of academic staff an iPad so that they can mark and annotate student work electronically and give students feedback. All student assignments must now be submitted in digital form, so all marking is paperless. The primary motivation for this initiative is to improve efficiency and tracking, by removing the need for handling paper copies.

Online tools

group management
Many engineering courses involve group projects in large classes, the logistics of which can be a challenge. In our 1st year design course, for example, we have over 1000 students selecting from 12 or so project options and then being allocated to project teams of 5 or 6 within each project. Each project has different resources and activities and each team also needs an online space in which to work.

In our online learning management system, students view the information on each project option, then use the online tools to select a project and gain access to more detailed information. In some projects there will be a questionnaire to support team allocation. Then the system can allocate students to teams automatically according to the criteria set up by the lecturer. The system also allows lecturers to view student activity by group or by team.

peer marking
We use a calibrated peer review (CPR) service to support peer marking of project reports in a number of courses. Students are 'calibrated' and given feedback on their ability to judge an appropriate grade in examples of different quality. Each student assignment submitted is then automatically allocated, randomly and anonymously, to several other students to mark. The final mark for each assignment can be adjusted using the marker calibrations.

Some lecturers use other external web services or customised tools as media for students to comment on each others' work.

peer feedback within teams
We use WebPA to allow students to give anonymous feedback and comments on their contribution to teamwork, using a rubric. The marks can be used to moderate individual marks allocated for team projects. But often they are used formatively, or to alert the tutor to problem teams.

quiz design
Some of our Computer Science lecturers have developed a quiz tool enhancement to improve multiple choice quiz design. Instead of the lecturers having to select marking schemes in detail, they can choose from some standard designs based on research into effective quiz design. However this is not being widely used.

adaptive online tutorials
In 2011, we are part of a project using adaptive tutorials for mechanics courses in engineering across several Australian universities. The aim is to address some of the challenges students face in learning threshold concepts in engineering mechanics. The adaptive tutorials are underpinned by a system allows teachers to monitor overall responses in a large group of students and to adjust the teaching, and the feedback given by the online tutorials themselves, to respond to common sticking points.

digital media
We use a number of technologies for capturing, editing and distributing recordings of lectures or shorter edited podcasts. The University provides a central file conversion and streaming service for these video recordings. Podcasts allow students to review what they learned in class and catch anything they may have missed, and may also replace some lectures. Lectopia provides automated sound recording of lectures, which are then available

for student to download as podcasts.

In 2008 we videorecorded lectures for a software engineering course, combining the lecturer's talk with material from his laptop (showing computer coding, animation software and web access). Each 1 hour lecture required 3–5 hours of post-editing work.

In 2010 we used new hardware and software to do the same job on the spot, so that edited high quality video podcasts with combined media were uploaded to the streaming service within half an hour of the lecture.

Virtual contexts

We have a few, but not many, examples of activities using games, simulations or online role plays, most in contexts that combine teamwork and individual assessment of learning.

serious games
The Faculty recently reviewed the 4th year undergraduate thesis – the capstone for the honours BE programs. One outcome was concern that most students beginning their thesis projects had inadequate information literacy, and that this was leading to inconsistent standards and extra work for thesis supervisors. The Faculty was awarded funding for a joint project with the University Library to develop and pilot a game-based activity that would engage thesis students in building information skills. The game is being developed and tested during semester 2 of 2011.

simulations
Many engineering disciplines use simulations as part of professional practice, and often students are introduced to these in learning activities. Particularly in disciplines such as mining engineering, where the consequences of engineering design decisions can take years to become evident, and where students often cannot be exposed to real working environments for safety reasons, simulations can provide valuable learning. Simulation activities are being used and evaluated in 1st and 3rd year undergraduate mining engineering. Whereas in 1st year students are given a fairly prescribed scenario to interact with, the 3rd year students are able to deal with more complex and open-ended simulations. Simulation activities are also used in other engineering programs.

virtual reality
Also in mining engineering, there is a 3D, 360 degree environment where students can experience simulations of a real mining environment, giving them an immersive experience (including sound) of hazardous underground events. Developed for training in the mining industry, this facility is now being used for learning through team projects using simulated scenarios.

online role plays
The Faculty has for some time had a customised environment for supporting online discussions in roles (i.e. with login in role rather than with student ID). We have also used a combination of learning management systems to run an online role play activity where postgraduate students of environmental impact in mining joined with postgraduate students in environmental health. The role play environment was set up in a separate online learning management system, with role-based log-in.

Analysis and discussion

Some of the tools are being used primarily in activities to support individual knowledge construction, while others can support both individual learning activities and social learning. Table 1 maps the technology-supported activities described above onto the types of learning, and onto efficiency gains in teaching work.

Table 1. Mapping techniques to learning

Technology-supported activities	individual learning?	social learning?	situated learning?	efficiency gains?
Mobile devices				
classroom voting	✓	✓		✓
peer marking (iPods, iPads, web services)	✓	✓	✓	✓
teacher marking (iPods, iPads)	✓		✓	✓
mobile media and questions	✓		✓	

Online tools				
group management	✓	✓	?	✓
peer marking	✓	✓	?	✓
peer feedback	✓	✓	?	✓
quiz design	✓			?
adaptive tutorials	✓			?
digital media	✓			✓
Virtual contexts				
games	✓	✓	✓	
simulations	✓	✓	✓	
virtual reality	✓	✓	✓	
online role play	✓	✓	✓	

Where there are specific challenges, such as in engineering mechanics courses with a high failure rate because students are failing to acquire skill with threshold concepts, there has been a reason to focus on tools for conversational interaction between teacher and learner, such as classroom voting and adaptive tutorials. These scaffold the learning process, presenting simple challenges with fast feedback to the student. Classroom voting does this face to face with a group and the adaptive tutorials as self-paced individual activity. In both cases this forms part of a collective conversation between one teacher and many students – up to several hundred at a time. Both technologies allow the teacher to perceive and respond to general patterns across the whole class.

Where the focus is on students gaining skill in teamwork and design problem solving, there is heavy use of online group communication and peer feedback tools. These tools not only help groups and teams to learn from each other, but also support automated organisational processes, so that the teachers have less administrative workload in setting up, monitoring and facilitating the teams.

Peer marking tools have a combined individual and group learning focus. Students are given guidance in how to mark each others' work. As they become accustomed to doing this, they learn in more depth about the criteria being used to judge their own work, and about how to learn from and critique constructively the work of others. Although not always specifically situated in a real engineering context, the activities using these tools attempt to replicate aspects of professional practice where multidiscipline teamwork, critical analysis and feedback on work by peer is the norm.

The more authentic and complex learning activities are also beginning to take advantage of virtual environments. Although these need a lot of investment to set up and are often very specialised, they can take advantage of staff experience with professional and research technologies. For full-time undergraduate study in particular, the opportunities for situated learning in the true sense are limited. Simulations and games provide an engaging and challenging alternative. Role plays are ideal for exposing students to some of the complex social and ethical issues they are likely to come across in their professional practice.

In a research-focused context, it is not surprising that the tools that help maintain learning quality and save teaching time have had more adopters than tools that require more individual work on the part of the teacher. Some of the technologies we use have been able to automate processes that would otherwise have to be created and carried out repeatedly by teachers. For example, the peer marking and team feedback criteria embody in software the experience of previous best teaching practice and team decisions. In large classes run by teams of academics, as in our first year design subject, this fits the distributed cognition model, where the teaching knowledge is spread among teams of individuals, organizational processes and systems and technologies that support shared activity. Figure 3 summarises how learning technologies form part of an open distributed knowledge system in engineering education.

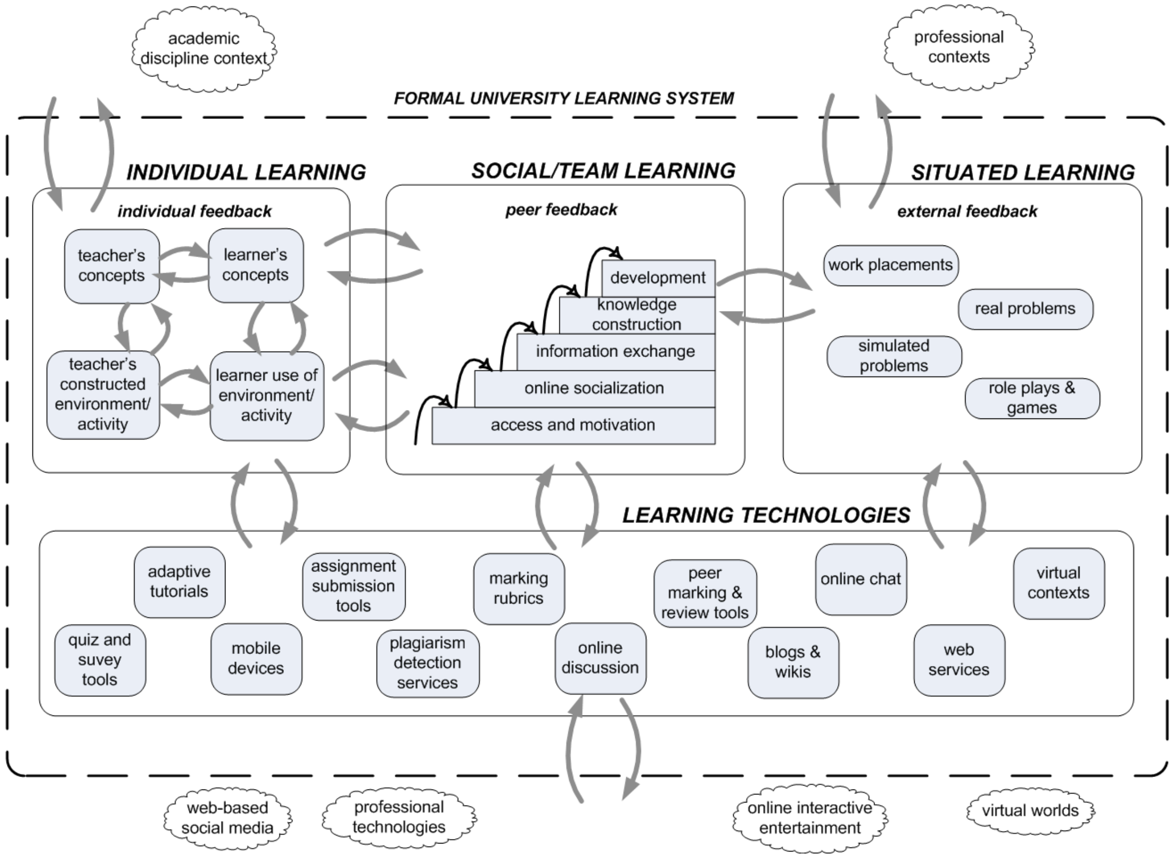

Figure 3. Learning technologies in engineering education as an open distributed knowledge system

Conclusions – next steps

We set out to identifying some patterns of innovation with learning technologies in the context of developing the Engineering curriculum within UNSW, and we have been able to relate different technological tools to some of the main curriculum development priorities, using different theoretical perspectives on the learning and teaching process.

The development of the Faculty's technology use so far has been ad hoc, adopted within particular subjects. Nevertheless, having identified where technologies have been introduced to support specific learning needs, we have been able to begin developing a framework for evaluating technology use across a whole curriculum, in relation to graduate learning outcomes required in the discipline.

Since we are aiming to be reflexive in our approach to this research, it is worth noting what we have excluded from our analysis:

- Our analysis has focused on the formal aspects of learning and cognition. We have not fully addressed the affective dimension of learning – how to engage students, the role of emotional intelligence (Mayer, Salovey, & Caruso, 2004), the nature of 'flow' in balancing skills and challenges (Csikszentmihalyi, 1992).
- We have not examined the educational effectiveness of the technological solutions chosen, but have merely reported on use and teaching intentions. This raises a question about whether the teacher perceptions and intentions about using the technologies are broadly complete and accurate. While some of the examples in this paper have been evaluated, many have not. A more comprehensive evaluation of learning experiences and outcomes might provide more complete picture.
- We are aware of some student project teams who have chosen to set up their own Facebook or Google groups to coordinate their work, instead of using the online learning management system as set up by their teachers. As indicated in Figure 3, these are outside the scope of the formal university learning and teaching system and the technologies that support it. However, in a healthy open system, the boundaries between formal and informal are highly permeable.

- We have mapped only what we have evidence of within our own Faculty, from actual use in one Australian metropolitan university. The same exercise with the same technologies might generate an entirely different pattern in another disciplinary context, because the nature of the learning needs and the learning activities is different (Russell, 2005). The institutional context, and even geography, will also influence technology use. A multi-campus regional university, for example, is may place more focus on technologies that support remote teacher and peer interactions for campus-based study, in addition to home or workplace-based.

Overall, our analysis provides an example of a structured reflection on how digital technologies can be used and adapted fit particular curriculum development needs, using educational theory. In this sense we have begun to carry out a research-style approach to innovation with learning technologies, advocated by Laurillard (2008), at the level of curriculum. In Engineering at UNSW, next steps are to develop and refine the evaluations of effectiveness of each of the solutions. A similar process of mapping of technologies onto their affordances for individual, social and situated learning, and for efficiency gains, could be applied in other disciplinary and institutional contexts at the level of curriculum design for graduate learning outcomes.

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Please cite as: Russell, C. & Posada, J.P. (2011). Mix and match: m/e-learning and engineering curriculum. In G. Williams, P. Statham, N. Brown & B. Cleland (Eds.), *Changing Demands, Changing Directions. Proceedings ascilite Hobart 2011*. (pp.1096-1106). https://doi.org/