Chapter 17

An Integrated Approach to Teaching Freshman Multi-Disciplinary Materials Science and Engineering

AARON S. BLICBLAU
Swinburne University of Technology, Hawthorn, Victoria, Australia 3122. E-mail: ablicblau@swin.edu.au

The learning initiative described in this paper looks at how the adoption of various technology applications can be used to optimize teaching and learning in an engineering materials science subject across a variety of engineering disciplines. The main driver for adopting this approach was to increase the effectiveness of delivery of the subject matter. Practical examples are given of delivery strategies, activities, and assessment protocols. This teaching approach required the development and implementation of an integrated technology and web-based teaching strategy (LMS) for the provision of online lectures; audiovisual material; discovery based learning activities; and communication tools for the guidance of students in the self-management of their personal learning styles. The implementation of such an online initiative was considered novel, and led to an encouraging response from both students and staff. This was seen as pivotal in its contribution to the success of the overall learning strategy.

INTRODUCTION

The restructuring of a university teaching program brings with it concomitant changes in the provision of teaching activities and an opportunity to develop new teaching strategies [1-4]. In 2012, the Swinburne Engineering Programs Renewal initiative involved the regeneration of all engineering programs. The process resulted in student-centered programs leading to better student learning, as well as allowing subject program panels to review their programs holistically, and clarify what is required in each unit within each discipline/program. Materials and Processes, a first year unit, is an interdisciplinary unit which provided a challenge to its teaching in the various disciplines [5].
Since the latter half of 2012, Swinburne University of Technology engineering subjects have undergone a number of structural changes (known as Swinburne Engineering Programs Renewal) which has amongst other matters brought with it initiatives for student-centered and outcomes-based projects incorporating a variety of flexible delivery modes for learning; in the field of Materials Engineering an initiative was developed to deliver educational materials for learning and teaching to a variety of engineering disciplines [5-7]. The university was encouraging pedagogical initiatives, which were underpinned by good flexible learning principles. They would be a practical demonstration of how new educational technologies could stimulate learner participation and satisfaction, whilst lowering academic workload.

**IMPLEMENTATION OF COMPETENCIES**

In recent years, international engineering accreditation bodies have moved to an Outcomes-Based Education (OBE) framework. This specifies what a graduate should be able to do as an outcome of their program, rather than detailing the content and processes they were exposed to. Engineers Australia has recently changed their accreditation requirements in-line with OBE, specifying the Stage I Competency Standard for a Professional Engineer, which specifies in detail what each graduate can do by the completion of his or her degree [8]. The basic syllabus of the first year materials and Processes subject underpins the majority of engineering disciplines delivered in the tertiary environment (Figure 1). The Swinburne Engineering Competencies (SECs) in the area of Materials are a simple set of competencies graduates must attain by the end of their specific program. They describe what a graduate needs to be able to do, not what was taught to them.

![FIGURE 1](variety_of_engineering_disciplines_involved_with_engineering_materials.png)

They are grouped into three areas, Knowledge (K), Skills(S) and Attributes (A). The unit of study aims to introduce students to the basics of materials engineering, including
their microstructure, properties, structure, failure modes and sustainable use. After successfully completing the unit, the competencies students should be able to achieve are described in Table 1.

- Describe the difference in atomic/molecular structure between the major classes of materials that result in different material properties. \(^{(K1)}\)
- Analyze the material response to mechanical and physical stimuli. \(^{(K1, S1)}\)
- Determine mechanical properties of all major classes of materials on the basis of experiment. \(^{(K1, S1)}\)
- Determine physical properties of materials. \(^{(K1, S1)}\)
- Describe the suitability of different methods of strengthening of materials and their potential for material degradation. \(^{(K1, S1, A2)}\)
- Select materials using appropriate methods that consider microstructure, manufacture, performance and sustainability. \(^{(K1, S1)}\)
- Safely execute experiments, formulate conclusions and generate laboratory reports. \(^{(K6, S1, A2)}\)

| TABLE 1 |
| Example of Competencies in Materials and Processes |

- \(^{(K1)}\) Basic Science: Proficiently applies concepts, theories and techniques of the relevant natural and physical sciences.
- \(^{(S1)}\) Engineering Methods: Applies engineering methods in practical applications.
- \(^{(A2)}\) Communication: Demonstrates effective communication to professional and wider audiences.
- \(^{(K6)}\) Professional Practice: Appreciates the principles of professional engineering practice in a sustainable context.

**TECHNOLOGY AS A TEACHING TOOL**

Technology is but one of many tools that can be used to accomplish pedagogical goals [9, 10]. The underpinning theoretical presumption of this initiative was that educational outcomes would determine the selection of teaching delivery media [11]. Only media that would support the long-term achievement of these outcomes would be selected and trialed.

This new initiative looks at how the traditional subject delivery approach, incorporating an on-line teaching, delivery, learning and assessment approach could be used as an effective method of teaching and learning in the Materials Engineering area for first year engineering students using a variety of delivery modes, especially a Learning Management System, and Tablet PCs for lecture delivery [18-20]. It was decided the delivery approach would implement new technologies for the delivery of learning material [12], the conduct of online tutorials [13, 14] and delivery of laboratory classes [15, 16]. In particular, tutorial-based inquiry was to be combined with a problem-based learning approach [17] and a team approach to problem solving. The hands-on laboratory work was to be fully integrated within the learning delivery system for both pre-laboratory discovery-based learning, and post laboratory team review and assessment. The delivery and evaluation of the learning material would be assessed using an on-line Learning Management System [12]. The combined implementation of these teaching approaches and techniques is considered novel.

This work incorporated tablet PCs and wireless technology use during classroom instruction to enhance the instructor’s ability to solicit active participation from all
students during lectures, to conduct immediate and meaningful assessment of student learning, and to provide needed real-time feedback and assistance to maximize student learning [18-20]. Swinburne’s Flexible Learning and Teaching Plan guided the approach, where in addition to traditional on-campus study, the institution offers a number of flexible delivery options, i.e., “…we will build optimal learning environments throughout the university” [21]. These learning environments will develop in all students, their innate capacities for creativity and deep learning, and will be characterized above all by flexible learning and a more learner-centered approach.”

**IMPLEMENTATION AND SUBJECT DELIVERY**

A project team of academics, teaching and learning advisors, and development staff was formed to examine a number of key issues: the technical skills of the staff; students’ computer literacy; technology limitations of the delivery platform; accessibility; and the educational relationship between the content, teaching methodology, assessment methodology and course outcomes. The theoretical basis of the initiative was the Flexible Learning and Teaching Plan developed by the university, which looked for ways in which the use of technology could be mainstreamed across the university, linking it to external clients to optimize convenience and improve accessibility for students [21]. From the outset, the project team was committed to establishing some fundamental principles to maintain the integrity of teaching process while ensuring online delivery did not jeopardize the learning experience for participants. The syllabus content was revised to ensure that it was student centered and had definable outcomes of benefit to the student as a graduate. Details of the content are given in Table 2.

<table>
<thead>
<tr>
<th>Subject Content with Student Centered Features with Definable Outcomes</th>
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<tbody>
<tr>
<td>Applications of Materials</td>
</tr>
<tr>
<td>Atomic structure, electron configuration, bonding</td>
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<tr>
<td>Crystal structure, unit cells, planes and direction, x-ray diffraction, density</td>
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<td>Amorphous structures, composition</td>
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<td>Dislocation theory, critical resolved shear stress</td>
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<td>Recovery, recrystallization, grain growth</td>
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<td>Mechanical testing of metals, polymers, ceramics;</td>
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<td>Failure; fatigue, ductile, brittle, impact, tensile, creep</td>
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<td>Properties of polymers</td>
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<td>Properties of concrete, composites</td>
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<td>Materials selection strategies,</td>
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<td>Sustainability of materials utilization</td>
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TABLE 2

Subject Content with Student Centered Features with Definable Outcomes

It was decided that a common first year engineering subject (HES1230 Materials and Processes) which had a large cohort of students from a variety of engineering disciplines as depicted in Figure 1 was to be trialed in this initiative. All students enrolled in first year engineering at Swinburne University of Technology must undertake a first year subject dealing with engineering materials: HES1230 Introduction to Engineering Materials [22]. This subject is taught at the mainland campus in Hawthorn and at the recently established Malaysian campus in Sarawak. The main cohort of students varied between 300 in 2010 and 350 in 2012. The lecture theatre resources only accommodated
half that number. The subject was delivered twice. Students were allocated to small tutorial groups of approximately 24 and laboratory groups of six students per session. In addition, only one staff member was available for the delivery of lectures. A diagrammatic representation of the teaching, tutorial and laboratory delivery is shown in Figure 2. Due to the comprehensive subject management and large enrolments, there was a large workload for the delivery of classes, tutorials, and laboratories, compounded by the need for timely and pedagogically sound assessment for all activities. To address these issues a new e-learning approach for delivery of material and associated assessment was developed and trialed.

**THE LECTURE SERIES**

Due to the large enrolment numbers, and staff redeployment, two lecture streams were conducted in parallel, but displaced in time. Furthermore, the students benefited from such a delivery mode, through the enhancement of the learning and teaching features that were employed [23]. The delivery of lecture material was presented with tablet PCs [18-20] and coordinated through Blackboard©; a web-based Learning Management System. Blackboard© supplied students with a number of online communication and media tools that can be used by students for personal and group exploration and practice (both in synchronous and asynchronous modes), as well as automated grading and marking for academics, a basic necessity in the completion of the feedback loop with students. All written material was made available to students electronically and via their own tablet (PC or Apple©) or smart devices at the commencement of the semester. In addition, the notes were available in pdf (Adobe Acrobat©) and students were expected to consult any additional material and appropriate references before class and be ready to engage the lecturer and their peers in appropriate subject thematic discourse. Audio-visual presentations during lecture sessions were delivered using Microsoft PowerPoint© and were correlated with the notes previously available in pdf format.

Integrated within these presentations were problem-based computer tutorials. The computer tutorials could be revisited at a time independent of the classroom experience [16]. To ensure that students reviewed lecture material, each set of notes had sections missing, which could only be obtained by attending the appropriate class. These were not merely skeleton or fill in the gap notes, but were a substantive set of vital pieces of information, e.g., equations, graphs and diagrams. Main points were emphasized and analyzed in-class and operated as an addendum to the written materials. The pre-identified main points were the central focus or theme for the particular class. These main points were (also the missing sections) written comments, an important equation or a diagram, for each alternate slide. This ensured that students would be active listeners during the lecture presentation, be engaged in the material presented and would be active scribes for the remainder of the oral lecture presentation. During lectures the students would undertake small exercises, solve problems and offer suggestions for a problem solution. The lecturer assigned students small-applied tasks during the lecture, which had the added benefit of allowing for “rest periods” during the presentation. They involved the solution of a small problem by students, or suggestions for an activity. By actively involving the students in the subject delivery, students reported an increased sense of ownership and responsibility. Although a whole semester of notes could be downloaded from the web, the main focus of each class could only be obtained by physical attendance, active engagement and participation in the class [23, 24].
When lecturing to large classes it is sometimes difficult to answer all the questions put forward by students. Often students will approach a lecturer after the class seeking to ask clarifying questions. Unfortunately given this scenario the rest of the class does not have the opportunity to listen to the answers provided. In some cases students can often be reluctant to ask questions in person. To try and overcome this issue, two approaches were utilized: interactive lecture demonstrations (ILD) previously used in a Physics environment [24], and an online question and answer forum, established using Blackboard©. The Frequently Asked Question (FAQ) “e-mail forum” on Blackboard© gave students the opportunity to ask each other (e.g. peer group learning) as well as staff, various focused questions with answers that could come from a variety of sources. For both forms of supplementary material delivery, the lecturer and student had immediate, public dialogue and feedback in an environment that allowed other students to observe and learn from.

ONGOING ASSESSMENT OF LECTURE MATERIAL
With a limited semester of 12 weeks, ongoing assessment using the online Blackboard© system grade book was initiated. This was supplemented by “mini” classroom quizzes. The assessment procedures and feedback were developed with student needs in mind, and provided students with a current percentage grading of their total semester result. This allowed assessment results to be immediately available through auto correction and suggestive responses (for incorrect answers), as well as providing timely textural and descriptive feedback to the students. Each student was required to log on to the subject via the Blackboard© system, with a unique username and password. At the
commencement of the semester the students were given full details of the timing and topics assessed. At the conclusion of each major lecturing theme (approximately 4 and 8 weeks) both an instant mini in-class quiz and formal class test was conducted online. Students were given one week and one attempt to complete the formal class assessment. This approach facilitated formative classroom assessment—whilst monitoring an electronic conference gave invaluable feedback on what students were thinking about the subject matter and whether they were having difficulty understanding key concepts.

The formal assessment was quiz-based incorporating selection of appropriate answers (words, phrases, numbers or pictorial representations) and was composed of a random block of 20 questions from a question pool of over 100. The mini-quiz questions were integrated within the formal quizzes. The system was set to allow many attempts at the assessment item. Prior to undertaking the assessment students had been encouraged to work in groups to promote team-work and research skills. Students were encouraged to work collaboratively on the quizzes in small groups discussing, evaluating and answering each set of questions, which were different for each student. When completed, they would move on to the next student’s unique set of questions, which were similar but not necessarily the same. Once a group of four students had completed all question sets they would have intensively discussed and evaluated each of the problems and posed appropriate solutions.

Without perhaps knowing it, the students had engaged in active deep learning. Rather than plagiarizing answers, each student was actively involved in learning and questioning. This was seen as providing a fuller understanding of the quiz topic. The relatively high score achieved by the students working in this manner compared to prior years evidenced the benefit of this form of learning. Of the students who chose not to work in a group environment, considerably lower scores were recorded, although there were of course outliers, i.e. those students who worked alone and achieved high (or low) grades. This approach implied that there are a number of ways of using on-line managed learning and presentation technology - probably many more than we have imagined which can help educators assist their students to learn.

**THE LABORATORY LEARNING STRUCTURE**

Laboratory work, an integral part of the subject, was organized so that students participated in experimental work as a small group, but were assessed individually. The cohort of students were divided into groups of five students, for each laboratory session, necessitating 12 sessions per week spread over 4 weeks, i.e. approximately 48 laboratory sessions were held for one activity. These sessions had to fit into the timetable of the demonstrator as well as laboratory availability. Working in groups of five, the students would conduct the experiment, take measurements, and record results. The students worked as groups to research their experimental topic but were required to submit individual results. They were given different sets of conditions to answer as individuals. Again, collaborative learning was encouraged and ‘discovery’ promoted [25]. However, as most students tested different samples of materials their results were often different from each other, but their learning outcome (see Table 1) was essentially the same.

This style of delivery is considered to be a form of Guided Active Discovery [25]. This methodology strives to hand ownership of learning over to the student and drives the student into experimentation and discovery, and was seen as peer group tutoring to arrive at appropriate answers. In all instances, the submission of experimental outcomes was of
a high standard. Shown in Table 3 is a summary of the concepts of discovery-based learning applied to engineering materials. It appeared that the collaborative group work had succeeded in enhancing the students’ learning process. It allowed students to gain exposure to equipment and techniques such as tensile testers, hardness testers, and operation of heat treatment furnaces, whilst participating in more student-centered collaborative learning.

<table>
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<th>TABLE 3</th>
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<td>Concepts of Discovery Based Learning Applied to Engineering Materials</td>
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Materials are everywhere around you, from the computer mouse under your hand to the wooden computer desk. Materials selected for different uses are chosen because their properties fit the need. But no matter where the material originated, its properties, processing and performance are all interdependent and interrelated. These material properties, such as strength, can be measured and analyzed using tensile testing equipment.

Key concepts:
- People have exploited materials for useful purposes.
- Find out that the structure, properties, processing, and performances of materials are all interdependent and interrelated.
- Learn about the different types of engineered solid materials.
- Learn the useful engineering properties of materials.
- Sustainability is important to society. Learn how to choose the correct material and manufacturing process to minimize harm to the environment.

Access to the Blackboard® quiz was by a password, which was only available to students who had actually participated in the hands-on laboratory experiment. Further, the number of laboratory reports was overwhelming for one lecturer to mark and provide feedback to students in the time frame allowed (one week turnaround time). Consequently, the outcomes of the laboratory investigations were assessed online allowing for quick turnaround, ‘instant’ feedback and importantly satisfied students.

**The Tutorial System**

The most difficult aspect of applying the e-learning process was the implementation of the tutorial. The subject, HES1230, was assigned a one-hour tutorial over twelve weeks, which was considered a minimum contact tutorial requirement. Students were given the opportunity to gain content knowledge through a variety of online and face-to-face mechanisms (f2f). Some students took part in in-class discussions of a particular aspect of their work; others attempted problems in-class with tutor support, whilst another group of students enhanced their understanding by discussing problems amongst themselves and working collaboratively to solve them [26]. The tutorials were conducted in an f2f environment to classes of approximately 20 students. The tutorial sessions were used to explain, in depth, concepts from the lecture sessions that were considered important with tutors using tablet PCs for student engagement and interaction. However, not all students had the same difficulty with the same sections of the lecture material and needed support in varied and diverse areas of the curriculum.

Adopting this style of delivery allowed for multifaceted learning to take place. The tutors (in many instances the same person as the lecturer) were able to be more efficient in their teaching. This efficiency came, not from employing a totally new online teaching methodology, but rather through timely presentation of material, use of peer support and
utilization of self-paced activities as extension exercises via Blackboard®. New technologies were not necessarily driving the process but rather supporting it.

**EDUCATIONAL DELIVERY, INNOVATIONS AND EXPECTATIONS**

The on-line learning management initiative allowed students to be actively engaged with the material outside class; it extended the classroom walls. It promoted active student learning because students had to do something with the technology. If they didn’t, they could not complete their required tasks. The educational delivery and assessment innovations undertaken correlated well with educational expectations put forward by the host university:

- The design and development of educational materials provided comprehensive access to subject resources as all print based resources were available online in compressed format and ready to print.
- The curriculum design of the subject involved many examples of flexible communication, timely assessment, subject evaluation and flexible subject management, often allowing students the opportunity to select their time, place and pace of study.
- Learning activities and interactions were implemented using a flexible means of communication to facilitate whole group and small group communication; evaluation, publication of results, formal assessment, and marking of laboratories and tutorials was online and available 24 hours a day, 7 days a week.
- Currently, all subject and program evaluations at Swinburne are carried electronically through anonymous online surveys via Blackboard enhancing a flexible approach to subject and program management.

For the majority of situations this worked well, combining an online learning environment with a peer tutoring structure, which was established amongst students; along with the traditional lecturer/student form of tutoring. The laboratory work culminated in discovery-based learning which gave the students the opportunity to undertake group projects in an attempt to improve teamwork skills.

**CONCLUDING REMARKS**

The learning-teaching initiative developed in this work demonstrated how a traditional subject delivery approach, could be integrated with an on-line teaching, delivery, learning and assessment approach which was used for effective delivery of teaching and learning in the materials engineering area.

The on-line communication component derived its advantages over traditional forms of communication because it is not necessary to occur at the same time or at the same place. Tablet PCs, e-mail and electronic conferencing enhanced active student learning simply by doing what it is designed to do - promote conversation and dialogue. There were a number of innovative and unique ways of using tablet PCs and an on-line Learning Management Systems that, together with presentation technology, can assist educators and, importantly, support their students. The challenge lies in adopting the right tools for the right situations, and in ensuring that the adoption of new technologies is student-centered and educationally driven rather than technologically driven.
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REFERENCES


Aaron S. Blicblau received the BE in Materials Engineering from Monash University and the M Eng. Sci. in Engineering Materials from the University of NSW. He has held appointments as a project engineer for a large mining and manufacturing company before commencing his academic appointment at Swinburne University of Technology. In 2007 he received an Australian Learning and Teaching Council, Carrick citation for ‘outstanding contribution to student learning’, and in 2009 he received a Vice Chancellor’s award for his work in ‘internationalisation of engineering teaching’.