

**AC 2010-682: EMPHASISING PROFESSIONAL ENGINEERING ELEMENTS IN
THE TEACHING OF MATERIALS TECHNOLOGY**

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Emphasizing Professional Engineering Elements in the Teaching of Materials Technology

ABSTRACT

The re-development of pedagogy and curriculum in the Materials and Manufacture subject in the School of Architectural, Civil and Mechanical Engineering (ACME) at Victoria University (VU) in Melbourne was driven by changing pedagogical philosophy of engineering education at the university. The new pedagogical approach was to focus away from the traditional instructional models without fully discarding them. Though this subject was designated to be delivered as a Problem-Based Learning (PBL) subject, the educational approach taken was such that the PBL delivery was only a part of a pedagogical toolbox. The main educational thrust was one of inductive learning and teaching derived from courses such as creative arts. Aside from PBL, the inductive teaching approach incorporated Case-Based (CBL) and Enquiry- Based learning (EBL) which provided the appropriate pedagogical scaffolding for knowledge integration. Material technological sciences, manufacturing engineering, engineering design, issues of ethics, sustainability and environment were weaved together. Such educational approach was necessary if strictly academic knowledge discourse was to be replaced by professional knowledge discourses. Students were exposed to the open-endedness and messy nature of professional engineering discourses, to appreciate the interconnectedness of knowledge disciplines and the multidisciplinary nature of professional engineering work, and to instil into students' with skills and knowledge which are convergent with the higher levels of Bloom's taxonomy. Despite the reduction of contact hours for this subject the new pedagogical activity allowed to maintain the transmission of full body of knowledge and thus proved to be fairly effective. Students' responses to surveys have, on the one hand indicated concerns with the amount effort required for this subject, but on the other hand showed an overwhelming satisfaction with this subject.

Key words: Education for professions, inductive education, engineering education

Introduction

The re-making of Victoria University (VU) as *A New School of Thought* has led to, in 2005, both engineering schools at VU to adopt new educational paradigms. It was thought that the adoption of a Problem and Project Based Learning (PBL) as a tool for a pedagogical and curriculum design would address some of the problems confronting engineering education at VU. The new pedagogical paradigm was to address the ongoing problems and issues which have beset engineering education at VU, which were:

- Poor student intake into undergraduate engineering courses at VU. Student intake into all the engineering disciplines at VU had the lowest entrance of any university in Melbourne. Such poor intake often translated into high attrition rates combined with unacceptable graduation rates, which reflected poorly on the university as a whole. It was hoped that the adoption of a new educational paradigm would differentiate engineering education at VU from those at other universities and make it a more attractive alternative for senior secondary students in choosing as a course of study at a university;
- Engage students with their course of study, and as a consequence reduce the prevailing high attrition rates; and

- Address the current skill and knowledge deficit among engineering graduates as shown by a number of enquiries and studies into engineering profession and engineering education¹⁻⁸.

The two engineering schools at VU decided on a different tact in implementing the PBL pedagogy into their undergraduate curricula. The School of Architectural, Civil and Mechanical Engineering (ACME) decided on subject-based PBL model and that 50 percent of the subjects constituting their undergraduate curricula designated to PBL delivery. In contrast, the School of Electrical Engineering (EE) at VU adopted a course curriculum based PBL model found At Aalborg University, Denmark. The Aalborg model PBL model seemed to be less realistic at VU because it relied on the assumption of full-time student body completing year stages before ongoing to the next year stage. At VU students were enrolled in subjects across years and the reality of student body focusing on full time academic engineering activity did not exist.

Subject coordinators were charged with the task in developing appropriate subject-based PBL approaches. It was the responsibility of the relevant PBL-based subject coordinators to develop educational delivery based on their perspective on subject epistemology and the role it plays in professional engineering practice. It meant that there were diversity of PBL delivery approaches and each approach was guided by the coordinators' perspective on the nature of the subject and the role each subject plays in the professional engineering discourse. Each subject, whether PBL or not, relied on a set pre-requisites subjects to provide a knowledge and skills platform for further development. The coursework component in the PBL subject is essential in constructing knowledge and skills scaffolding to enable students to tackle any assigned open-ended projects and problems. In some ways, the PBL subject with a coursework component resembled a mini curriculum-based PBL model.

In the undergraduate engineering curriculum there are subjects which integrate knowledge and subjects which are narrowly discipline focused. It is the former that that it is most suitable for a PBL delivery because of the its nature in integrating knowledge it allows the development of open-ended student projects and problems. Engineering Design, For example, is one integrative subject that pulls threads of fundamental sciences and engineering sciences together. Materials and Manufacture is another integrative multidisciplinary subject. It constitutes a part of the undergraduate mechanical engineering curriculum. It serves as a knowledge junction or the meeting point for engineering sciences, engineering design, mathematics, environmental technologies, business as well as ethics and sustainability issues. It constructs a backdrop for the most quintessential multidisciplinary engineering subject, and that is, engineering design. For example, all engineering design in its final stages requires appropriate selection of materials and with each selection merit indices need to be considered. These indices take into account the mechanical, physical, durability, economic, that incorporate cost, physical and mechanical properties, health and safety issues, fabrication properties, recyclability and re-usability, and merit indices for the embedded energies with their associated carbon foot-prints. Casting of materials is associated with engineering sciences such as thermodynamics, heat transfer, fluid mechanics and rheology. Forming of solid or partly solid materials as well as their extrusions, for instance, require knowledge of stress analysis and theories plasticity. Modelling and simulations of manufacturing processes are dependent on continuity equations and hence mathematics.

Curriculum Design Methodology

The change in the pedagogical delivery of Manufacturing Materials subject was the result of the embracement by the faculty of PBL pedagogies, and the necessity in being able to cover the same amount of academic material in less time. In 2005 the precursor subject Engineering Materials has been transformed from two semester subject of three contact hours per week to a single semester subject of 5 contact hours per week. This translated into a reduction of contact hours from 72 to 60 hours. The time allocated to this subject was thus reduced by 16.7 percent. Despite such reduction the original subject syllabus was largely retained.

The educational approach for the subject teaching and learning used a mixture of pedagogies with a general commonality centred on inductive teaching and learning methodologies^{9, 10, 11}. These pedagogies focus on active and student-centred learning. The pedagogical approach adopted for this subject is based on the view that the knowledge-based academic and professional communities differ in their knowledge practices. This is particularly true in the case of professional engineering where professional courses have been over-scientificized and have adopted the norms of science. This differentiation between academic and professional discourses and epistemologies has underpinned the teaching and learning model for this subject. The objective of this model was to initiate students into a professional way of thinking which encompasses the professional and the vocational elements. The subject was partitioned into three components in which the PBL component played a key strategic role. Greater onus was placed on students to seek out knowledge and information to compensate for the reduction in teaching hours.

Though the students attended common lectures, they were placed in separate tutorial groups. Within this PBL subject, students were allocated into teams, each team containing no more than 5 members. Each team was allocated a unique open-ended project or a problem for the duration of the semester. As part of subject engagement, students were required to maintain a reflective journal. In the journal, students were encouraged to engage in a kind of a conversation with the subject, their thoughts about the subject and its teaching and it was to include diaries of student's team meetings, any perspectives and perceptions on project ideas raised during such sessions and provide feedback to the lecturer. Besides students' musings, students were also required to evaluate the team members' performance. The reflective journal provided an invaluable feedback to the subject coordinator so essential for educational improvements. Submissions of reflective journals were mandatory for this subject. The objective of this approach was to introduce to students constructivist attitudes in which the constructivist knowledge – a kind of situation knowledge- which blurs the boundaries between the subjective and objective domains.

The pedagogical scaffolding for this subject consisted of three major components, and these were:

1. Instructional delivery;
2. Experimentation and observation; and
3. Problem and Project based team assignments.

The relationship between the three pedagogical components is outlined in figure 1.

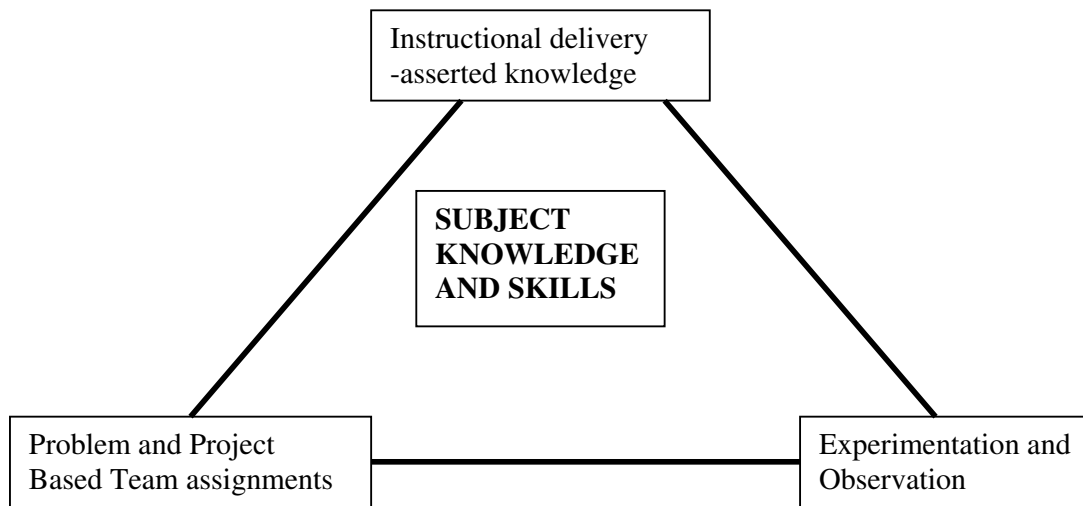


Figure1. The three subject scaffolding components.

Instructional Delivery

The instructional delivery represents the traditional educational spectrum in which knowledge is transmitted via formal lectures, tutorials and informal consulting sessions. It forms the key process for the delivery of the canon of the subject (asserted) knowledge and skills. It is also an essential part of the educational process to raise students' educational attributes to the third level of Application in the Bloom's taxonomy of knowledge model¹². The subject material is taught in a "big picture" manner. The fundamental principles of structure-material properties are followed by illustration of case-studies of failed articles or manufacturing processes. Students are asked questions concerning classical engineering failures, dangers of material substitutions, environmental and social impact on product design and also on materials used in the school's laboratories by research students and staff. Instructional knowledge forms a platform for further inquiry.

The teaching, in this subject, is presented in grand narrative form. Students are required to undertake further reading of recommended and referenced texts. The course material is also supported by the course material I written and compiled by this author.

Experimentation and Observation

In a traditional schema this is normally referred to as to laboratory practical session. However, as important as traditional laboratory sessions are in developing students' experimental and observational skills, processing and evaluation of experimental data and communicating such evaluations through written reports, there are added twists. This particular component's objective is to develop the Analysis skills in Bloom's taxonomy model. The inductive educational methodology of enquiry based learning (EBL) is a feature of this component.

Students performed a set of experiments and were required to write and submit a team report for each experiment. The enquiry based activity takes on a form of questions, related to the areas of engineering design, which emanate from the real world of industry, sport, medicine, architecture and other areas concerning materials selection and fabrication processes. These

questions had to be addressed in the submitted laboratory report. Though lecture material provided a starting point for tackling these questions, students were required to undertake further inquiry in areas of materials, manufacturing processes and product design.

In addition to performing pre-prepared set of experiments, students in teams were also required to undertake an investigation of a particular set problem, which requires laboratory investigation. The set laboratory project is of one semester duration and each team had to submit an experimental proposal that included laboratory methodology and addresses issues such as occupational health and safety. Students were exposed to grounded-type investigation that was accompanied with a significant literature research. Typical investigative problems were:

- Determination of activation energy in curing of cements;
- Determination of residual stresses in moulded polymers;
- Characterization of visco-elastic properties of polymers;
- Environmental effects on polymer properties;
- Formability of aluminium alloys.
- Corrosion of steels in various environments
- Flowability of recycled polymer melts.
- Effect of moisture and the marine environment on mechanical properties of polyester.
- Determination of permeability to water vapour for designated plastic films.

Problem and Project based team assignments

The project/problem objectives focused on student development of skills in synthesis and evaluation.

Each team has an allocated assignment for the duration of the semester. The assignment topics came in two forms. One being project based assignment where material covered in lectures forms the platform for the knowledge base needed for the project. Students then seek out the required data and need to develop skills to successfully tackle the project. The second type of assignment is one of problem based where the lecture material provided the primary knowledge source upon which students were expected to acquire further knowledge to tackle the problem at hand. Interpretation and conceptualization of a given topic was a part and parcel of the assignment.

Each team selected a team or team coordinator whose functions were to ensure division of labour, to organize and conduct team meetings, and to finally edit the team report and ensure that all the individual threads from team members' work were brought together in the executive summary, introduction, discussion and conclusion. Each team member contributed a chapter in the report. The report could be assessed as an overall document and as individual contribution. Throughout the report students were expected to develop an argument and an evaluation of their conclusions by contrasting it to other possibilities. Thus engineering calculations was an essential ingredient of a report. Typical assigned topics for this component are:

- Manufacturing bicycles frames from re-cycled plastics;
- Design and manufacture of bicycle wheels and drive systems from plastic components;
- Manufacture of string instruments from plastics;
- Replacement of metal alloy components in cars with composite materials, ceramics

- and plastics. Case studies;
- Substitution of timber floorboards with polymer floorboards.
- Design and manufacture of bicycle wheels and drive systems from plastic components;
- Replacement of metal alloy components in cars with composite materials, ceramics and plastics. Case studies.
- Hydrogen Economy: Case Study
- Ski Construction from polymers
- Material substitution in musical instruments;

Subject Assessment

Academic assessment is on the percentile scale with 50 percent constituting the minimum pass mark. Students are not only required to achieve and surpass this mark in the overall subject assessment, but must also demonstrate reasonable competence in each subject component. To pass the subject students needed to obtain a minimum 40 percent of the maximum marks allocated to each of the subject component.

The instructional delivery component accounts for 50 percent of the total marks and is assessed by written tests and examination. These assessments tests are designed to test students' knowledge, comprehension and application skills as well as general awareness of material in the other two components. To qualify for an honours grade in this subject, students must also reach an honours standard in this component.

PBL and laboratory components accounted for the remaining 50 marks with a 38/12 marks split respectively. The assessment is a guide rather than a rigid rule and students can gain bonus marks in each of the components by demonstrating excellence well above assessment requirements.

Evaluation of the subject

Any educational evaluation of a subject is methodologically difficult without some standard reference. Though the syllabus has remained roughly the same since 2000, the reduction in contact hours combined with the introduction of professional elements through inductive and PBL pedagogies had substantially altered the subject texture. Such comparisons are further complicated by the fact that the subject once offered at third year level of the course has shifted to the second year level. The equivalent previous two semester subject EMW 3001 Engineering Materials, was taught in the third year of mechanical engineering course whereas the subjects EMW 2761 and VAM 2062 were offered in the second semester of the second year of mechanical engineering course. Both the maturity and the quality of students would be substantially different and need to be taken into account when such comparisons are made, and any conclusions concerning the efficacy of PBL pedagogy is reached..

The content and the standard of the written examinations were of equivalent standard, and student performance is shown below in Table 1. The poorer students' examinations performance as the subject was transferred from the third to second year level of the course, was not surprising given the different maturity and educational standards of students.

However, perhaps as a result of further subject refinement in combination with increased student response to meet the relevant subject standards, the proportion of students gaining more than 50 percent in the examination rose from 58.3 to 77.8 percent. The associated

overall pass rates for this subject also rose correspondingly from 62.5 . The overall subject pass rates are generally were higher than pass rates in the examination because these included assignment and laboratory marks. It must be noted that these inclusions only benefitted students who were not far below the examination mark of 50 percent.

Table 1. Comparison of student performance in Materials and Manufacture prior and after the subject transformation.

Year level of the course and subject codes	Third Year Subject: EMW3110		Second Year Subjects				
			EMW 2761		VAM 2062		
Year of teaching	2002	2003	2004	2005	2006	2007	2009
Number of students who passed the subject exam	23	16	14	13	21	21	26
Percentage of students who passed the subject exam	76.7	76.2	58.3	59.1	67.7	77.8	61.9
of students who failed the subject exam	7	5	10	9	10	6	16
Number of students who overall passed the subject	27	19	15	17	25	23	33
Percentage of students who overall passed the subject	90.0	90.5	62.5	77.3	80.6	85.2	79.8

Student evaluation of the subject and its pedagogy is just as difficult to compare. The subject has generally been a popular one amongst the mechanical engineering students. Increased workloads due to the introduction a more inductive educational approaches and PBL assignments had not dampened the student enthusiasm. Responses to student evaluation seem to indicate this (Table 2)

Table 2. Student evaluation of the subject based on a Likert scale: 1-Very Poor, 2-Poor, 3-Satisfactory, 4- Good, 5-Very Good.

Year level of the course and subject codes	Third Year Subject: EMW3110		Second Year Subjects				
			EMW 2761		VAM 2062		
Year of teaching	2002	2003	2004	2005	2006	2007	2009
Lecture organisation	4.3	4.3	4.1	4.1	4.0	4.7	4.3
Clarity of lecture presentation and delivery	4.4	4.3	4.0	4.0	3.9	4.5	4.5
Knowledge of the subject material	4.8	4.7	4.7	4.8	4.2	4.8	4.8
Effective use of Teaching aids	4.2	4.4	4.2	4.0	4.0	4.5	4.3
Interest displayed and evoked	4.8	4.8	4.5	4.5	4.7	4.7	4.7
Assistance Provided	4.5	4.5	4.1	4.3	4.5	4.3	4.4
Approachability	4.9	4.7	4.3	4.7	4.5	4.9	4.8
Teaching quality	4.6	4.7	4.2	4.3	4.6	4.7	4.6
Average score	4.5	4.5	4.3	4.3	4.3	4.6	4.5

Conclusion

The introduction of inductive pedagogy and its associated PBL was the result of necessity rather than intent. The reduction in contact hours and transfer of this subject into the second year level of the mechanical engineering provided an opportunity to re-think the subject philosophy and re-orient it away from its academic framework to one composed of professional and vocational elements. Introduction of PBL facilitated such a process. However such changes have a negative dimension. From the academic's point of view, a greater pastoral care needs to be exercised and consultations with students consume a large portion of free time at the expense of scholarship and research. From the students' aspect there is an emphatic requirement to stay on campus and be in constant touch with team members. Time management for many students in part time employment is impossible to achieve with many students dropping out from the subject. The laboratory part of the course is also problematic since technical staff is short in supply and unfortunately many compromises had to be made.

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Your paper titled AC 2010-682: EMPHASISING PROFESSIONAL ENGINEERING ELEMENTS IN THE TEACHING OF MATERIALS TECHNOLOGY has been accepted pending changes. Please submit your revised paper before the deadline date.

Reviewer Comments	
<p># 1 _____ [None Provided]</p>	
<p># 2 _____ The following paragraph in the introduction is confusing</p> <p>"The School of Architectural, Civil and Mechanical Engineering (ACME) designated 50 percent of the undergraduate curricula subjects to PBL delivery. This was in contrast to a course curriculum based PBL model found in institutions such as Aalborg University and embraced by the School of Electrical Engineering (EE) at VU .The subject based PBL approach relied on the relevant subject coordinators to develop educational delivery based on their perspective on subject epistemology and the role it plays in professional engineering practice. Such "horses for courses" approach also made sense given the number of students enrolled in subjects across all years."</p> <p>What is the author saying? The ACME school identified 50% of their subjects for PBL. What about the EE school? I don't understand the reference of "horses for courses" at all. Also, why isn't the PBL model from Aalborg University referenced?</p> <p>This is another sentence that I do not understand (p.3) "The hybrid teaching and learning model wasw implemented was underpinned by an underlying objective to initiate students into professional way of thinking which encompasses the professional vocational elements."</p>	<p>This section has been re-written to make it accessible to the reader <i>The two engineering schools at VU decided on a different tact in implementing the PBL pedagogy into their undergraduate curricula. The School of Architectural, Civil andMechanical Engineering (ACME) decided on subject-based PBL model and that 50 percent of the subjects constituting their undergraduate curricula designated to PBL delivery. In contrast, the School of Electrical Engineering (EE) at VU adopted a course curriculum based PBL model found At Aalborg University, Denmark. The Aalborg model PBL model seemed to be less realistic at VU because it relied on the assumption of full-time student body completing year stages before ongoing to the next year stage. At VU students were enrolled in subjects across years and the reality of student body focusing on full time academic engineering activity did not exist.</i></p> <p>It is difficult to comment on EE without displaying bias. Needless to say, that after merging both schools into a single school of engineering, it is the ACME PBL model that has been retained. I have provided a concise desceiption lof the Aalborg model.</p> <p>This sentence has simplified and the underlying philosophy explained. It reads ; <i>The educational approach for the subject teaching and learning used a mixture of pedagogical deliveries based on inductive teaching and learning methodologies described elsewhere^{9, 10,11}. These pedagogies focus on active and student-centred learning. The pedagogical approach adopted for this subject is based on the view that though academic and professional communities are communities which participate in knowledge discourses, they also differ in their</i></p>

<p>I do not understand the first paragraph in the assessment section.</p> <p>"To pass the subject students need to obtain 50 or more marks with a minimum 40 percent of maximum marks allocated to each of the subject component."</p> <p>Overall, this paper appears to be written assuming that the reader has a high level of background knowledge. Instead of saying on page 2 "The educational approach for the subject teaching and learning used a mixture of pedagogical deliveries based on inductive teaching and learning methodologies described elsewhere," the author should provide a summary of the educational approach so that the rest of the paper is understandable.</p>	<p><i>perspective on knowledge practices. This is particularly true in case of professional engineering where professional courses have been over-scientized and adopted the norms of science. This differentiation between academic and professional discourses and epistemologies underpinned the teaching and learning model. The objective of this model was to initiate students into a professional way of thinking which encompasses the professional and the vocational elements. The subject was partitioned into three components in which the PBL component played a key strategic role. Greater onus was placed on students to seek out knowledge and information to compensate for the reduction in teaching hours.</i></p> <p>Has been addressed</p> <p>The abstract has been condensed to take into account the thrust of this paper. In the curriculum design section a brief description of inductive methodologies is included.</p>
<p># 3 _____</p> <p>Title: Emphasizing Professional Engineering Elements in the Teaching of Materials Technology</p> <p>Summary: This paper presents the re-developed Manufacturing Materials courses at Victoria University (VU). This paper needs major revision.</p> <p>CREATIVITY AND ORIGINALITY 2</p> <p>Positive Points</p>	

It is nice that the authors introduce the problems and issues that the reformed courses are designed to address (Attrition and skill and knowledge deficit). Also, it is nice that the authors identify the three components that constituted the pedagogical scaffolding and summarize them in a graph.

Thing(s) Can Be Improved

The paper needs to show how the re-developed courses help to solve the problems and issues mentioned in the introduction. I would like to see some qualitative or quantitative assessment that shows that the attrition rate or the knowledge deficit is decreased after re-developing the courses.

It would be better if the authors can provide a short literature review that compares this program with others that are related and summarizes the contribution of this paper.

RELEVANCE 2

The authors explain on page 2 paragraph 3 why they choose Materials and Manufacture as the course to work on. However, by the explanations, I do not see how Materials and Manufacture courses are multidisciplinary. Also, I would like to see how the topics and problems mentioned in experimentation and observation part were chosen because of the multidisciplinary nature of the courses.

REFERENCES 2

It would be better if the authors can refer to some literature regarding Problem-Based Learning (PBL) and similar re-designed courses.

There have not been any data concerning the effect of introduction of PBL on the attrition rate. The reason for the relatively high attrition rates at VU could be due to economic reasons because of the socio-economic background of students, and also due to poor scientific knowledge platform of the student intake. There has been an improvement of the average high school score of the student intake- a situation reflected at other universities. However increased in popularity for engineering courses has not been reflected in the minimum entrance scores of the student intake. However if PBL pedagogy anchors in public consciousness, then perhaps we will see a positive impact on attrition rates at VU. However my point in this paper is that PBL provides a useful educational tool to maintain qualitative and quantitative educational outcomes with less time dedicated to the course.

Addressed in pages 2&3

PBL is bit like a religion and political ideology. It has many interpretations, and many institutions who have introduced their models of PBL have made claims backed-up

<p>OTHER There are several typos in the article that need to be corrected. Title 'Emphasising' Page 2 line 2 'wasw'</p>	<p>by student and employer surveys. However the jury since the measuring tools are less than perfect. I addressed these issues in 2009 ASEE paper.</p> <p>Done</p>