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Aligning Renewable Energy Engineering Units to a Design Studio-based Curriculum

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Abstract

A number of constraints have initiated a major curriculum revision of the Bachelor of Engineering degrees offered at Murdoch University (MU). The new curriculum will have mostly traditionally taught units in first and second year followed by design studios in third and fourth year, incorporating problem and project-based learning. Two examples from European Universities where problem and project-based learning have been embedded in engineering curricula are reviewed. They highlight many positive aspects of student-focused teaching methods, but also show that there is inevitably some loss of technical competency for engineering graduates. The paper then investigates the transition from two traditionally taught units in Photovoltaics and Wind Energy Engineering at MU to an engineering design studio that is part of the Renewable Energy Engineering specialisation. First core content-centred learning objectives are determined before a number of possible projects are evaluated. It is found that, in order to achieve technical as well as process skill competency, students should be exposed to a number of projects and a combination of traditional and problem/project-based learning methods should be applied. The paper also discusses the challenges of a successful implementation of the design studio model at Engineering MU, which will require resources, training and support for staff so that they are prepared for their new roles in a more student focused learning environment.

1. INTRODUCTION AND BACKGROUND

Engineering at Murdoch University (MU) is a relatively small discipline area with nine academic staff members (two of whom are part-time) and approximately 160 students. It is located within modern, purpose built facilities at Murdoch University's Rockingham Campus, 50 km south of Perth, which opened in 1997. Undergraduate Engineering programs offered currently address four main specialisation areas: Instrumentation and Control, Software, Industrial Computer Systems and Renewable Energy.

When Engineering was established at MU, the Bachelor of Engineering (BE) degree structure for each specialisation area was based on a common first year, prescribed curricula for 2nd, 3rd and 4th year (incorporating dedicated units for each specialisation area) and a number of common core engineering units (e.g. Mathematics, Economics and Accounting, Project Management and Organisation, Law) in subsequent years. An overview of this curriculum structure is given for the Bachelor of Engineering in Renewable Energy Engineering (REE) in Table 1.

Since 2003 financial and staff constraints have required a more efficient use of the available resources and are a major driver for change. The challenge is to enable continuation of the degree offerings in the four main specialisation areas without compromising on the quality of education. After a series of discussions between academic staff, a new degree structure has been proposed.

The new degree structure divides the BE degree into two parts:

1. The 1st and 2nd year are common for all areas of specialisation and include units in the sciences, mathematics, computing, electrics, mechatronics, and control engineering;
2. The 3rd and 4th year are built around a *Design Studio* model, which uses a problem-based learning approach to convey the discipline-specific knowledge while exposing the students to design, team work, project management tasks and professional issues.

Table 1. REE Bachelor of Engineering Degree Curriculum in 2003 (Highlighted are units common to all Bachelor of Engineering Degrees and units specific to the REE specialization, hyperlinks refer to the MU Handbook entries (Murdoch University Western Australia, 2004)).

SEMESTER	TITLE	POINTS
1	Engineering Computing I	3
	Engineering Mechanics	3
	Engineering Mathematics I	3
	Foundation Unit: Interactions of Society and Technology	3
2	Engineering Computing II	3
	Engineering Electrics	3
	Engineering Mathematics II	3
	Introduction to Process Analysis	3
3	Data Communications and Industrial Electronics	3
	Engineering Mathematics III	3
	Process Engineering	3
	Energy Management	4
4	Applied Photovoltaics	3
	Control and Instrumentation	3
	Engineering Statistics	3
	Energy Systems	4
5	Engineering Thermodynamics	3
	Energy Economics	4
	Wind Energy Engineering	3
	Bioenergy Engineering	3
6	Solar Thermal Engineering	3
	Engineering Economics and Accounting	3
	Project, Operational and Personal Management	3
7	Engineering Internship or	12
	Engineering Thesis	12
8	Engineering Law	3
	Stand Alone Renewable Energy Systems	3
	Grid Connected Renewable Energy Generation	3
	Engineering Management and Organisation	3

For each specialisation area a student will complete six design studios: three within their chosen specialisation, one generic (and common) Engineering Practice design studio on project management, law, ethics and professionalism, and two studios chosen from other areas of specialisation.

The proposed design studio model for 3rd and 4th year is shown in Figure 1.

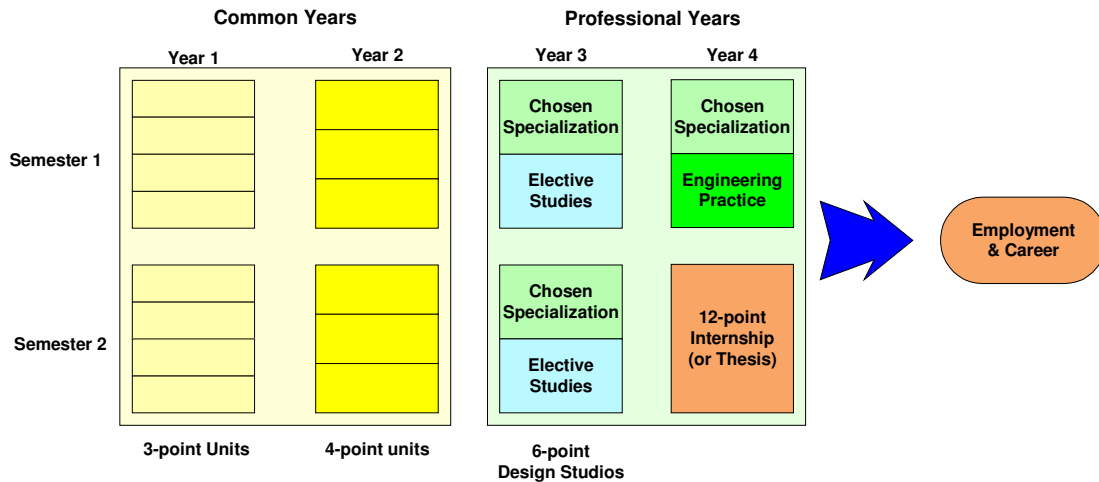


Figure 1 Engineering curriculum for 2005 (Roy & Armarego, 2004).

Engineering staff is now facing the transition to the new degree structure, to be in place from 2005. This paper addresses this transition process in discussing the alignment of the previously separately taught units Applied Photovoltaics and Wind Energy Engineering into the new Engineering Design Studio "Photovoltaics and Wind Energy Engineering", the first of three design studios in the REE specialisation (more details on the new REE curriculum can be viewed on the MU Engineering web page (Murdoch University, 2004)). First the concept of design studios together with examples from the literature will be discussed. The discussion will then assist in:

- defining the intended outcomes (the objectives) for the Engineering Design "Studio Photovoltaics and Wind Energy Engineering";
- the choice of the teaching and learning activities within the design studio; and
- the assessment of the student's learning outcomes (Biggs, 2002).

Finally, the challenges and problems that may arise during this transition and possible measures to overcome these are discussed.

2. DESIGN STUDIOS IN ENGINEERING EDUCATION

Traditional engineering education is characterised by first teaching basic science, engineering and technology concepts, and then exposing students to applied engineering problems (Waks, 2001). *Teacher directed or controlled* teaching methods and activities (Biggs, 2002) such as lecture-based delivery (particularly in the early years of study), tutorials and laboratories are most commonly used. In the later years of their study students apply their knowledge to real world problems, often on their own in a final year project (Mills & Treagust, 2003).

The first dilemma with this content-driven approach is that technical competency is often not sufficient to solve real life engineering problems and that many other skills, which have not been taught, are required to be successful. These include communication and teamwork skills, the ability to keep up with technological change, and a broader understanding of, and ability to deal with, non-technical issues concerning the profession (Waks, 2001, Director et al., 1995, Mills & Treagust, 2003).

A second dilemma is that traditional teaching methods are not very successful in teaching design approaches, concepts and methodologies. Designing can best be learned through personal experience and reflection, experimentation and doing it oneself (Waks, 2001). It requires *student-focussed* or *student-centred* teaching methods (or rather *learning* instead of *teaching* methods) where the teacher is rather a coach or facilitator, who may teach by initially or partially demonstrating, with the students following and expanding on the teacher's example, or by guiding students and letting them experiment and experience by themselves. (Andresen et al., 2000, Biggs, 2002, Mills & Treagust, 2003, Waks, 2001)

The *Design Studio*¹ model proposed by Engineering at MU attempts to overcome these dilemmas by embracing a number of learning models described in the literature (Woods, 1996, Mills & Treagust, 2003, Andresen et al., 2000), in particular, problem-based learning (PBL) and project-based learning. These have similar learning outcomes and are based on self-direction, collaboration and a multi-disciplinary approach. Perrenet quoted in Mills and Treagust (2003), describes some of the differences between problem-based and project-based learning: project work is more directed to the *application* of knowledge, whereas problem-based learning is more directed to the *acquisition* of knowledge. Project tasks are closer to professional reality and therefore take a longer period of time than problem-based learning problems. Project-based learning is often accompanied by traditional teaching methods providing students with the background knowledge required to complete the project. With problem-based learning students control the content and acquire knowledge through their own research.

Some (although not many) engineering education institutions have adopted project-based learning in a significant part of their degree curricula (Mills & Treagust, 2003). Two examples from European universities are presented below:

- *Engineering at Aalborg University, Denmark.* A predominantly project-organised curriculum has been implemented in the Master of Science programs in Computer and Electronics and Electrical Engineering at Aalborg University (Denmark) since 1974 (Fink, 1999, Mills & Treagust, 2003). The 5 year degrees start with a common year in basic science and technology, which also includes an introduction to the methods of project work and teamwork. In the remaining four years the curriculum consists of 50% project work, 25% course work (i.e. lectures, seminars, laboratory exercises that support the project work), and the remaining 25% coursework in core studies such as mathematics, physics etc. Each semester has a theme (e.g. analogue and digital electronics, or real-time communication systems), with students working in groups of 4-6 on a major project that fits within the semester theme and is often industry related. Each group is provided with a workspace, equipped with PC/terminals, where they can work and drink coffee, an environment similar to that found in most engineering work places. Each group has a project *facilitator* who meets with the group approximately once a week to discuss progress. The workspaces are also used for solving problems or computer-based work after lectures. Lecturers walk from group to group to assist in this problem-based learning process. Therefore both problem-based and project-based learning form an integral part of the engineering education at Aalborg.

Evaluation of the engineering education at Aalborg in comparison to the traditionally operating Technical University of Denmark has revealed a number of positive outcomes including (Fink, 1999):

- Higher completion rates (on average 80% as opposed to 60% at the traditionally operating University);
- An average completion time close to the nominal;
- Better preparation of graduates for their first job in terms of presentation, communication and team skills; and a
- Higher degree of self-study and higher student satisfaction with their study.

However, graduates from the Technical University of Denmark were generally stronger in engineering fundamentals and more capable of independent work.

- *Institute for Electro-Mechanical Construction, Darmstadt University of Technology, Germany.* Here project-based learning is part of the latter years of the five to six year Degrees in Precision Electro-Mechanical Engineering (Institute for Electro-Mechanical Construction, 2004c). Students first complete two years of common studies of basic sciences, mathematics and computing together with other engineering students who will go on to one of nine specialisations.

In the 3rd-6th year of their study, approximately 70% of the curriculum consists of prescribed subjects and electives from selected engineering, science and humanity areas, which mainly follow traditional teaching methods. The remaining 30% consist of individual project work towards the end of the study (including a final year thesis) and four semester-long *Project Seminars* in the middle years of study (Institute for Electro-Mechanical Construction, 2004c).

¹ The name *Design Studio* originates from architectural training but is also used in the literature to describe education in technically-based design fields such as software engineering (see Kuhn (2001)).

The first Project Seminar is accompanied by a series of lectures, which provide students with the necessary background in product development and design methodology, as well as problem-solving techniques. Students then work in teams of three to five. During the four semester-long Project Seminars students are exposed to a range of project types. They may work on an individual group project, or a subtask of one common project for all student groups of that year, or they may compete with other groups solving the same project in different ways. In all cases, students work towards a working prototype, a technical documentation of their product and presentation of their work. Each group has a designated supervisor (usually a doctoral student/tutor), a workspace, receives assistance from and has access to the university workshops. Group meetings with the supervisor (usually chaired and organized by the students) occur at least once per week to discuss the project status; assist in decision-making processes and their documentation; and provide a basis for assessment of the individual student contributions (Institute for Electro-Mechanical Construction, 2004b, Institute for Electro-Mechanical Construction, 2004a, Blechschmidt et al., 2001).

Graduates described the Project Seminars as the ideal preparation for their jobs (Institute for Electro-Mechanical Construction, 2004b). The first author has communicated with industry employers who have pointed out the better teamwork skills, and strengths in communication and presentation skill of graduates from this Institute. The time they take to become an effective team member is considerably shorter than for graduates from the same university not having participated in Project Seminars.

These European examples follow a mostly project-based learning approach accompanied by coursework aimed at enhancing technical competence as well as providing the necessary support mechanisms to enable the students to succeed in their project and group work.

The challenge for Engineering at MU is there is little specific training prior to embarking on design studio-learning which prepares the student with the necessary *process skills* (such as group processes, self assessment, and managing change (Woods, 1996)) or design methodology skills. Also, Engineering at MU aims to completely move away from traditional “units” in 3rd and 4th year and teach discipline-specific content solely within design studios.

3. INTRODUCING THE DESIGN STUDIO MODEL IN RENEWABLE ENERGY ENGINEERING

The initial curriculum of the REE degree presented in Table 1 highlights units specific to the REE specialisation. In the 2nd and 3rd year, students study a range of renewable energy technologies and resources associated with solar thermal, photovoltaic, wind and biomass systems. In the 4th year, the focus is on system aspects and technology integration into existing systems such as remote area power supplies and grid-connected systems.

Both Applied Photovoltaics and Wind Energy Engineering had 5 hours contact time (2 hours of lectures, 3 hours of tutorial, workshop or laboratory sessions). Brief unit descriptions are provided in the MU Handbook ((Murdoch University Western Australia, 2004). Both units are relatively new, having only been offered twice. Class sizes have been small ranging from four to thirteen students. Assessment has been based mainly on laboratory reports, assignments, case studies, closed book examinations and student presentations on topics covered in the units.

In planning for the Design Studio “Photovoltaics and Wind Energy Engineering”, one of the aims is to introduce more student-centred learning methods. These will allow for a higher focus on design content and learning outcomes associated with improving generic and process skills. This may result in some loss of specialised knowledge and content-centred skills.

To facilitate the merging of the two existing units into a design studio a reflection on the learning objectives was undertaken. This helped to identify content-centred learning objectives students should achieve in the design studio. These are listed in Table 2. A range of projects were then “brainstormed” and evaluated, based on how they could contribute to achieving the content-centred learning objectives. The projects are listed in Table 3 and described briefly below. Table 3 also lists which content-centred learning objectives the individual projects may achieve.

Table 2 Core learning objectives for Photovoltaics and Wind Energy Engineering

Area	Core Content-Centered Skills and Learning Objectives
Photo-voltaics	<p>PV1. Being able to explain the photovoltaic effect and electricity generation within crystalline silicon cells</p> <p>PV2. Being able to monitor and evaluate the solar resource for a particular site and be able to analyze and estimate the impact of the factors which reduce energy output of photovoltaic systems</p> <p>PV3. Comprehend and gain practical experience on the electrical characteristics of photovoltaic modules and PV interconnection issues</p> <p>PV4. Comprehend and gain practical experience with PV system components such as inverters, batteries, charge controllers and diesel generators.</p> <p>PV5. Be able to analyze the differences in inverter technologies for grid-connected and stand-alone PV systems</p> <p>PV6. Evaluate and analyze different types of Photovoltaic systems for grid-connected and stand-alone applications</p>
Wind Energy	<p>WE1. Be able to explain the aerodynamic principles used for energy capture and power control in wind turbines</p> <p>WE2. Be able to classify wind turbines and compare different turbine concepts</p> <p>WE3. Be able to estimate the long term annual energy output of a wind farm and provide economic analysis information</p> <p>WE4. Comprehend the mechanical forces acting on wind turbine components</p> <p>WE5. Gain experience in aspects of design, installation and maintenance of small wind turbine systems</p> <p>WE6. Be able to address environmental, social and economic constraints and issues when planning a wind farm</p>

Table 3 Possible projects and anticipated learning outcomes

Projects	Learning Outcomes
1. PV trough concentrator system performance evaluation	<p>PV3 to a high extent</p> <p>PV6, PV2, PV1 to some extent</p> <p>PV4, PV5 partially, if at all</p> <p>Additionally: Detailed knowledge of sun position calculations</p>
2. Monitoring and evaluation of a grid-connected system including islanding test and PV cell technology evaluation	<p>PV2, PV3 to a high extent</p> <p>PV1, PV4, PV5, PV6 to some extent</p> <p>Additionally: Data Communications system knowledge</p>
3. Engineering weather station	<p>PV2 to a high extent</p> <p>WE3 to some extent</p> <p>Additionally: good understanding of renewable energy resource measurement, data communications</p>
4. Installation of a small wind turbine system at the REE outdoor laboratory	<p>WE5 to a high extent</p> <p>WE4, PV4, PV5 to some extent</p>
5. Planning and optimizing a wind farm layout given certain economic and environmental constraints	<p>WE2, WE3, WE6 to a high extent</p> <p>WE1 to some extent</p> <p>Additionally wind farm planning, design and installation aspects</p>
6. Small wind turbine maintenance at the Rockingham Regional Environment Center	<p>WE2 to a high extent</p> <p>WE1, WE4 to some extent</p> <p>WE2 partially, if at all</p>

Possible Projects

1. PV trough concentrator system performance evaluation

The Photovoltaic (PV) Trough Concentrator System at the MU Rockingham Campus (see Fig. 2 below) uses parabolic mirrors to focus sunlight on rows of highly efficient photovoltaic cells for electricity generation. One receiver/mirror pair can be used for individual experiments; the remaining 39 pairs are grid-connected via three single-phase inverters. The system lends itself to investigate current-voltage characteristics of the receivers and mirror concentration factor, to study the effect of by-pass diodes, and evaluate the overall system performance;



Figure 2 REE student cleaning the PV trough concentrator system at the MU Rockingham Campus

2. Monitoring and evaluation of grid-connected systems including inverter and PV cell technology evaluation

Engineering at MU has a number of small grid-connected inverters, which can be connected to one or two PV modules on the DC input side. This allows the assembly of a modular grid-connected PV system with various PV modules of different cell technologies. The system also has some data logging facilities so that energy production can be monitored over time. Students can isolate the DC side from the inverter and perform I-V curve measurements on individual PV modules. Additionally there will be the possibility to safely (due to electrical isolation) observe the inverter voltage and current output waveforms as well as the system behaviour under grid-trip conditions (islanding tests);

3. REOLab weather station installation

Provisions will be made for the installation and commissioning of a monitoring system for wind and solar radiation data in the REE outdoor laboratory (REOLab) at Engineering MU. A number of tasks could be incorporated into student projects including sensor installations, data logging system setup, data analysis and interpretation;

4. Installation of a small wind turbine system at the REOLab

The REOLab currently houses an 18m tower suitable for housing a small wind turbine and wind monitoring equipment. A project could include the installation of the wind turbine, associated controller and dump load/inverter/battery bank with the help of an electrician (equipment provided) and the design of a monitoring system to evaluate/visualize the performance of the system;

5. Planning and optimizing a wind farm layout given certain economic and environmental constraints

Software tools (such as WindFarm (ReSoft, 2004) or WindFarmer (Garrad Hassan, 2004)) allow creating, analyzing and optimizing of a wind farm layout for a particular site. Tasks of this project could be based on given economic and environmental constraints and/or size of a wind farm and could include wind resource description and data input to the software, selection, description and justification of a wind turbine technology and size, optimization of wind farm layout with regard to energy yield and costing of the wind farm and comparison of costs of various technology and layout choices, as well as documentation of the proposed project in view of hypothetical community meetings and discussions;

6. Renewable energy system maintenance at the Naragebup Rockingham Regional Environment Center

The Naragebup Rockingham Regional Environment Centre (Naragebup RREC, 2004) located not far from the MU Rockingham Campus houses a Wind-PV system with a 2.5 kW wind turbine, 2.4 kWp PV array and battery bank. Regular annual maintenance is required for this system and the Centre has sought the support from MU Engineering with this task. Students could be involved in planning of the required maintenance and discussion of maintenance procedures with the electrician on site, attendance during maintenance on site and compilation of a maintenance log recording the list of events during the servicing of e.g. the wind turbine and detailing what maintenance was necessary for each component and any recommended actions for the future.

4. DISCUSSION

In order to achieve the core content-centred learning objectives for “Photovoltaics and Wind Energy Engineering”, a combination of projects and additional (possibly project-assisted) learning sessions are required. Involving students only in for example two semester-long projects, one related to Photovoltaics and the other to Wind Energy Engineering does not seem a suitable approach unless a further reduction of content is tolerated.

In contrast to the Aalborg and Darmstadt models, Engineering at Murdoch does not plan to offer specialised technical or knowledge-enhancing units concurrently to the design studios. In preparation for the design studio model at MU it is therefore very important to first define the content-centered objectives of each design studio so that a certain level of technical competence with graduates is ensured. The use of project-based or project-assisted learning, where the unit coordinator predominantly controls the content (in contrast to problem-based learning where the students predominantly control the content) seems more appropriate.

Incorporating any of the above projects into a design studio will expose students to design tasks only to a varying extent. However, one needs to keep in mind that this is the first of six Engineering design studios and it will be introducing students to a new way of studying and learning. It is therefore appropriate if not desirable to gradually lead students into more complex design projects and focus more on content-centered learning outcomes and process skills in the early design studios.

Combining projects with traditional teaching methods in the design studio allows the immediate application of technical knowledge within a project. This mixed mode approach is supported by Mills and Treagust (2003). They discuss the approach (although applied to an engineering degree curriculum and not on a unit by unit basis) and describe it as “best satisfying industry needs, without sacrificing knowledge of engineering fundamentals”.

Mixing teaching styles may also be appropriate for conveying process skills or non-content-centred learning outcomes: traditional teaching methods may again be suitable for initial introduction, whereas project work is required to enhance the skills. Exposing students to the full range of teaching/learning strategies from recalling and comprehension, via application and analysis, to synthesis and evaluation (Bloom, 1956, Anderson & Krathwohl, 2001) is known to be successful in achieving desired learning outcomes. The design studio environment is especially suited to addressing all these levels.

The hierarchical knowledge structure in Engineering (also present within physics and mathematics) (Mills & Treagust, 2003) poses a challenge to the design studio model. For example, REE students must gain an understanding of the nature of the wind resource, the characteristics of wind turbine technology, and the characteristics of an electric system, before being able to effectively integrate wind farms into an electricity grid. Similarly, in control engineering, before being able to solve complex non-linear control tasks, students need to gain an understanding of basic control principles. Generally, there is a need to provide students with opportunities to practice the application of engineering principles to more basic problems (or projects) before embarking on more complex tasks. Within a design studio environment this challenge could be addressed either through a combination of some learning exercises using traditional teaching methods alongside a significant project-based component or several project-based components of increasing complexity.

5. CHALLENGES

Brainstorming possible projects for “Photovoltaics and Wind Energy Engineering” and trying to address the content-centred learning outcomes felt like opening a can of worms. Now we face the challenge of identifying the learning outcomes in terms of process skills, generating appropriate assessment methods related to both content-centred and process skills learning objectives, and creating the resources and the environment for the learning to take place. In particular the latter should not be underestimated since some projects require significant infrastructure and laboratory set-ups, which still need to be designed and realised.

So far only the first in a series of three specialised REE design studios has been looked at more or less in isolation. However, this should not be the case and the transition should be reviewed as part of the complete revision of the curriculum to the design studio model and in relation to meeting desired content-centred and process skill learning outcomes as well as meeting the graduate attributes required by Engineers Australia (Institution of Engineers Australia, 1999).

Engineering at MU is planning a series of workshops for its academic staff in preparation for the transition to the design studio model. This will provide an opportunity to learn from staff members and presenters who have experience in facilitating problem and project-based learning. The workshops will also provide the opportunity to address some key challenges:

- **Process skills** are not developed by just exposing students with opportunities to gain these (Woods, 1996); cycles of practice and feedback are required. In addition the tutors/coaches/facilitators supervising the students and their project work should possess these skills (which may not necessarily be the case). Training in process skills is therefore required for both students and staff. Woods (1996) provides suggestions on various process skill training examples and Engineering at MU will need to decide how to address this challenge. One possibility could be to prepare engineering students in 2nd year e.g. as part of a common unit or in a pre-semester orientation course providing a foundation to process skills which can then be reinforced during the design studios;
- **Assessment** - With the shift towards more problem-based or project-based learning and the consequent change in learning objectives away from mostly knowledge-based skills to knowledge based *and* process skills, assessment approaches need to be reviewed. Staff may not be familiar with assessment methods suitable for group work, peer and self-assessment, and assessment of process skills and training should be provided;
- **Learning Environment Resources** – Shifting to the design studio model will require different resources and lead to a different learning environment. Academic staff will need to dedicate a larger proportion of their time in providing these resources and creating a suitable learning environment. For example, for the proposed Project 2 above, qualified personnel will need to design and install the majority of the power circuits for the grid-connected PV system before students can be involved, since the system operates at dangerous voltage levels. Other projects may require student access to the workshop, or require space for regular and multiple group meetings. The School and MU will need to recognise that needs may change and provide funding and a support structure to facilitate a learning environment which is suitable for the design studio model;
- **Recognition of the changes and evaluation** - Students as well as staff will need to come to terms with the changes imposed by the transition to the design studio model. Many academic staff members (including the first author of this paper) have been exposed to a very traditional

engineering education; lecturing is what they are familiar with, and the coach/facilitator role is relatively new to them. The new model will only work if academic staff are appropriately trained and put in the effort to make the transition. This needs to be facilitated by a supportive, collaborative environment where the model is evaluated and reviewed on a regular basis, changes are decided upon in an open consultation process and where efforts to implement the changes are recognised, valued and supported.

6. SUMMARY

A number of constraints have initiated a major curriculum revision of the Bachelor of Engineering degrees offered at Murdoch University. The new curriculum will have mostly traditionally taught units in first and second year followed by design studios in third and fourth year, incorporating problem-based and project-based learning.

The transition from traditionally taught units to a design studio has been investigated for one example: the Engineering Design Studio "Photovoltaics and Wind Energy Engineering", which is part of the REE specialisation. Determining the core content-centered learning objectives for this particular design studio allowed a better evaluation and determination of suitable projects. However, to determine desirable learning outcomes in terms of process skills, one design studio cannot be looked at in isolation. Also, student training in process skills is recommended, possibly in the second year of study with the aim of reinforcing these skills in the subsequent design studios.

A review and a closer examination of two examples of problem and project-based learning embedded in engineering curricula highlighted many positive aspects of student-focused learning methods and their effectiveness in preparing engineering graduates for the engineering profession. However it was also noted that the transition may lead to reduced technical knowledge with engineering graduates. In order to keep this to a minimum, a mixed mode approach is recommended combining traditional and problem- as well as project-based learning methods.

Finally, for the transition to the new design studio model to be successful, Engineering at MU will need to provide resources and support as well as train its staff so they are prepared for their new roles in a more student-focused learning environment.

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