

Introduction to Engineering Concepts – a Broader First Year Course

Keith Godfrey

School of Engineering, Murdoch University, Western Australia

Abstract

Murdoch University is transforming its first year engineering course to meet the emerging needs of the engineering profession. Traditional courses have focussed on engineering theory, with specialised science and mathematics being the historical bases of engineering. The new course introduces wider skills and knowledge associated with the practice of professional engineering, in addition to fundamental rather than specialised theory.

At the heart of the first year is a new unit called Introduction to Engineering Concepts. This unit combines teamwork, communication, ethics, law, problem solving and professionalism in addition to a cross section of traditional engineering theory. Students are encouraged to think logically about situations that they might encounter in their careers. The assessment places as much emphasis on good communication as on technical theory.

The challenge in teaching such a unit is the broad range of its content. It introduces the evolution of the profession, codes of ethics and ethical reasoning, common law and the tort of negligence, English grammar and scientific writing, preparation of a curriculum vitae, presentation of a talk, techniques of conducting meetings and recording minutes, problem solving techniques, and fundamentals of statics, dynamics, electric circuits, digital logic and thermodynamics. Each of these topics is a specialised domain and would previously have been taught by a different specialist lecturer. As the university structure allows only one or two academics to run this introductory unit, the staff must become broad experts to encompass the syllabus – just like today's professional engineer.

With the changing engineering profession, Murdoch believes that its proactive approach in tailoring its courses to industry needs will enhance its position and add further value to its students.

Introduction

The educational environment in Western Australia is unique because of its distance and isolation; Perth is the most isolated capital city in the world. Each year the engineering schools of four universities compete for a pool of around 1000 new students. The next closest university catchment is unrelated because it is 2000 kilometres away.

Each of these universities has carved a niche in the market. One has the prestige of being the oldest; one has the distinction of a heavy overseas presence; one focuses on broad teaching but specialised fields of research; and this leaves Murdoch University, the smallest and

youngest of the engineering schools. The challenge for Murdoch is to grow its niche in this competitive environment.

There are two ways to expand the student population. One is to increase the intake. The other is to increase the retention rate. It is easier to retain an existing student than to recruit a new one, especially from a very limited pool of applicants. Thus Murdoch has recognised that it can grow faster by improving its retention rates than by increasing its market share or by increasing demand for engineering in general, although all these efforts are important.

Improving the First-Year Experience

The first-year course is the most crucial in terms of improving the retention rates. The drop out rate is higher in the first year than in any subsequent year. A survey of first year students found that the top five reasons for switching majors were:^[1]

1. Poor teaching by Science, Mathematics and Engineering faculty,
2. Inappropriate reasons for having chosen a Science, Mathematics or Engineering course,
3. Inadequate advising or help with academic problems,
4. Lack of interest or loss of interest in Science, Mathematics or Engineering, and
5. Non-science major offering better education or more interest.

Engineering is not a subject taught in high school and it may not meet students' expectations. Students may have chosen engineering because people told them their mathematics and science skills qualified them for this career, or perhaps they were aware that engineers can earn good salaries. Students may like the engineering curriculum outlined in the course handbook but may drop out during or after the first year because they do not see the relevance of the first-year engineering units.

The first year at university marks a transition in the lives of young people both socially and academically. The university environment provides a change in schedules, expectations and relationships. At Murdoch, where there is a significant mature age entry, the transitions experienced by the students are very individual and diverse.

Despite it being the most formative year, the first year at university can also often be the least satisfactory in terms of concept, curriculum and pedagogy.^[2] Many students spend time in remediation programmes to catch up on inadequate prerequisites. Introductory courses often repeat subject matter that the students have already studied for years instead of introducing new subjects that broaden their horizons and give them a sense of adventure and learning.

Designing a first year curriculum involves a balancing act between several opposing forces:^[3]

- A minimum knowledge of fundamentals in science and mathematics is required to prepare students for the second-year units;
- Exposure to the nature of engineering and its opportunities is needed to enable students to identify an appropriate career path;
- The academic rigor of first year engineering may be overly challenging for some students, especially those with inadequate prerequisites in mathematics and physics;

- There is external pressure for engineering education to include communication skills, ethics, professionalism, design, teamwork, leadership, entrepreneurship, global understanding, all of which vie for curriculum time; and
- There is a need to monitor the ongoing research in engineering education and to consider issues such as diversity and social responsibility.

Murdoch University has a common first-year programme that mixes students of the BE (Bachelor of Engineering) and BTech (Bachelor of Engineering Technology) courses. The BE course leads to a professional engineering qualification and has prerequisites in calculus and physics. The BTech is a 3-year course for engineering technologists and has much lighter prerequisites. The different backgrounds are an additional complication in designing uniform first-year content.

Styles of Teaching and Learning

Academics are familiar with calls to move away from the traditional lecture theatre and engage students in interactive learning, student-centred learning instead of a teacher-centred learning. With the traditional lecturing approach, universities tend to focus on what curriculum is being taught, rather than focusing on what the students are learning.^[4] The Boyer commission's report on reinventing undergraduate education, a detailed survey of 120 American research universities, recommends an inquiry-based first year, a linking of communication skills and course work and a change in the faculty reward systems to promote excellence in undergraduate education.^[2]

When financial constraints make the lecture theatre approach necessary, the challenge for lecturers is to adjust their teaching styles to achieve the intended learning outcomes. The opportunities for learning are extended through assignment work, presentation work and teamwork.

Inquiry-based learning and collaborative learning are known to engage students in the process of discovery.^[5] The lecturer's task then is to frame the problems such that the students are guided appropriately in their learning. Albert Einstein observed that "*The history of scientific and technical discovery teaches us that the human race is poor in independent thinking and creative imagination. Even when external and scientific requirements for the birth of an idea have long been there, it generally needs an external stimulus to make it actually happen. Man has, so to speak, to stumble right up against the thing before the right idea comes.*"^[6] Einstein was speaking in the context of research and invention but his comments apply equally to teaching. The discovery learning approaches are less likely to be effective in helping students to acquire an understanding of engineering and design than a teacher-driven approach where the learning is shaped carefully so that the students stumble to just the right conclusions.^[7]

Murdoch has chosen a teacher-driven lecture-based approach in the first year, with student collaboration in written assignments and oral presentations, and mutual critique of work in parallel with traditional assessment.

Comparisons with Universities Internationally

Murdoch is not alone in revising its first-year course. Across all disciplines, 27% of American universities reported that their greatest innovations in the previous three years were to revise the general education curriculum including increasing the emphasis on teaching writing, communication and math skills.^[5]

Interestingly there is a greater emphasis on writing skills than on oral communication skills. Writing skills were infused in the first-year units in 95% of universities surveyed, with 52% continuing the emphasis into two semesters. Only 19% of the same universities responded that oral communication skills are taught in their first-year courses and about 30% reported that they do not offer any units or activities to promote development of oral communication skills, anywhere in their degree courses.^[5]

Some universities are so large that they have had an entire department dedicated to their first year course. Purdue University for example has an annual intake of 1600 students and has had a separate Department for Freshman Engineering for more than 50 years.^[3] Vanderbilt University has been able to trial two different styles of freshmen courses in parallel on different groups of students within the same year, demonstrating that problem based learning is more beneficial than traditional teaching techniques.^[8] Murdoch University is small by comparison, with an annual intake of 65 students. The resources available do not permit such broad research into first year teaching nor parallel trials of different approaches.

To increase retention rates and market share, Murdoch is making best-guess decisions as to the direction of its first year course, implementing them, and waiting to see the results. This paper is written at the implementation stage, while the new unit is in its final week of teaching.

Introduction to Engineering Concepts - a new first year unit at Murdoch University

At the heart of the new first-year structure at Murdoch University is a new unit called Introduction to Engineering Concepts. The traditional view of an “engineering concept” comes from the abundance of technical theory that an engineer must absorb. In today’s playing field however, engineers must also have an understanding of teamwork, communication, ethics, common law, analysis and professionalism.

The subject material is broad, ranging from ethics to thermodynamics. Students spend some of their time in lectures where material is presented in traditional ways, and they work on project exercises both individually and in teams, depending on the topic.

The unit has been divided into the three sections shown in Table 1.

Section 1. Introduction to Engineering	
• What is Engineering?	
• Historical Perspective	Engineering from the beginning, engineering in the 20th century, Research, Commercialisation.
• Evolution of the Profession	Professional organisations, international standards, evolution of global companies, profession in Australia.
• Engineering Today	Basic sciences, Disciplines, Intellectual property, Management, Career paths, Entry into employment, Entrepreneurship.
Section 2. Core Skills	
• Ethics	Ethical thinking, Codes of ethics, Ethical problems, Ethical problem solving.
• Problem Solving	Problem definition, Problem solving strategies, Teamwork, Error-free problem solving, Estimation, Creativity, Design
• Communication	General writing, Scientific writing, Presenting a talk, Developing a web page, Professional record or diary, Preparing a CV, Interview techniques, Conducting meetings
Section 3. Basic Knowledge	
• Modelling	Models and bounds, Time-dependent models, Probabilistic and stochastic models.
• Engineering Mathematics	Numbers, Tables and graphical techniques, Statistics, Calculus, Software tools.
• Engineering Fundamentals	Measurement, Units and dimensions, Newton's laws, Statics and dynamics, Thermodynamics, Electricity and circuits, Digital logic, Counting and accounting for work and energy

Table 1. Unit Outline for “Introduction to Engineering Concepts”

Examples of Project Work

The breadth and depth of the subject material are best illustrated by examples of the project work that the students are asked to complete. Examples of both individual work and team work are shown below.

Negligence:

A girl runs across the road, in a hurry, but catches her foot on a concrete island in the middle of the road, trips and breaks her glasses. She wants a new pair of glasses. Discuss whether the engineers who specified the height of the concrete island could be found negligent.

Ethics:

Suppose you are an engineer designing a housing development. Your development is for 100 homes. The property adjacent to your property is a large hilly area, currently heavily treed, but one day may be converted into a shopping centre. What factors determine the size of drainage pipe that you recommend for your sewerage system? If your client, the housing developer, wants to get by with the minimal costs, who should bear the cost of expanding the drainage system in the future to take account of additional run-off from the neighbouring site? What action can you take if your housing developer shows no concern for who should bear this cost in the future?

Estimation:

Estimate the weight of traffic on the northbound Narrows Bridge in the middle of the morning rush hour. Marks will be awarded for your approach rather than your final solution.

Written communication and application skills:

You are offered the opportunity to submit an application for a university scholarship that is funded by the XYZ Heartbeat Corporation. The XYZ Heartbeat Corporation is a multinational company with headquarters in Perth that specialises in writing embedded software for artificial hearts and pacemaker inserts. The company employs about 400 people worldwide. The scholarship is a cash prize of \$1,000 with no strings attached, although the company would like to discuss the possibility of vacation employment.

- Explain in no more than 50 words why you are studying at Murdoch University.
- Explain in no more than 50 words why you chose your degree course.
- Write an essay of no more than 500 words explaining why you should be selected.

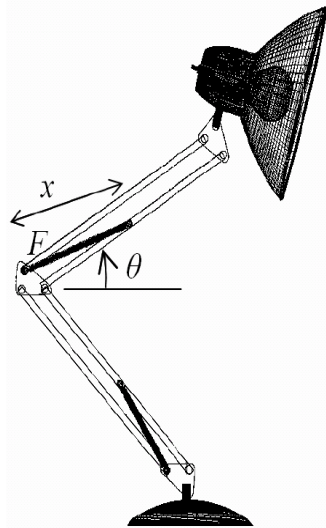
Job application process:

Suppose that you are a referee who has been asked to write a letter of reference in support of a student's application (it can be either yours or for another student.) You are asked to comment on the student's academic ability and on why you have nominated this student. Your letter should be marked confidential and addressed to the attention of the Human Resources Manager, Mr Irkin Firkin, at the company address 34 Pace Place, Bedford 6199.

- Write a good reference that gives excellent support for this student.
- Write a reference that is presented correctly and that can be seen by the student but that does not assist the student. (The trick is to show that you know how to write references but that this particular candidate is not special. Deliberate ambiguity is not required.)

Engineering Statics:

Consider the following sketch of a common desk lamp.



Assume that:

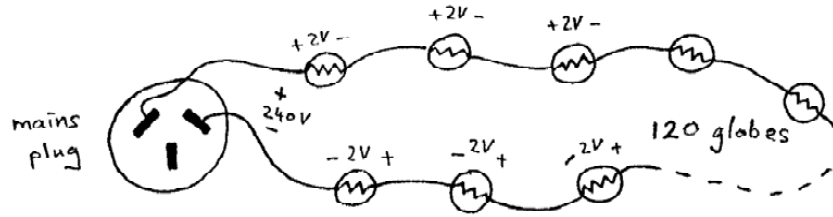
- the lamp head weighs 10 N,
- the lamp head weight acts between the pair of upper strut pins,
- the struts, springs, joints and other components have no weight,
- the struts are 50 cm long,
- the elbow joint angle is 30° to the horizontal,
- the strut pins at the joints are 4 cm apart, and
- the springs are connected to the centres of their struts.

Now consider only the upper portion of the lamp.

- Draw a detailed geometrical diagram for the upper portion.
 - Derive an expression for the spring length x as a function of the upper arm angle θ .
 - Derive an expression for the spring force F required to hold the lamp in position without movement. (Hint: Consider the component perpendicular to the struts and relate geometry to x).
- (d) Use a graphing package or spreadsheet such as Excel to sketch:
- The length x of the spring as a function of angle $0 < \theta < 90^\circ$
 - The required spring force F as a function of angle $0 < \theta < 90^\circ$
 - Required spring force F as a function of spring length x
- (e) From your graph in part (d)(iii) determine the optimal spring constant k and length at rest x_0 . Sketch the line that k and x_0 make on the graph. Justify why you chose that part of the curve.

Electric Circuits:

To illuminate a Christmas tree, 120 decorative light globes are connected in series as shown below. These are connected to the mains voltage supply, which in Perth is 240V rms (this means 240V root mean square of a sine wave - but the sine wave doesn't matter for this question.)



When operating normally, the voltage across each globe is 2 volts (i.e. 240 volts shared across 120 globes in series.) This means that small 2V light globes can be used.

Now consider what happens if one globe fails. All the lights will stop shining because they are in series. If you decide, foolishly, to change the blown globe while the tree is still connected to the mains, what will be the voltage drop across the empty globe socket? Justify your answer.

Thermodynamics:

When brakes are applied to stop a moving vehicle, the energy is transferred into heat in the brakes. If you increase the weight of the vehicle by 10%, how much is the increase in heat created when stopping? If instead you increase the velocity by 10%, how much is the increase in heat? Why?

If an engine is 20% efficient in converting heat energy to mechanical energy, what happens to the other 80% of heat?

Probability:

Suppose that a manufacturing defect occurs in 1 in 1000 microchips being produced in a production line. For quality control, there is a test that can be applied to a microchip to investigate whether it has this defect, however this test is only 99% accurate (i.e. it gives the correct result in 99% of the cases and gives the wrong result in 1% of the cases.) If you apply this test to a microchip chosen at random, and if the test says that the microchip has the defect, what is the probability that the microchip actually has the defect? Justify your answer.

Individual presentation arising from team work:

Your team is tasked to deliver a "super marble tanker" – a floating paper vessel that can contain the maximum number of marbles without sinking. The tanker shall be made out of a single piece of A4 paper, which you may cut if you wish. You may use staples and common stationary only. Document every step of your problem solving effort.

Present individual talks on your group problem solving exercise.

As this is an individual talk, you may vary your approach from your group.

- Your talk should cover the design principles or concepts that were found to be effective, and explain the theory behind them.
- You should show a knowledge and understanding of scientific or engineering principles. Assume that your audience is intelligent but has not studied Physics.
- You may wish to describe how alternate solutions were generated in your group and the process that led you to select your final design.
- You may wish to compare the performance of your design with other designs, or aspects of yours with others, justifying your choice objectively.

Group presentation:

Groups of 4 to 5 people are required for this presentation.

Design and build a rubber-band powered vehicle (car) that uses common materials and costs less than \$20. The car should travel as far as possible, in a straight line, using the energy in the rubber band.

You are required to make a scientific presentation, as a group, about your car design.

Your presentation should include:

- An explanation of the problem (a scientific approach to the issues involved in making your car travel as far as possible, using fundamental concepts such as acceleration, friction, torque, etc.)
- A mathematical model for your car leading to estimates of its performance, having measured its mass and the various forces involved. Compare your estimates with the actual performance.
- Graphs and/or tables showing the effects of changing the various design parameters in your mathematical model, and therefore how you selected the values for your car. (For example you might show a graph of maximum speed against a range of wheel diameters, leading to your choice of the optimal diameter.)
- Statistical results (graphs and/or tables) describing the actual performance of your car, having run it through several tests.

There is no need to mention how you worked as a group. You should concentrate on justifying your car design by convincing the audience that you understand the engineering principles involved.

Table 2 (across three pages). Examples of individual work and project work

Teaching Issues

This new unit spans an incredibly broad range of topics. It introduces topics that would have been taught previously by several distinct schools or faculties, as indicated in Table 3:

Topics in “Introduction to Engineering Concepts”	Traditional Faculty
Common law and the tort of negligence	Law
Presentation of a talk, conducting meetings, ethical reasoning	Management
Grammar, writing skills	Arts
Preparation of a curriculum vitae	Careers Service
Evolution of the profession, codes of ethics	Professional body
Scientific writing, problem solving, graphical techniques	Science
Statics, dynamics, electric circuits, digital logic, thermodynamics	Engineering

Table 3. Traditional sources for the topics in “Introduction to Engineering Concepts”

The funding structure for this unit does not allow the luxury of employing staff from other departments. The task therefore falls to one or two teaching staff from engineering to cover the entire syllabus.

An interesting challenge for the teaching staff is that they did not study the material themselves when they went through university. Whilst engineers are used to adapting to a changing technical field, the situation is different with this unit because it extends into different schools such as Law and Arts. These have never previously come under the umbrella of engineering. The staff must adapt to handle excursions into discipline areas that are substantially non-scientific.

Results

The impact of the new course cannot be measured yet because the unit has been adopted starting with the first year intake in 2005. Early indications are that the new unit is maintaining student interest and creating a higher than usual level of interaction in the classroom. These indicators are subjective. Objective indicators will include the student numbers on intake, the retention rates and ultimately the rate of uptake in Murdoch graduates compared with the competing local universities. The predictions are that the retention rate will increase and that the students will present better applications for vacation employment.

Future Direction

The new unit will evolve and be improved, iteratively, in subsequent years beyond 2005. Thoughts for improvement at this stage include:

- Inviting guest lecturers for specific topics such as writing a CV,
- Inviting professional engineers to serve as role models,
- Formalising the mutual critique of work,
- Involvement of students in teaching other students, as a means of increasing their own learning, and
- Creating laboratory classes with practical investigation of the scientific component.

Conclusions

The new unit “Introduction to Engineering Concepts” has been established at Murdoch University in 2005. This unit is a broad introduction to the wider concepts of engineering including ethics, written communication, oral communication, teamwork, professionalism and problem solving, in addition to traditional engineering theory such as statics, dynamics, electric circuits and thermodynamics.

The unit is an interesting challenge to the staff teaching it because of its breadth. Instead of all the lectures relating to a single curriculum area, each lecture spans a different field that would traditionally have been taught by an expert from a different department.

With the changing engineering profession, Murdoch believes that its proactive approach in tailoring its courses to industry needs will enhance its position and add further value to its students. The next few years will establish whether this change from traditional philosophy achieves the desired goals of increasing the student retention rate and increasing the market share of Murdoch University’s engineering school within the small Western Australian environment.

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Biography

Keith Godfrey gained his Bachelor of Engineering from The University of Western Australia in 1988 and then lectured the first-year programme there for 12 years, whilst also establishing annual engineering summer camps for high school students and an electronics programme for 120 high schools across Australia. After leaving UWA in 2000 for a job in industry, he worked around the world on meteorological telemetry projects, becoming the technical lead and project manager for wind shear alerting systems, airport weather observation systems and national networks of weather stations. After starting a family in 2004 he decided to return to academia, joining Murdoch University in 2005.