IPENZ
ENGINEERS NEW ZEALAND

FUTURE EDUCATION OF PROFESSIONAL ENGINEERS IN NEW ZEALAND

WHAT FORM SHOULD THE EXEMPLIFYING QUALIFICATION TAKE IN 2020?

Purpose: The purpose of this paper is to outline the changes to the Washington Accord graduate profile exemplar, the relevant international benchmark for New Zealand professional engineering education, and to discuss options for ensuring that New Zealand can continue to conform to this standard in the future. This paper will be used to inform the consultation with industry, the engineering profession and tertiary providers.

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1. EXECUTIVE SUMMARY

In June 2009 the exemplar graduate profile of the Washington Accord[1] was enhanced by:

- a stronger statement of the knowledge profile
- an expectation that graduates will be able to operate close to the frontiers of knowledge in their discipline
- an expectation that graduates have the capability to research rather than just investigate problems
- an expectation that students are exposed to the practice (non-theoretical or codified) knowledge being applied within day-to-day practice in their discipline
- stronger comprehension of contextual knowledge and the ability to apply that knowledge
- the ability to apply ethical principles.

It is suggested by the Washington Accord, that achieving this graduate profile requires 4 - 5 years of tertiary education, dependent on the entry level. Possible strategies for ensuring that our professional engineering qualifications conform to this now more demanding Washington Accord graduate profile include:

- continuing the present qualification structures and entry criteria to both degree types, but squeezing out unneeded material
- continuing the present qualification structures, but raising the entry standard to the Bachelor of Engineering (BE) degree
- setting a higher entry standard for the BE degree but developing a “Year 0” or foundation year that all but the very best students would be required to take
- as in the previous option, but restricting the foundation to only one semester, so the poorer students take 4.5 and not five years
- developing a five-year qualification including a one semester foundation (exempt for the very best students) and an extra semester of study on top
- moving to an integrated five-year qualification

[1] New Zealand professional engineering education has been benchmarked to the Washington Accord since 1989.

- moving to a first cycle (three-year Bachelor) and second cycle (two-year Masterate) structure.

This discussion paper is intended to inform the tertiary sector, industry and graduates about the issues and seek feedback which will be used to formulate a national strategy which ensures our professional engineering education continues to be benchmarked to international good practice.

2. BACKGROUND

This paper should be read in conjunction with a paper entitled *Review of Engineering Qualification Structures – Overview* which sets out the wider context in which the present discussion paper sits.

3. CHANGES IN THE NEEDS OF NEW ZEALAND

The last decade has been characterized by supply of more graduates, rather than of different graduates. In the next two decades, the needs may be different. There will be continuing demands for engineers to build increasingly complex infrastructure, but also a desire for engineers to lead the development of intellectual property that can be commercialised to grow new industries or transform existing industries. There may also be an increased need for engineering leaders and for greater ability of graduates to conduct and apply research in an industrial or business context.

4. CHANGES IN THE WASHINGTON ACCORD

In June 2007, a review of the Washington Accord graduate profile exemplar commenced. That has led to a revised profile (Table 1) approved in June 2009. Changes made since the profile exemplar was first developed in 2005 include:

- a stronger statement of the knowledge profile
- an expectation that graduates will be able to operate close to the frontiers of knowledge in their discipline
- an expectation that graduates have the capability to research rather than just investigate problems
- an expectation that students are exposed to the practice (non-theoretical or codified) knowledge being applied within day-to-day practice in their discipline
- stronger comprehension of contextual knowledge and the ability to apply that knowledge
- the ability to apply ethical principles.

It is further suggested by the Washington Accord that achieving this graduate profile requires four - five years of tertiary education, dependent on the entry level.

Table 2 shows the graduate profiles approved under the EUR-ACE trademark, and operated by the European Network for Accreditation of Engineering Education (ENAEE). These graduate profiles are for first cycle (three-year) and second cycle (after a further two-years) study. The latter profile more closely correlates with the Washington Accord exemplar in Table 1.

5. PRELIMINARY CONSULTATION

In May 2009, two consultation meetings were held with small groups of leading thinkers in engineering from industry and the tertiary providers. The focus was on the graduate profile and the future needs of New Zealand. Key outcomes from the discussion were:

- There is a need for professional engineering graduates who are “rounded” and not just technical boffins – many of the existing graduates do not have strong “soft” skills.

- Professional engineering graduates should aspire to leadership roles, and their education should equip them to commence their preparation towards such roles.
- Graduates entering industry have technical knowledge that is largely theoretical, and industry needs to invest considerably to close off the knowledge gap between principles as taught and codified knowledge as used in industry.
- Graduates entering industrial research roles are educated in insufficient depth towards the frontiers of knowledge.

The participants were challenged as to whether the 2009 Washington Accord graduate profile described the graduate they desired. There was general consensus that it did represent the ideal professional engineering graduate for the future. The focus of the National Engineering Education Plan (NEEP) Project should therefore be on educational models to achieve that graduate profile.

6. POSSIBLE QUALIFICATION STRUCTURES

Possible strategies for ensuring that our professional engineering qualifications conform to the more demanding Washington Accord graduate profile include:

- continuing the present qualification structures and entry criteria to both degree types, but squeezing out unneeded material
- continuing the present qualification structures, but raising the entry standard to the BE degree so the quality of students is higher, allowing more material to be covered. In essence this option would change the balance in graduate numbers between the four-year BE degree (for which fewer students would reach the entry level) and the three-year Bachelor of Engineering Technology (BEngTech)
- setting a higher entry standard for the BE degree but developing a "Year 0" or foundation year that all but the very best students would be required to take – in effect some students would be required to do five years
- as in the previous option, but restricting the foundation to only one semester, so the poorer students take 4.5 and not five years
- developing a five-year qualification including a one semester foundation (exempt for the very best students) and an extra semester of study on top (but noting that the form of this study could be industry-based and not necessarily academic)
- moving to an integrated five-year qualification
- moving to a first cycle (three-year Bachelor) and second cycle (two-year Masterate) structure.

Each of these options has advantages and disadvantages as set out below. There may also be others not set out here.

6.1 SQUEEZED EXISTING QUALIFICATIONS

As outlined above, there appears to be considerably more educational development of the student required to meet the 2009 Washington Accord graduate profile than the 2005 profile. All tertiary institutions have already progressively moved material to the first year so the ability to squeeze more in is limited, and such squeezing in puts at risk the time to be reflective (see criticism about narrow technical views above). All tertiary providers complain that that the entry standard in calculus and physics from schools remains only marginally satisfactory. The biggest single factor in determining success or otherwise of engineering students is their ability to pass first and second year mathematics papers, with ability in physics and to some extent chemistry the next determinant.

Taking these factors into account, if this option was adopted then it is likely that the entry standard would need to be raised, meaning that either the balance of student numbers between the BE and BEngTech would change, or many students would end up doing extra pre-enrolment study. Even with that change, the broader skill base desired in the graduate profile would be difficult to achieve.

Conclusion: Not a viable option.

6.2 RAISED ENTRY STANDARD

The rationale has been set out in Section 6.1.

Conclusion: Not a viable option.

6.3 FOUNDATION YEAR 0

Year 4 – Higher level of technical knowledge than in current BE, industry-based project work
Year 3 –Specialisation papers plus contextual knowledge
Year 2 – Specialisation papers plus contextual knowledge
Year 1 – Broad engineering papers plus contextual knowledge
Foundation Year 0 – some first year papers of current four-year BE e.g. Maths, Physics and other preparation papers for entry to a higher level second year

In this model, if some content from the first year of the current BE drops into the Foundation Year, then students will accelerate through the degree to attain a higher level of technical knowledge in the fifth year. Employers value a graduate with a broad knowledge of engineering so specialization might not occur until the third year. Exposure to contextual knowledge is as important as technical knowledge and is included in each year to develop the work-readiness of students. In the third year, students develop their research skills and in the final year, students use their research skills in an industry-based project (up to 60 credits or half the year) while in supervised work experience. The other papers (up to 60 credits) in the final year focus on attaining a higher level of technical knowledge at the forefront of the discipline.

In effect, this option makes the BE a five-year degree for the normal student, with the best students being exempt the first year. The weakness of the model is that if a fifth year is to be added, then it would be better designed as an integrated part of the qualification. Further, it is questionable whether doing a fifth year to get a Bachelor's degree would be valued by students if others can get a Masterate after five years.

Conclusion: Could be viable, but not desirable.

6.4 FOUNDATION SEMESTER ONLY

Year 4 – Higher level of technical knowledge than in current BE and industry-based project work
Year 3 –Specialisation papers plus contextual knowledge
Year 2 – Specialisation papers plus contextual knowledge
Year 1 – Broad engineering papers plus contextual knowledge
Foundation Semester – some first year papers of current four-year BE e.g. Maths, Physics and other preparation papers for entry to a higher level second year

This option would still leave a squeeze on the final four years – it could be a useful transitional model.

Conclusion: Not a viable long term option.

6.5 Split First Year and Final Year

Year 5 – Industry-based project work
Year 4 - Higher level of technical knowledge than in current BE plus contextual knowledge
Year 3 – Specialisation papers plus contextual knowledge
Year 2 – Specialisation papers plus contextual knowledge
Year 1 – Broad engineering papers plus contextual knowledge
Foundation Studies which includes Maths, Physics from the first year of the current BE

This model includes a half year of Foundation Studies to prepare students for entry into a higher level first year. Years 2 – 4 includes technical content at a higher level plus contextual knowledge with specialization occurring from Year 3. In Year 4 students develop their research skills; attain a higher level of technical knowledge; and prepare for the industry project. The final year is a half year or 60 credits of supervised work experience working on industry projects.

The flexibility of this model may be attractive to both students and employers. Students could gain exemption from the Foundation Studies year and enter directly into the first year if their entry grades are high enough. If they do not gain an exemption, they would have the opportunity of working part-time during the first year. They may also enter the workforce in the fifth year and complete the industry-based project while working.

Conclusion: Could be problematic as it does not fit the normal academic year well, but potentially viable.

6.6 Integrated Five Year Qualification

Year 5 – Higher level of technical knowledge than in current BE, industry-based project work
Year 4 –Specialisation papers plus contextual knowledge
Year 3 – Specialisation papers plus contextual knowledge
Year 2 – Broad engineering papers plus contextual knowledge
Year 1 - Broad engineering papers plus contextual knowledge

In this model, students enter Year 1 through the current entry requirements and have two years of exposure to broad engineering knowledge and contextual knowledge. Industry representatives have commented on the need to broaden graduates as the current four-year degree tends to specialize too early. During Years 3 - 5 students work on their specialization with a goal of attaining a high level of knowledge at the forefront of their discipline in Year 5.

A variation to the fifth year could be four streams of learning:

- a technical paper with content at the forefront of the specialization
- a contextual knowledge paper
- a study of the sector where students use their research skills to conduct a broad study of a major development or issue in the sector they propose to work in
- an industry-based project which, if possible, is supervised work experience.

The risk with moving to such a structure is that students will be less willing to enroll for a longer qualification. However experience in the UK when the engineering degree was lengthened, was that students elected the longer and higher level (better) qualification.

Conclusion: This model conforms to international best practice and will produce graduates conforming to the 2009 Washington Accord profile and meeting industry needs; the issues are of attracting sufficient students and obtaining funding for delivery.

6.7 Two Cycle Model

In this model the three-year programme would be a foundation programme of general studies in engineering, and the Masterate would do the integration. A student choosing to exit after three years would not necessarily receive a BEngTech (the integrated Sydney Accord qualification), but rather might be awarded a degree in engineering principles or engineering studies. The first cycle would then probably include mathematics and engineering analysis to above the BEngTech level, but would not include the integrating studies typical of a final year of a BEngTech.

The role for the first cycle graduates in industry has not been established if it is different from a Sydney Accord qualification. It might provide a base for students doing a double degree in engineering and business (with career pathways to being an engineering-informed business person).

Conclusion: This model also conforms to international best practice and will produce graduates conforming to the 2009 Washington Accord profile. It is less suited than the previous model for meeting industry needs in respect of those graduates who exit after the first cycle degree (because of less industry-related material in the first three years). The employment prospects for those exiting at the end of the first cycle are not known. The issues of attracting sufficient students and obtaining funding for delivery that applied for the previous model also apply to this model.

7. NEXT STEPS

Further discussion on these models is required with universities and industry representatives to establish which model best meets long term needs. It would be reasonable to assume that a movement to a longer qualification or to a qualification with a higher entry standard would reduce the number of applicants for the programme. It is not clear whether those not meeting the entry standard or concerned about length and/or cost of study would transfer to a BEngTech or be lost from engineering. It might depend on the status designated to the BEngTech by employers. If they state that it meets many of their technical roles then student enrolment is more likely. The role of a first cycle degree that differs from a BEngTech is also not established.

7.1 Consultation Questions

7.1.1 Even if it proved no longer possible to be certain of meeting the Washington Accord standard with a four-year qualification, does your constituency consider that to meet the future needs of New Zealand, we should continue the status quo (four-year BE degree) or lengthen our professional engineer education?

7.1.2 Is it vitally important that New Zealand has the same length professional engineer qualification as Australia, or is wider international benchmarking more important?

7.1.3 In some of the options proposed, the number of students qualified or motivated to enter the professional engineer qualification might reduce. Would the needs of your constituency still be met if there were relatively more engineering technologists (who would fill more general practitioner employment roles) and relatively fewer but higher level professional engineering graduates?

7.1.4 Is there an employment role for a three-year degree in engineering principles (the first cycle degree) that is different to the Sydney Accord degree (BEngTech) – given that this three-year degree may not be accredited to any Accord?

7.1.5 What type of research and industrial familiarization experiences should a New Zealand professional engineering graduate have experienced – how do these relate to delivery of contextual knowledge and its application?

7.1.6 Which of the models for the qualification is considered to most effectively prepare graduates in accordance with the desired graduate profile and the needs of New Zealand, also taking into account practical factors like cost and likely student responses?

7.1.7 Within the context of the chosen model, are there any changes in the nature of the delivery seen as desirable (in particular how to recognize and assess learning from working in industry e.g. applying contextual knowledge)?

There now needs to be debate about the possible models and which will best enable New Zealand to maintain Washington Accord status while meeting our industry needs and attracting sufficient numbers of the right types of student. In this debate the questions set out above should be answered, as well as selecting a preferred model.

Once a clear engineering sector consensus emerges towards one model the implications of adopting that model need to be discussed with the tertiary providers and a business case developed for the Tertiary Education Commission (TEC).

8. TIMELINE FOR CONSULTATION AND DEVELOPMENT OF A BUSINESS CASE

11 August 2009	Consultation begins with industry, the engineering profession and tertiary providers on a proposed model for the exemplifying qualification. A discussion paper will be available online from this date.
Mid-October 2009	Consultation completed with industry, the engineering profession and tertiary providers through a series of meetings held in five main centres in mid-September.
31 December 2009	Consultation completed with tertiary providers on the implications of adopting a preferred model.
31 March 2010	Development of a business case for the TEC.

TABLE 1: 2009 WASHINGTON ACCORD GRADUATE PROFILE

(A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 4 - 5 years of study, depending on the level of students at entry.)

• Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.
• Identify, formulate, research literature and analyse *complex* engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
• Design solutions for *complex* engineering problems and *design* systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
• Conduct investigations of *complex* problems using research-based knowledge and knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
• Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to *complex* engineering activities, with an understanding of the limitations.
• Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice.
• Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.
• Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.
• Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
• Communicate effectively on *complex* engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and reports and design documentation, make effective presentations, and give and receive clear instructions.
• Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
• Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Knowledge profile

• A systematic, theory-based understanding of the natural sciences applicable to the engineering discipline focussed on by the programme.
• Conceptually-based mathematics, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline.
• A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
• Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
• Knowledge that supports engineering design in a practice area.
• Knowledge of engineering practice (technology) in the practice areas in the

engineering discipline.
• Comprehension of the role of engineering in society and identifies issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability.
• Engagement with selected knowledge in the research literature of the discipline.

Complex engineering problems

Engineering problems which cannot be resolved without in-depth engineering knowledge, much of which is at, or informed by, the forefront of the professional discipline, and having some or all of the following characteristics:
• Involve wide-ranging or conflicting technical, engineering and other issues.
• Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.
• Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and that supports a fundamentals-based first principles analytical approach.
• Involve infrequently encountered issues.
• Are outside problems encompassed by standards and codes of practice for professional engineering.
• Involve diverse groups of stakeholders with widely varying needs.
• Have significant consequences in a range of contexts.
• Are high level problems including many component parts or sub-problems.

TABLE 2: EUR-ACE GRADUATE PROFILES – FIRST AND SECOND CYCLE DEGREES

<table>
<tr><td colspan="2">Knowledge and Understanding
The underpinning knowledge and understanding of science, mathematics and engineering fundamentals are essential to satisfying the other programme outcomes. Graduates should demonstrate their knowledge and understanding of their engineering specialisation, and also of the wider context of engineering.</td></tr>
<tr><td>First Cycle graduates should have:
• knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering;
• a systematic understanding of the key aspects and concepts of their branch of engineering;
• coherent knowledge of their branch of engineering including some at the forefront of the branch;
• awareness of the wider multidisciplinary context of engineering.</td><td>Second Cycle graduates should have:
• an in-depth knowledge and understanding of the principles of their branch of engineering;
• a critical awareness of the forefront of their branch.</td></tr>
<tr><td colspan="2">Engineering Analysis
Graduates should be able to solve engineering problems consistent with their level of knowledge and understanding, and which may involve considerations from outside their field of specialisation. Analysis can include the identification of the problem, clarification of the specification, consideration of possible methods of solution, selection of the most appropriate method, and correct implementation. Graduates should be able to use a variety of methods, including mathematical analysis, computational modelling, or practical experiments, and should be able to recognise the importance of societal, health and safety, environmental and commercial constraints.</td></tr>
<tr><td>First Cycle graduates should have:
• the ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods;
• the ability to apply their knowledge and understanding to analyse engineering products, processes and methods;
• the ability to select and apply relevant analytic and modelling methods.</td><td>Second Cycle graduates should have:
• the ability to solve problems that are unfamiliar, incompletely defined, and have competing specifications;
• the ability to formulate and solve problems in new and emerging areas of their specialisation;
• the ability to use their knowledge and understanding to conceptualise engineering models, systems and processes;
• the ability to apply innovative methods in problem solving.</td></tr>
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<tr><td colspan="2">Engineering Design
Graduates should be able to realise engineering designs consistent with their level of knowledge and understanding, working in cooperation with engineers and non-engineers. The designs may be of devices, processes, methods or artefacts, and the specifications could be wider than technical, including an awareness of societal, health and safety, environmental and commercial considerations.</td></tr>
<tr><td>First Cycle graduates should have:
the ability to apply their knowledge and understanding to develop and realise designs to meet defined and specified requirements;
an understanding of design methodologies, and an ability to use them.</td><td>Second Cycle graduates should have:
an ability to use their knowledge and understanding to design solutions to unfamiliar problems, possibly involving other disciplines;
an ability to use creativity to develop new and original ideas and methods;
an ability to use their engineering judgement to work with complexity, technical uncertainty and incomplete information.</td></tr>
<tr><td colspan="2">Investigations
Graduates should be able to use appropriate methods to pursue research or other detailed investigations of technical issues consistent with their level of knowledge and understanding. Investigations may involve literature searches, the design and execution of experiments, the interpretation of data, and computer simulation. They may require that data bases, codes of practice and safety regulations are consulted.</td></tr>
<tr><td>First Cycle graduates should have:
the ability to conduct searches of literature, and to use data bases and other sources of information;
the ability to design and conduct appropriate experiments, interpret the data and draw conclusions;
workshop and laboratory skills.</td><td>Second Cycle graduates should have:
the ability to identify, locate and obtain required data;
the ability to design and conduct analytic, modelling and experimental investigations;
the ability to critically evaluate data and draw conclusions;
the ability to investigate the application of new and emerging technologies in their branch of engineering.</td></tr>
<tr><td colspan="2">Engineering Practice
Graduates should be able to apply their knowledge and understanding to developing practical skills for solving problems, conducting investigations, and designing engineering devices and processes. These skills may include the knowledge, use and limitations of materials, computer modelling, engineering processes, equipment, workshop practice, and technical literature and information sources. They should also recognise the wider, non-technical implications of engineering practice, ethical, environmental, commercial and industrial.</td></tr>
<tr><td>First Cycle graduates should have:
the ability to select and use appropriate equipment, tools and methods;
the ability to combine theory and practice to solve engineering problems;
an understanding of applicable techniques and methods, and of their limitations;
an awareness of the non-technical implications of engineering practice.</td><td>Second Cycle graduates should have:
the ability to integrate knowledge from different branches, and handle complexity;
a comprehensive understanding of applicable techniques and methods, and of their limitations;
a knowledge of the non-technical implications of engineering practice.</td></tr>
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<tr><td colspan="2">Transferable Skills
The skills necessary for the practice of engineering, and which are applicable more widely, should be developed within the programme.</td></tr>
<tr><td>First Cycle graduates should be able to:

function effectively as an individual and as a member of a team;
use diverse methods to communicate effectively with the engineering community and with society at large;
demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice;
demonstrate an awareness of project management and business practices, such as risk and change management, and understand their limitations;
recognise the need for, and have the ability to engage in independent, life-long learning.
</td>
<td>Second Cycle graduates should be able to:

fulfil all the Transferable Skill requirements of a First Cycle graduate at the more demanding level of Second Cycle;
function effectively as leader of a team that may be composed of different disciplines and levels;
work and communicate effectively in national and international contexts.
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