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Group of National Experts on the AHELO Feasibility Study

TERTIARY ENGINEERING CAPABILITY ASSESSMENT (TECA): CONCEPT DESIGN

by Hamish Coates and Alexandra Radloff
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Paris, 17-18 December 2008

This paper provides an overview of the Tertiary Engineering Capabilities Assessment (TECA) which has been designed by ACER in 2008. It offers ideas which are intended to stimulate discussion and to provide a starting point for operationalising the construct for the purposes of measurement.

The overarching aim of the TECA is to measure what Australian later-year bachelor degree students in selected sub-fields of engineering know and can do in an internationally relevant manner, and the extent to which those who are close to graduating have developed the capabilities required for effective professional performance as global engineers.

The paper begins with a brief background on the growth and development of engineering education, and broader considerations pertaining to higher education quality. It then presents and explores the conceptual framework that has been developed through research and by consultation with the sector. By way of conclusion, preliminary thoughts are offered on key properties of the TECA instrument, and on aspects of administration and reporting.

The AHELO GNE is invited to TAKE NOTE of the TECA initiative.

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INTRODUCTION

The Tertiary Engineering Capability Assessment (TECA)

1. This paper provides an overview of the Tertiary Engineering Capabilities Assessment (TECA) which has been designed by ACER in 2008. It offers ideas which are intended to stimulate discussion and to provide a starting point for operationalising the domain for the purposes of measurement.

2. The overarching aim of the TECA is to measure what tertiary students know and can do in an internationally relevant manner, and the extent to which those who are close to graduating have developed the capabilities required for effective professional performance as global engineers. This psychometric assessment is designed for use with later-year (either third-, fourth- or fifth-year) bachelor degree students in selected sub-fields of engineering.

3. It is important to stress that neither this paper nor the assessment is intended to provide a conclusive depiction of engineering graduate capabilities or curriculum, or of how these could be assessed. The assessment is low stakes for individual students. It is not a registration or licensing examination designed to assess individual competence or achievement. Rather, it is designed to supplement and enhance existing data on student achievement, graduation rates, graduate destinations and teaching quality. Universities can use the data to enhance curriculum, graduate outcomes and engagement with industry.

Growth and development of engineering education

4. Over the past few decades, the profession of engineering and the role of engineers in society have changed rapidly. The problems faced by engineers in today's world are increasingly complex and require engineers to have strong technical knowledge and skills, as well as an understanding of relevant environmental, social, economic and cultural contexts (King & Bradley, 2008; Institution of Engineers, 1996; Walther, Mann & Radcliffe, 2005; Bons & McLay, 2003). On top of this, there is an increasing need for engineers to be good communicators, able to work effectively in interdisciplinary teams, to conduct themselves ethically and professionally, and to be able to constantly update and improve their technical skills (Gill, Mills, Sharp & Franzway, 2005; Institution of Engineers, 1996).

5. In light of the changing requirements for engineers, in recent years many changes have been made to modernise engineering education. Competencies such as communication skills, collaborative skills, ethical practice and an understanding of the context in which engineering problems and projects exist have been given more emphasis and have been incorporated into the engineering curriculum explicitly or indirectly (see, for example: Boles, Murray, Campbell & Iyer, 2006; Walkington, 2001; West & Raper, 2003).

6. Through this process of design and revision, engineering is now one of the most well specified areas of university education. This is demonstrated by the considerable degree of clarity (and commonality) that is provided in key documents published by the Washington Accord (2005), European Network for Accreditation of Engineering Education (ENAEE) (2008), USA Accreditation Board for

Engineering and Technology (ABET) (2008), Engineers Australia (EA) (2006), UK Quality Assurance Agency (QAA) (QAA, 2006) and EU Tuning Process (Tuning Project, 2004).

Contribution to higher education quality

7. While educational processes and outcomes in engineering are well defined, a need remains to produce robust data on learning outcomes and graduates' potential for subsequent work and study. An assessment such as the TECA has the potential to contribute to broader considerations pertaining to higher education quality.

8. Current grading systems are limited in the extent to which they, by themselves, could be used to understand the standards attained in a qualification. Without some form of external check, such as moderation of assessment tasks or student work, or comparison against cross-institutional objective data, student grades do not usually provide sufficiently generalisable evidence of learning outcomes (Coates, in press).

9. Uncertainties surrounding grades are compounded by complexities surrounding qualifications. As higher education has expanded over the last few decades, so too have the number and variety of engineering qualifications. Such proliferation adds to the challenge of mapping and equating content and standards across qualifications. While engineering education is regulated by well-documented frameworks, the complexities of provision generate uncertainty surrounding standards of achievement.

10. As suggested for the OECD's Assessment of Higher Education Learning Outcomes (AHELO) Feasibility Study (OECD, 2008a), the provision of common objective data on graduates' capability has the potential to play a significant role in assisting institutions to monitor and enhance the standards of their educational provision. At the same time, developing a greater range of information on learning outcomes enables institutions to demonstrate the diversity of their programs. This links with one of the key drivers underpinning the current work – that institutions need more information on learning outcomes to assist with international positioning.

ENGINEERING CAPABILITY – A CONCEPTUAL DESIGN

Overview

Background and approach

11. The TECA focuses on the domain of 'engineering capability'. This domain is broad, and it incorporates the wide range of intellectual, interpersonal and personal capabilities that a high-quality engineering graduate should possess.

12. The success of the design hinges in large part on developing a structured conceptual understanding of the domain. Such understanding provides a substantive foundation for subsequent development, along with technical and practical considerations of what would be appropriate and feasible to assess. It is important to emphasise that not all aspects of the conceptual domain outlined in this paper may be amenable to measurement.

13. The domain of engineering capability has, as noted, been explored and specified in a large number of documents. Key documents include:

- Graduate Attributes and Professional Competencies (Washington Accord, 2005)
- European Accreditation of Engineering Programmes (EUR-ACE) (ENAEE, 2008)
- Engineers Australia National Generic Competency Standards – Stage 1 Competency Standards for Professional Engineers (EA, 2006)
- Subject Benchmark Statement for Engineering (QAA, 2006)
- Criteria of Accreditation of Engineering Programs (ABET, 2008), and
- Graduate Competencies (EU, 2004).

14. A conceptual framework has been developed through analytical review of these documents. To develop this framework, the large number of capabilities that appeared in the majority of the reviewed documents were grouped thematically into thirteen capabilities. These capabilities were then organised into three conceptually distinct 'sub-domains'. The sub-domains include basic technical knowledge or 'first principles', understanding of engineering processes and using knowledge to identify and solve problems, and professional attributes which involve managing real-world complexities.

15. Consultations were held with the Australian engineering community. This involved an all-day workshop in Melbourne on 29 October 2008 with university representatives and other key stakeholders, consultation with industry partners over the following week, and a teleconference on 11 November. Meetings were also held with Engineers Australia, the Australian Council of Engineering Deans, the Australasian Association of Engineering Education, the Australian Government Department of Education,

Employment and Workplace Relations (DEEWR), the Group of Eight universities, and a representative of the European Union Tuning Process. Results of the research and consultation were drawn together and subjected to a series of technical analyses and reviews.

Conceptual framework

16. The conceptual framework that underpins the TECA incorporates a forward-looking definition of engineering capability, which acknowledges change in the discipline and is based on expert thinking about labour markets, the economy and social well-being over the next decade.

17. Figure 1 summarises the TECA domain, sub-domains and capabilities. It shows that the three variables are measured by assessing students on the underpinning capabilities. As noted, this conceptual design assumes a dimensionality which needs to be empirically validated during instrument development.

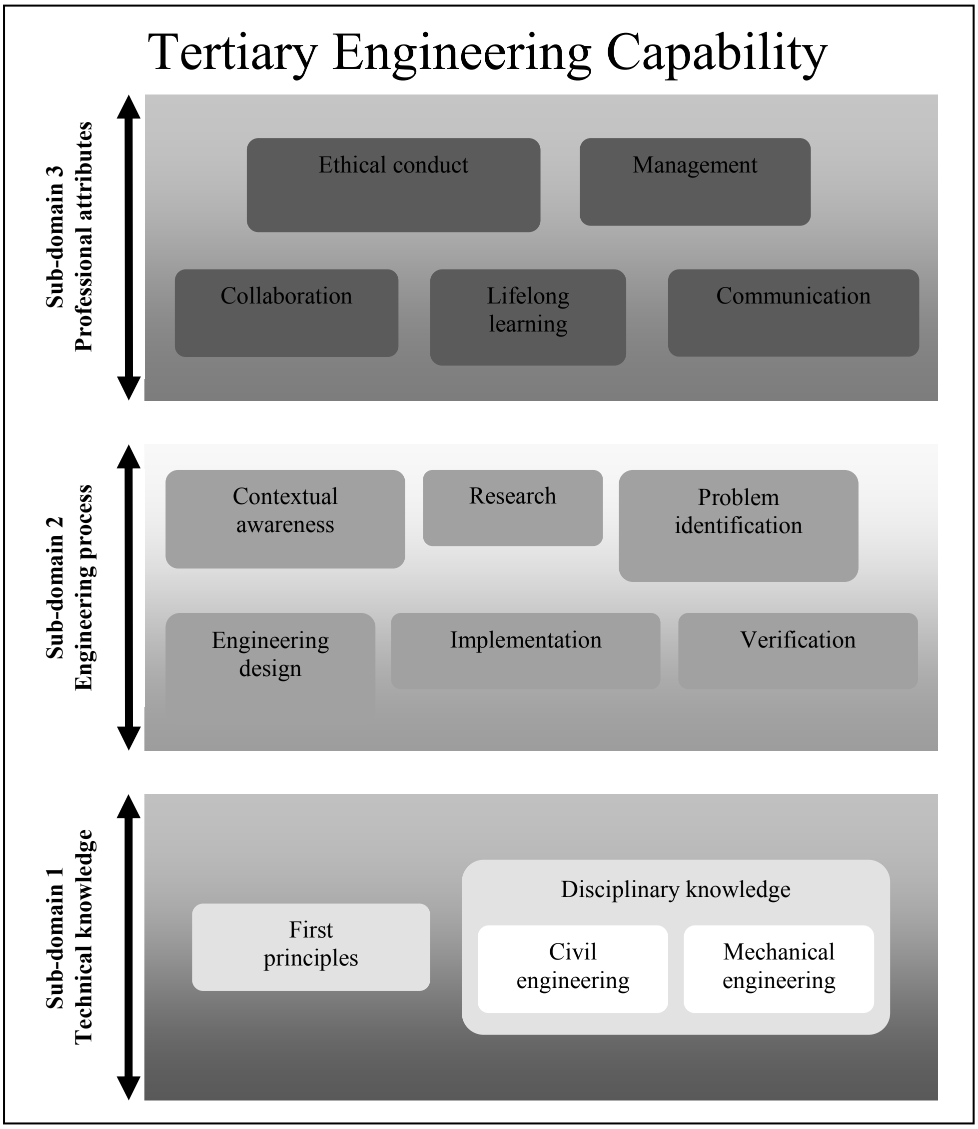

Figure 1 TECA domain, sub-domains and capabilities

Sub-domain 1: Technical knowledge

18. The TECA does not focus on specific technical knowledge or skill, but rather knowledge and skills that are, in the OECD's terms, 'above content' (OECD, 2008a). The emphasis is on the capacity of students to extrapolate from what they have learned and apply their knowledge and skills in novel contexts unfamiliar to them, an approach that is similar to that taken with the OECD's Programme for International Student Assessment (PISA) (OECD, 2008b).

First principles

Definition: The 'first principles' capability refers to knowledge of basic sciences and of engineering fundamentals.

19. In recognition of the complexities that arise as a result of course and curriculum diversity, the 'first principles' capability focuses on technical knowledge that most learners could be assumed to have studied in their engineering qualification. It would not outline in granular detail the characteristics of the many sub-fields. Rather, it would focus on the broad functional areas that are covered by learners during their first year of study.

20. These broad functional areas might include:

- design concepts, including defining, describing, and creating designs in a context that will address the design problem;
- learning and problem solving, including analysing, gathering information, synthesising, planning and implementing solutions to solve engineering problems;
- mathematics and basic science, including understanding and applying laws of nature and associated theoretical models;
- empirical modelling, data analysis, using models and graphs; and
- foundation knowledge in main engineering sub-fields.

Disciplinary knowledge

Definition: The 'disciplinary knowledge' capability focuses on discipline-specific knowledge in the sub-fields of civil and mechanical engineering.

21. The 'disciplinary knowledge' capability focuses on the technical knowledge that most graduates would be expected to have acquired by their final year of a tertiary qualification – either third, fourth or fifth year.

22. For the purposes of initial development, the TECA would focus on two broad sub-fields of engineering – civil and mechanical. These sub-fields were selected as they are different in scope and would provide a good indication of the feasibility of assessing other areas. Each student would be assessed in one of the sub-fields depending on their area of specialisation.

23. Subject to further consultation and review, the USA National Council of Examiners for Engineers and Surveying (NCEES, 2008) exam specifications provides an indicative guide as to areas across which

these capabilities might range. The EU Tuning Project with respect to Civil Engineering (ECCE, 2006) provides further insight into this disciplinary sub-field.

24. In terms of civil engineering the capability might cover: surveying; hydraulics and hydrologic systems; soil mechanics and foundations; environmental engineering; transportation; structural analysis; structural design; construction management; and materials.

25. The mechanical engineering component might focus on: mechanical design and analysis; kinematics, dynamics and vibrations; materials and processing; measurements, instrumentation and controls; thermodynamics and energy conversion processes; fluid mechanics and fluid machinery; heat transfer; and refrigeration and HVAC.

26. It is important to re-emphasise that purpose of the TECA is not to test detailed technical competence. Rather, this aspect of the assessment would test students' capacity to reason with the broad technical knowledge that they could be assumed to have acquired during their study.

Sub-domain 2: Engineering process

27. A common analytical approach underlies many aspects of engineering and may be seen, in certain respects, to characterise the field. Koen (2003: 28), for instance, defines the 'engineering method' as the "use of heuristics to cause the best change in a poorly understood situation within the available resources". A more explicit specification is provided as part of the Conceive – Design – Implement – Operate (CDIO) Initiative (CDIO Initiative, 2008).

28. Engineers are primarily concerned with developing innovative, practical and effective solutions or specifications to address real-life problems while working within a number of constraints. Problems encountered by engineers vary considerably. They range from routinely encountered problems that can be solved using prescribed standards or codes of practice, to much more complex problems that require in-depth technical knowledge, innovative thinking, or a large number of stakeholders with differing needs. To resolve these problems, engineers need to first diagnose the problem, and then investigate and analyse the problems within its specific context and accounting for various constraints.

29. Various skills are required to solve problems effectively. Engineering graduates need to have the ability to identify, diagnose and define problems, generate and test multiple hypotheses, evaluate information presented to them and synthesise this information into an effective solution. Engineering graduates also need to display creative and innovative thought processes to devise solutions to problems that have no obvious resolution.

30. 'Engineering ability' can be seen to involve six key steps: awareness, research, diagnosis, design, implementation and verification. These are given considerable emphasis in the competency statements that underpin this framework.

Contextual awareness

Definition: 'Contextual awareness' refers to understanding the impact of engineering solutions in various global, cultural, social, environmental and economic contexts and demonstrating the knowledge of and need for sustainable design and development.

31. Complex engineering problems and their solutions take place within specific and varied contexts. To create effective solutions, engineering graduates need to understand and appreciate the various contexts, including the economic, social, cultural and environmental contexts in which they work. Increasingly, for instance, importance is being placed on engineering graduates having an understanding and appreciation of

sustainable development, an ability to take a global perspective and create design solutions within a global context and understanding the importance of creating sustainable design solutions.

32. Sustainable development can be defined as the process of striving towards an ideal state of long-term social, economic and ecological stability (Johnston, 2003). Working to create sustainable designs and developing sustainably is appreciated as being increasingly important, by both the engineering profession and society as a whole (Neal, 2005). To work sustainably, engineering graduates need to appreciate sustainable design and development, understand why it matters, and the costs associated with not working or developing sustainability (Beder, 1996).

33. As a point of reference, the Global Reporting Initiative (GRI, 2006) outlines core areas in which the sustainability of a business's actions need to be considered. These areas include economic considerations, the environment, labour practices, human rights, society and community, and product responsibility. The United Nations has also outlined a set of ten core values for businesses that cover the contexts of human rights, labour standards, the environment and anti-corruption (UN, 2000).

34. Key aspects of the 'contextual awareness' capability can be further differentiated into:

- an appreciation of the interaction between engineering and technical systems and the social, cultural, environmental and political contexts in which they occur, and their understanding of the relationships between these factors;
- an understanding of the global society and the global context;
- an appreciation of the importance of designing solutions that are safe and sustainable; and
- an awareness of the risk involved in engineering, both technical risk and risk to clients, users, the wider community and the environment.

Research

Definition: 'Research' refers to the ability to locate, evaluate and use relevant information from a range of sources and to effectively analyse and interpret this information.

35. Engineers work in an ever-changing environment and will inevitably need to design a solution for a problem or situation that they have not encountered before. In order to tackle a problem that is unfamiliar to them, an engineer will need to have well-developed research skills that allow them to locate and analyse relevant information that will help them design an effective solution to these novel problems.

36. In order to be effective researchers, engineers need to be able to identify possible sources of data and information, locate and select relevant information from these sources, and manage and organise this information in a logical way. Engineers should also be able to evaluate the robustness of the information and its source, and should be able to analyse this information and incorporate findings from research into existing knowledge. It is important that engineers also understand issues such as intellectual property and plagiarism and are aware of the need to cite references accurately and give credit to sources of information.

37. The 'research' capability can be differentiated into:

- ability to locate, catalogue and use relevant information;

- proficiency in identifying sources, accessing information, methodically searching and analysing information;
- ability to find out information from colleagues, co-workers and fellow engineers;
- ability to evaluate the reliability, accuracy and robustness of information;
- information management skills; and
- understanding issues about intellectual property and plagiarism.

Problem identification

Definition: 'Problem identification' refers to an ability to identify, scope and define problems, specify parameters and resources, and analyse and synthesise information.

38. To design and implement an effective solution, engineers first need to understand all components of the problem, diagnose the known and unknown/uncertain factors of the problem and consider all relevant aspects of the problem including the context in which it exists.

39. Engineers also need to understand and articulate any assumptions that they have made about the problem or situation and be able to identify the main concepts involved. Once this has been done, engineers can start to identify ideas and approaches for the design and implementation of a solution, specify what resources they will require to implement a solution and begin planning the design.

40. The 'problem identification' capability can be further split conceptually into the following components:

- the ability to comprehend complex engineering problems;
- identifying the nature of a technical problem, and articulating and redefining the problem using appropriate simplifying assumptions;
- articulating the known and unknown aspects of a technical problem;
- investigating a situation or problem and ascertaining the relevant causes and effects that may be involved;
- addressing engineering issues and problems that have no obvious solution and that require originality in analysis; and
- identifying the contribution that engineering makes in situations requiring multidisciplinary inputs and recognising that the contribution made by engineering is often a single element in a total approach.

Engineering design

Definition: The 'engineering design' capability refers to an ability to create innovative and effective solutions for complex engineering problems and conduct life-cycle analyses within realistic economic, environmental, social, political and ethical constraints.

41. The process of designing a solution involves analysing the problem and investigating a range of potential design solutions that take into account the constraints of the situation and the context of the problem. These solutions are then evaluated against standards or codes of practice, client needs and other contexts and constraints, and the most suitable design is selected and further developed for implementation.

42. More specifically, the ‘engineering design’ capability would focus on the ability to:

- employ technical knowledge, design methodology and appropriate resources and tools to effectively design individual components, systems or processes that meet certain specifications;
- use a systems approach when designing a solution;
- comprehend, understand and document the required outcomes of a project;
- consider all factors impacting on the development and implementation of a design solution, including constraints and risks;
- write functional specifications that meet user requirements;
- identify and analyse possible design concepts, and propose and decide upon an optimal solution;
- ensure the chosen solution maximises functionality, safety and sustainability and identify areas for further improvement;
- ensure the sound performance of the system as a whole and the performance of each component of the system; and
- check the design solution against the engineering and functional specifications.

Implementation

Definition: ‘Implementation’ refers to the capacity to execute effective and creative design solutions in sound, safe and effective ways.

43. This step in the design or life-cycle process involves the implementation of a chosen design solution to the problem or situation. Implementing an innovative design solution to solve a complex engineering problem requires engineering graduates to be able to apply their knowledge and use the information they have collected about the problem in practical and innovative ways. It includes the capacity to monitor and review feedback on implementation, and to modify and adjust practices accordingly.

44. The ‘implementation’ capability focuses on students’ ability to:

- plan the application of technical solutions to complex issues or problems that have no obvious solution;
- identify what resources, tools and processes are needed to implement the selected design;
- manage the implementation of the solution; and

- evaluate the soundness and safety of a design, and optimise the design.

Verification

Definition: 'Verification' refers to the ability to validate and test a design solution and use feedback to improve future practice.

45. The final step in the engineering process is the verification of the chosen design solution. In order to ensure that the design solution meets the constraints of the situation, the needs of the stakeholders and will solve the problem, it is necessary to evaluate the solution. If the solution has not been adequately verified, the solution may need to be refined or revised.

46. The 'verification' capability focuses specifically on students' ability to:

- test and evaluate the effectiveness of the chosen design solution;
- ensure that the solution meets the needs of the situation, problem, stakeholders, clients and wider community and the specifications;
- understand the importance of feedback and incorporate feedback received from clients, stakeholders, and the operational performance of the solution into improvements and future practice; and
- select an optimal solution and justify its selection.

Sub-domain 3: Professional attributes

47. The way in which engineers manage their work shapes their capacity to implement solutions in effective ways. In line with contemporary educational and professional practice, this design assumes that interpersonal and personal capabilities play a vital role in the work of effective engineers. Conceptually, this sub-domain consists of five capabilities: conduct, management, collaboration, learning and communication. Competence in these areas is integral to the idea that a graduate is 'work ready'.

Ethical conduct

Definition: 'Ethical conduct' refers to an understanding and commitment to professional and ethical responsibilities in engineering practice.

48. The role of the engineer is one of great social responsibility, and the decisions made by engineers can have wide-ranging consequences for society at large (Reid, 2006). Because of the impact that their decisions may have for the wider community, engineers are expected to perform their duties in a professional and ethical manner. Engineering graduates should appreciate the importance of working in an ethical way and should also recognise the legal and regulatory aspects of their role and engineering activities. Although not widely taught as a separate unit in the engineering curriculum, once graduates become professional engineers, ethical considerations will become an important part of their role (Ilic, 2003).

49. Due to the level of responsibility held by engineers, codes of ethics have been developed to guide engineers in ethical work practices. The Engineers Australia Code of Ethics is one such code (EA, 2000). The code includes nine specific tenets, with the broad principles being to respect the inherent dignity of the individual, act on the basis of a well-informed conscience and to act in the interest of the community.

50. In summary, the ‘ethical conduct’ capability focuses on:

- familiarity, understanding and commitment to ethical practice, including students’ familiarity with relevant codes of ethics;
- awareness of legislation and statutory requirements relevant to engineering discipline and practice;
- awareness of the standards and codes of practice relevant to engineering discipline and practice;
- the ability to present a professional image in all circumstances and situations, with clients, stakeholders, colleagues and the community as a whole; and
- the ability to maintain a professional attitude at all times.

Management

Definition: ‘Management’ refers to understanding and knowledge of management and business practices and the commercial and economic contexts of engineering processes.

51. In order to implement solutions effectively, engineers need to understand project, business and resource management, and the economic and commercial contexts in which engineering is embedded. This includes the capacity to manage workflows, budgets, risk and quality, and to contribute to ongoing monitoring of processes and deal with change and compliance issues.

52. Specific aspects of the ‘management’ capability might include:

- an understanding of project management techniques and the ability to apply them effectively in practice;
- an understanding of basic enterprise strategies, goals and long-term business planning;
- entrepreneurship and leadership;
- knowledge of how engineering businesses and enterprises are managed;
- understanding and appreciation of the commercial, financial and marketing aspects of engineering projects;
- the ability to realistically assess the scope and dimensions of a project or task in order to estimate costs, resources and efforts required;
- ability to manage an engineering project within realistic time and budget constraints; and
- general awareness and appreciation of business principles.

Collaboration

Definition: ‘Collaboration’ refers to the ability to work as part of a team with the capacity to be a leader or manager as well as an effective team member.

53. Engineering graduates are expected to be able to work on engineering problems and activities in collaboration with other engineers and people. It is important that engineering graduates display interpersonal skills that allow them to function as both an effective team member and leader of teams as well as have an understanding of interpersonal dynamics. Skills required by engineering graduates to work collaboratively include listening, discussing, questioning, respecting others' views and input, sharing ideas, communicating effectively and helping others. Increasingly, it is important for graduates to be able to function as global engineers who can move across borders and who have an international outlook.

54. The 'collaboration' capability focuses on a number of more specific abilities, including the ability to:

- identify, understand and infer thoughts, feelings, behaviours and intentions of others;
- earn and maintain the trust and confidence of colleagues;
- coordinate the work of others;
- communicate effectively with colleagues and team members and understand the importance of effective communication;
- take initiative and leadership in an interdisciplinary team while respecting the roles of others in the team;
- be aware of the value of teams, and especially the value of working in interdisciplinary and multicultural teams with members from diverse backgrounds; and
- function effectively as a team member and leader in multicultural, interdisciplinary teams.

Lifelong learning

Definition: 'Lifelong learning' refers to students' capacity to understand and engage in formal and informal kinds of learning across their professional lives.

55. Engineering graduates exist in a rapidly changing world and require lifelong learning skills to function as effective engineers through the course of their career (see, for example: Palmer & Tucker, 2003). The engineering curriculum needs to strike a balance between teaching current technical skills and teaching the ability to adapt and learn new technical skills (Bons & Mclay, 2003).

56. Not only do engineering graduates need to have marketable knowledge and skills, they must also have a range of personal attitudes and dispositions in order to navigate a future widely predicted to be one of constant change.

57. The 'lifelong learning' capability can be distinguished into more specific areas, including:

- self-reflective capacity – students' capacity to diagnose professional strengths and weaknesses, and to identify areas in need of improvement;
- interest in learning – students' intellectual engagement in and attitude towards continuous professional development;

- capacity for lifelong learning – whether students are aware of effective approaches for ongoing professional learning; and

- participation in professional communities – students' understanding of the importance of being part of a professional and intellectual community.

Communication

Definition: 'Communication' refers to an ability to effectively communicate, in graphical, oral and written forms, with other engineers and also the wider community.

58. It is essential for an engineering graduate to be able to communicate effectively with co-workers, the broader engineering community and the community at large. Effective communication skills are necessary for an engineering graduate as they should be able to contribute to discussions with community, industry, government and fellow engineers, and be able to comprehend and write effective reports and design specifications, present effectively, and understand and give instructions. In fact, employers often rate communication skills as one of the most essential and important skills that an engineering graduate needs (see, for example: Male, Bush & Chapman, 2008).

59. The 'communication' capability can be further distinguished into certain components:

- a high level of competence in written and spoken language;

- the ability to effectively present information to both engineering and non-engineering audiences;

- the capacity to hear and comprehend others' viewpoints and ideas;

- the ability to present an argument clearly and concisely;

- an understanding of different styles of communication;

- the ability to discuss, negotiate, question and listen effectively; and

- the ability to present engineering issues to the broader community.

CONCLUDING THOUGHTS

Key instrument properties

60. This paper offers a conceptual design for the TECA. An instrument will be designed to operationalise core aspects of the underpinning conceptual framework for the purposes of measurement. A preliminary overview of key properties is given here to provide insight into a few of the technical and practical considerations which can shape assessment processes and outcomes.

61. The TECA is designed to measure students' capacity to reason and work as effective engineers. To achieve this, the substantive weighting of the sub-domains within the instrument would need to be considered during instrument development and validation. It may be preferable, for instance, to emphasise the assessment of technical knowledge (EA, 2008b). Alternatively, the assessment might emphasise engineering process – students' capacity to 'think like an engineer' (Trevelyan, 2008). An equal weighting would then be given to each of the sub-domains.

62. The potential scope of the instrument is very broad as its conceptual foundations suggest. It is designed to assess capabilities close to the completion of the bachelor degree and to traverse two areas of engineering. Rather than produce a single instrument that contains all items, a number of psychometrically linked versions will be produced. The use of this matrix format (known commonly as 'rotated forms') facilitates coverage of a wider range of content, a greater range of difficulty levels, the targeting of items to particular learners, greater control over the security of the assessment, and greater control of response interference effects such as fatigue.

63. Each test version will likely be designed for 180 minute delivery, incorporating 100 to 160 minutes of testing, 10 minutes for context questions, 5 minutes of setup and 5 minutes to close the assessment. This time band is necessary given the content to be assessed.

64. The TECA would most likely be designed for online administration. In the last few years ACER has developed and tested large-scale administration of online assessments at universities, which has helped to refine technology and management. Online deployment would support an adaptive approach to item delivery and enable the development of items specifically designed for this format. It does carry extra technical and practical complexities, however, which will be necessary to manage and test during development.

65. The quality of the items underpins the quality of the instrument and hence of the overall assessment. A phased, consultative and technically rigorous approach will be used to develop items: item drafting and submission, expert panelling, cognitive testing, revision and proofing, resource production, and pilot administration.

66. A number of item types will be employed, including multiple choice response, closed-constructed response and open-constructed response. Within each sub-domain, items will be designed to measure varying levels of proficiency. Less demanding items will be designed to measure the kind of competence which is generally associated with reproduction. Higher levels of proficiency will be measured by items

that assess the extent to which individuals make connections between different aspects of knowledge and skill. Higher-order reflective forms of reasoning will be assessed by the most demanding items. Language difficulty will be set at an appropriate level.

67. The assessment will likely include a number of context items which are intended to: manage and assure the validity of the student sample; assist with the production of population estimates; and help explain variations in student performance in terms of key characteristics.

Administration and reporting

68. A well-designed administration methodology will be developed in consultation with institutions to underpin pilot implementation of the TECA. An important part of this will be the development of a valid and efficient sampling strategy. Related consideration will be given to engaging teaching staff in the assessment process and engaging learners in the assessment. The administration plan will be underpinned by a series of quality assurance checkpoints that help researchers and administrators manage project risks and ensure the validity of processes and outcomes.

69. In developing reports for the TECA, it would be critical to align the assessment with ongoing educational practice, develop agreed protocols for data use and reporting, and produce reports which are helpful to a variety of users. It is important to document carefully how TECA results align with other measures of achievement such as graduation rates, academic performance, industry expectations, graduate destinations, or teacher ratings.

70. General summary feedback sheets would be prepared for students about the performance of their cohort. The decision about passing these feedback sheets to students would be left up to institutions. The assessment is low stakes for students, and given the matrix structure of the instrument and sampling design, no student would receive individual scores. Thus all students within a target faculty, not just those who sat the test, could use these reports as a broad complement to other records of achievement. Results would be reported on an arbitrary metric that has no relation to metrics used for grading student performance.

71. Each institution would receive a detailed report. These reports would include an executive summary, tabulated results on each of the capabilities, and normative and criterion-referenced scores to assist with benchmarking. The measurement of three sub-domains would enable diagnostic triangulation of different patterns of performance and hence graduate characteristics. It would include guides on how institutions might use the results for evidence-based quality enhancement. The institution report may include a summary report for teaching staff.

72. A formative evaluation will be built into development of the TECA to help shape design and development, and to return information about the feasibility of the assessment. The evaluation could be overseen by an advisory group consisting of one or more experts on assessment methodology, engineering education, and university education. The evaluation would have technical, practical and substantive components. In line with the OECD's AHELO Feasibility Study, it would examine the science of the assessment as well as the practicality of implementation. It would also consider the substantive educational implications that arise from the development.

REFERENCES

Accreditation Board for Engineering and Technology (ABET). (2008). *Criteria for accrediting engineering programs: Effective for evaluations during the 2008-2009 cycle*. Engineering Accreditation Commission. Accessed 2 October 2008 from: http://www.abet.org/forms.shtml

Beder, S. (1996). Towards an environmentally conscious engineering graduate. *Australasian Journal of Engineering Education*, 7(1), 39-46. Accessed October 15 2008 from: http://pandora.nla.gov.au/nph-arch/O1998-Feb-4/http://elecpress.monash.edu.au/ajee/vol7no1/beder.htm

Boles, W., Murray, M., Campbell, D. & Iyer M. (2006). Engineering the learning experience: Influences and options. *Proceedings of the 17th Annual Conference of the Australasian Association for Engineering Education, Auckland, 10-13 December*.

Bons, W. & McLay, A. (2003). Re-engineering engineering curricula for tomorrow's engineers: Engineering education for a sustainable future. *Proceedings of the 14th annual conference for Australasian Association for Engineering Education and 9th Annual Women in Engineering Forum, Melbourne, 29 September to 1 October*.

Conceive — Design — Implement — Operate (CDIO Initiative). (2008). *The CDIO Initiative*. Accessed 1 November from: http://www.cdio.org

Coates, H. (in press). What's the difference? A model for measuring the value added by higher education. *Higher Education Management and Policy*.

European Network for Accreditation of Engineering Education (ENAEE). (2008). *European Accreditation of Engineering Programmes (EUR-ACE)*. Brussels: European Network for Accreditation of Engineering Education.

Engineers Australia (EA). (2000). *Code of Ethics*. Accessed October 10 2008 from: http://www.engineersaustralia.org.au/shadomx/apps/fms/fmsdownload.cfm?file_uuid=F0647595-C7FE-7720-EA17-70AC27062E0B&siteName=ieaust

Engineers Australia (EA). (2006). *Engineers Australia National Generic Competency Standards – Stage 1 Competency Standard for Professional Engineers*. Accessed 8 October 2008 from: http://www.engineersaustralia.org.au/shadomx/apps/fms/fmsdownload.cfm?file_uuid=E01497F2-F208-96A1-14C4-AA8CAE8CFD2A&siteName=ieaust

Engineers Australia (EA). (2008a). *Accreditation Management System*. Accessed 15 October 2008 from: http://www.engineersaustralia.org.au/education/program-accreditation/accreditation-management-system

Engineers Australia (EA). (2008b). *Accreditation Criteria Summary*. Accessed 15 October 2008 from: http://www.engineersaustralia.org.au/shadomx/apps/fms/fmsdownload.cfm?file_uuid=0B1C3966-ABE4-3D41-93FC-3B96534599B5&siteName=ieaust

European Council of Civil Engineers (ECCE). (2006). *Report on first results of the Tuning Project with the participation of EUCEET and ECCE*. Accessed 1 October from: http://www.eccenet.org/Activities/Edu-Train.html

Gill, J., Mills, J., Sharp, R. & Franzway, S. (2005). Education beyond technical competence: gender issues in the working lives of engineers. *Proceedings of the 4th ASEE/AaeE Global Colloquium on Engineering Education, Sydney, 26-29 September*.

Global Reporting Initiative (GRI). (2006). *Sustainability Reporting Guidelines*. Accessed 13 October 2008 from: http://www.globalreporting.org/NR/rdonlyres/ED9E9B36-AB54-4DE1-BFF2-5F735235CA44/0/G3_GuidelinesENU.pdf

Ilic, V. (2003). Ethics in an engineering curriculum. *Proceedings of the 14th annual conference for Australasian Association for Engineering Education and 9th Annual Women in Engineering Forum, Melbourne, 29 September to 1 October*.

Institution of Engineers. (1996). *Changing the culture: Engineering education into the future*. Canberra: Institution of Engineers.

Johnston, S. (2003). Sustainability and globalisation: A positive role for engineering. *Proceedings of the 14th annual conference for Australasian Association for Engineering Education and 9th Annual Women in Engineering Forum, Melbourne, 29 September to 1 October*.

King, R. & Bradley, A. (2008). *Addressing the Supply and Quality of Engineering Graduates for the New Century*. Sydney: Australian Learning and Teaching Council.

Koen, B. (2003). *Discussion of the Method: Conducting the engineer's approach to problem solving*. New York: Oxford University Press.

Male, S. A., Bush, M. B., & Chapman, E. S. (2008). *Generic Competencies Required by Engineers Graduating in Australia*. Unpublished draft paper.

National Council of Examiners for Engineers and Surveying (NCEES) (2008). *Fundamentals Exams*. Accessed 1 October 2008 from: http://www.ncees.org/exams/fundamentals.

Neal, I. (2005). Skills *for the global engineer. Engineers Against Poverty*. Accessed 7 November 2008 from: www.engineersagainstpoverty.com

Organisation for Economic Cooperation and Development (OECD). (2008a). OECD *Assessment of Higher Education Learning Outcomes (AHELO)*. Accessed 1 October 2008 from: http://www.oecd.org/document/22/0,3343,en_2649_35961291_40624662_1_1_1_1,00.html

Organisation for Economic Cooperation and Development (OECD). (2008b). *OECD Programme for International Student Assessment (PISA)*. Accessed 1 October 2008 from: http://www.pisa.oecd.org.

Palmer, S. & Tucker B. (2003). Information literacy for a sustainable career in engineering and technology. *Proceedings of the 14th annual conference for Australasian Association for Engineering Education and 9th Annual Women in Engineering Forum, Melbourne, 29 September to 1 October*.

Reid, M. (2006). A post-modern engineering education challenge: Developing an effective values-based engineering decision-making methodology. *Proceedings of the 17th Annual Conference of the Australasian Association for Engineering Education, Auckland, 10-13 December*.

Trevelyan, J. P. (2008). *Engineering Practice Models Shaping Engineering Education*. University of Western Australia: School of Mechanical Engineering.

Tuning Project (2004). *Tuning educational structures in Europe: Generic competencies*. Accessed 30 September 2008 from: http://www.tuning.unideusto.org/tuningeu/index.php?option=content&task=view&id=183&Itemid=210

Quality Assurance Agency (QAA). (2006). *Subject benchmark statement: Engineering*. Accessed 2 October 2008 from: http://www.qaa.ac.uk/academicinfrastructure/benchmark/statements/engineering06.pdf

United Nations (UN). (2000). *The 10 Principles of the UN Global Compact*. Accessed 10 October 2008 from: http://www.unglobalcompact.org/AboutTheGC/TheTenPrinciples/index.html

Walkington, J. (2001). Designing the engineering curriculum to cater for generic skills and student diversity. *Australasian Journal of Engineering Education, 9*(2), 127-135.

Walther, J., Mann, L. & Radcliffe, D. (2005). Global engineering education: Australia and the Bologna Process. *Proceedings of the 4th ASEE/AaeE Global Colloquium on Engineering Education, Sydney, 26-29 September*.

Washington Accord (2005). *Graduate Attributes and Professional Competencies*. Accessed 1 October 2008 from: http://www.washingtonaccord.org/IEM_Grad_AttrProf_Competencies_v11(2).pdf

West, M. & Raper, J. (2003). Cultivating generic capabilities to develop future engineers: An examination of 1st year interdisciplinary engineering projects at the University of Sydney. *Proceedings of the 14th annual conference for Australasian Association for Engineering Education and 9th Annual Women in Engineering Forum, Melbourne, 29 September to 1 October*.