
TERTIARY ENGINEERING CAPABILITY ASSESSMENT
CONCEPT DESIGN

Hamish Coates and Alexandra Radloff



Australian Council for Educational Research

ACN: 004 398 145; ABN: 19 004 398 145

November 2008

TABLE OF CONTENTS

1	INTRODUCTION.....	5
1.1	THE OECD AHELO FEASIBILITY STUDY	5
1.2	THE TERTIARY ENGINEERING CAPABILITY ASSESSMENT (TECA).....	5
1.3	KEY ENGINEERING AND QUALITY ASSURANCE CONTEXTS	6
1.3.1	<i>Growth and development of engineering education</i>	6
1.3.2	<i>Insights into higher education quality</i>	6
1.3.3	<i>Using TECA data.....</i>	7
2	ENGINEERING CAPABILITY – A CONCEPTUAL FRAMEWORK.....	9
2.1	TECHNICAL KNOWLEDGE	10
2.0.1	<i>First principles.....</i>	10
2.1.2	<i>Disciplinary knowledge</i>	11
2.2	ENGINEERING PROCESS	11
2.2.1	<i>Contextual awareness</i>	12
2.2.2	<i>Research</i>	12
2.2.3	<i>Problem identification</i>	13
2.2.4	<i>Engineering design</i>	13
2.2.5	<i>Implementation</i>	14
2.2.6	<i>Verification</i>	14
2.3	PROFESSIONAL ATTRIBUTES	15
2.3.1	<i>Ethical conduct</i>	15
2.3.2	<i>Management</i>	16
2.3.3	<i>Collaboration.....</i>	16
2.3.4	<i>Lifelong learning.....</i>	17
2.3.5	<i>Communication.....</i>	17
3	THE TECA INSTRUMENT	19
3.1	OVERVIEW	19
3.2	ITEM CHARACTERISTICS	19
3.2.1	<i>Objective (test) items</i>	19
3.2.2	<i>Context items</i>	20
3.3	DEVELOPMENT AND VALIDATION.....	21
3.3.1	<i>Item drafting and submission.....</i>	21
3.3.2	<i>Expert panelling.....</i>	21
3.3.3	<i>Cognitive testing</i>	21
3.3.4	<i>Revision and proofing.....</i>	22
3.3.5	<i>Pilot administration</i>	22
3.3.6	<i>Resource production</i>	22
4	IMPLEMENTING THE ASSESSMENT: POSSIBLE STEPS.....	23
4.1	SAMPLING	23
4.2	ADMINISTRATION.....	23
4.3	REPORTING.....	23
4.4	FORMATIVE EVALUATION.....	24
5	REFERENCES.....	25

1 INTRODUCTION

1.1 The OECD AHELO Feasibility Study

The OECD International Assessment of Higher Education Learning Outcomes (AHELO) (see: OECD, 2008) Feasibility Study is intended to assess student learning in ways that facilitate better understanding of higher education quality. The underpinning idea is to provide high-quality data that can be used for quality assurance and improvement.

The two aims of the OECD Feasibility Study are to test:

- the science of the assessment – whether it is possible to devise an assessment of the outcomes of higher education (what students know and can do) that enables reliable statements to be made about the performance/effectiveness of learning in institutions of very different types, and in countries with different cultures and languages, and
- the practicality of implementation, and of motivating institutions and students to take part in such an assessment.

The OECD work is divided into the following four strands:

- generic skills – assessment that focuses on competencies which are widely viewed as critical for the success of individuals and of rising relevance in the information age such as critical thinking, analytic reasoning, problem-solving, the generation of knowledge, and the interaction between substantive and methodological expertise
- discipline-specific – assessment of discipline-related competencies (initially engineering and economics) that are fundamental and ‘above content’ with the focus on the capacity of students to extrapolate from what they have learned and apply their competencies in novel contexts unfamiliar to them – an approach that is similar to the OECD’s PISA (the Programme for International Student Assessment (OECD, 2008)) that has been used since 2000 to assess 15 year-olds in literacy, mathematics and science in over 50 countries
- contextual – assessment of input, process and outcome factors at the student, teacher and institution level, with a view to using these to better understand and explain education, and
- value-added – an investigation of methods for estimating the incremental or net learning (or ‘value-added’, ‘gain’) deriving from higher education attendance with a view to assess the quality of education.

The Australian Government has informed the OECD that it will participate in the engineering assessment that forms part of the discipline-specific strand of the AHELO Feasibility Study. ACER has prepared this concept design to facilitate consideration within Australia about the characteristics of an assessment instrument that is capable of measuring engineering outcomes in an internationally comparable way. Preliminary research suggests that a purpose-specific assessment does not currently exist, and it is intended that the outcomes of the Australian deliberations, where international in scope, will play a formative role in shaping the international assessment used in the AHELO process.

1.2 The Tertiary Engineering Capability Assessment (TECA)

This concept design provides a preliminary overview of the proposed Tertiary Engineering Capabilities Assessment (TECA). It is intended to stimulate discussion and to provide a starting point for operationalising the construct for the purposes of measurement.

The TECA is a psychometric assessment designed for use with later-year (either third-, fourth- or fifth-year) students studying selected sub-fields of engineering in bachelor degree programs at higher education institutions.

The overarching aim of the TECA is to measure what tertiary students know and can do in an internationally comparable manner, and the extent to which those who are close to graduating have developed the capabilities required for effective professional performance as a global engineer.

Neither this concept design nor the assessment are intended to provide a conclusive depiction of engineering capabilities or curriculum or of how these could be assessed. The TECA is not a registration or licensing examination designed to assess individual competence or achievement. The assessment is low stakes for individual students. Rather, it is intended to provide information about graduate capability, not achievement, that institutions can use for the purposes of continuous improvement.

Any development such as this necessarily involves considering related aspects of higher education quality assurance, educational provision, research methodology, and standards of student assessment. Analyses of such matters will be conducted, including through a formative evaluation, to identify how best the TECA could add value to engineering education.

1.3 Key engineering and quality assurance contexts

1.3.1 Growth and development of engineering education

Over the past few decades the profession of engineering and the role of engineers in society have changed rapidly due to increasing globalisation, an emphasis on sustainable development and sharp economic, technological and social changes (King & Bradley, 2008; The Institution of Engineers Australia, 1996; Walther, Mann & Radcliffe, 2005). Engineering graduates need to be better equipped with both technical skills and the ability to adapt to changing situations and technologies (Bons & McLay, 2003).

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. 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; The Institution of Engineers Australia, 1996).

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).

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

1.3.2 Insights into higher education quality

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. Despite this, our understanding of the learning outcomes of engineering education is limited. In Australia, as in many countries, conversations about higher education quality have expanded over the last 20 years beyond institutional resources and reputations to include teaching processes and institutional supports, but until recently there has been a surprising lack of information and emphasis on learning processes and outcomes.

Current grading systems are limited in the extent to which they can be used to understand the standards attained in a qualification. While there are many pockets of excellence, developing generalisable measures of individual knowledge and skill outcomes remains a major challenge for higher education generally. While there have been enormous advances in assessment methodology, important aspects have yet to be widely applied to higher education. Currently, assessment tasks are developed by individual teaching staff to be used

in specific subjects whose content may change in various ways from year to year. Staff often develop such resources in relatively short periods of time for localised purposes with limited resources. Of course, many staff do not have detailed knowledge of educational assessment. As a result, while many staff develop excellent assessment tools, student knowledge and skill is often measured using uncalibrated tasks with unknown reliabilities and validities, scored normatively by different raters using unstandardised rubrics and then, often with little moderation, adjusted to fit percentile distributions which are often specified *a priori* by departments, faculties or institutions. 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.

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.

Thus current information on educational outcomes is generally limited to measures of throughput, employment rates and learners' satisfaction with provision. Convergence around limited indicators carries dangers for promoting convergence in practice. Sound quality improvement hinges on the availability of well-validated common data that institutions can use to identify points of similarity and difference. At the same time, a greater range of information on learning outcomes enables programs and institutions to demonstrate their diversity. 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.

The availability of objective data on learning outcomes also provides foundations on which decisions about graduate study can be based. Over the last few years many countries have identified workforce needs for more people to be taking their study of Science Technology Engineering and Mathematics (STEM) fields to graduate levels. Such objective data provides a necessary supplement to information provided through course-based grades. As such, it may help expedite the progression of highly capable students into more advanced research programs.

1.3.3 Using TECA data

TECA will provide universities with additional information on the capability of their final-year engineering students. As the above discussion suggests, it is designed to supplement and enhance existing data on student achievement, graduation rates, industry feedback, teaching quality.

Used as part of suite of information, TECA results are intended to be used primarily by participating institutions to inform continuous improvement processes at their institution. Universities might use the data to enhance their curriculum, enhance graduate outcomes and improve their engagement with industry.

It is important to be clear about the nature and use of assessments and data. To this end, a code of practice will be developed to provide guidelines on how TECA data should be used, as well as provide additional ideas on ways to use the data most effectively.

2 ENGINEERING CAPABILITY – A CONCEPTUAL FRAMEWORK

The AHELO Feasibility Study 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.

The success of this work 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 may be amenable to measurement. This chapter maps out the conceptual domain. The following chapters consider aspects of its operationalisation and use.

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) (ENAAE, 2008)
- Engineers Australia National Generic Competency Standards – Stage 1 Competency Standards for Professional Engineers (EA, 2006)
- Subject Benchmark Statement for Engineering (UK QAA, 2006)
- Criteria of Accreditation of Engineering Programs (ABET, 2008), and
- Graduate Competencies (EU, 2004).

For the purposes of this concept design, a conceptual framework has been developed through analytical review of these documents. This framework 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.

To develop the 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.

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

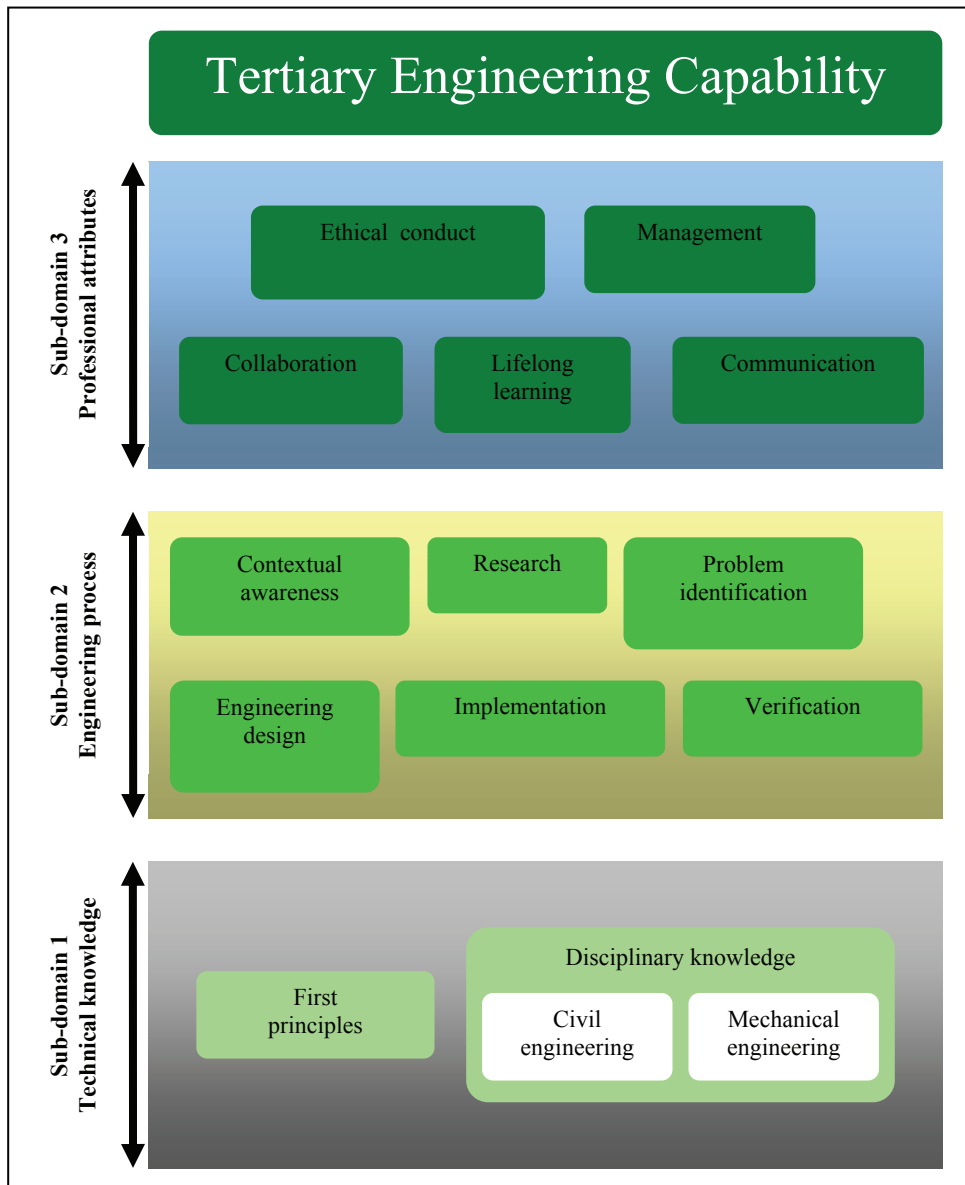


Figure 1 TECA domain, sub-domains and capabilities

2.1 Technical knowledge

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'. 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 PISA.

2.0.1 First principles

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

In recognition of the complexities that arise as a result of course and curriculum diversity, this 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.

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.

2.1.2 *Disciplinary knowledge*

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

This 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.

For the purposes of the pilot study, 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 fields depending on their area of specialisation.

This capability would focus on key areas of both civil and mechanical engineering. Subject to further consultation and review, the USA National Council of Examiners for Engineers and Surveying (NCEES, 2008) exam specifications provide a broad indicative guide as to areas these capabilities might range across. The EU Tuning Project with respect to Civil Engineering (ECCE, 2006) provides further insight into this disciplinary area.

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.

The mechanical engineering component might cover: 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.

It is important to re-emphasise that purpose of the assessment 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.

2.2 **Engineering process**

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, 2008).

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.

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.

‘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.

2.2.1 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.

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.

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).

As a point of reference, the Global Reporting Initiative (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).

Key aspects of this 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.

2.2.2 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.

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.

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.

This capability can be decomposed into the:

- 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.

2.2.3 *Problem identification*

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

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.

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.

This 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.

2.2.4 *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.

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.

More specifically, this 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, specifically to:
 - engage with situations and problems involving uncertainty, imprecise information and wide-ranging or conflicting factors
 - design and justify a holistic approach that incorporates all considerations
 - partition a problem, process or system into manageable elements and recombine into a whole
 - conceptualise and define possible solutions or approaches and evaluate these approaches in terms of their functionality, cost, sustainability and other relevant factors
 - select an optimal approach and justify this choice
- 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.

2.2.5 Implementation

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

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.

This 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.

2.2.6 Verification

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

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.

This 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.

2.3 Professional attributes

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'.

2.3.1 Ethical conduct

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

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).

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 (Engineers Australia, 2000). The broad principles described in this code are 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. The code includes nine specific tenets, which ask members to:

- place the welfare, health and safety of the community before their own interests
- act with honour, integrity and dignity
- act only in areas of their competence and in a careful and diligent manner
- act with honesty, good faith and equity and without discrimination
- apply their skills and knowledge in the interest of their employer or client without compromising ethical responsibilities
- take reasonable steps to inform themselves and relevant others of the social, environmental, economic and other consequences that may arise from their actions
- express opinions, make statements or give evidence with fairness and honesty and only on the basis of adequate knowledge
- continue to develop relevant knowledge, skill and expertise throughout their careers, and actively assist and encourage their associates to do likewise, and
- not induce or assist a breach of the tenets and support those who seek to uphold these tenets.

In summary, this capability focuses on:

- familiarity, understanding and commitment to ethical practice, including their 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.

2.3.2 Management

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

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 workflow, budgets, risk and quality, and to contribute to ongoing monitoring of processes and deal with change and compliance issues.

Specific aspects of this 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.

2.3.3 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.

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 a global engineer who can move across borders and has an international outlook.

This 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.

2.3.4 *Lifelong learning*

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

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).

Not only do engineering graduates need to have marketable knowledge and skills, but 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.

This 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.

2.3.5 *Communication*

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

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).

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.

3 THE TECA INSTRUMENT

3.1 Overview

This chapter considers some of the issues in developing a practical, technically robust and educationally informative assessment instrument. The Tertiary Engineering Capability Assessment (TECA) 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 some of the key technical and practical considerations which shape assessment processes and outcomes. Further specification hinges on developing greater clarity during development of key substantive, technical and practical considerations.

The potential scope of the instrument is very broad as its conceptual foundations suggest. It is designed to assess capabilities at the upper end of the bachelor degree and to traverse three areas of engineering. Within each institution it would be necessary to obtain accurate and reliable estimates for each of the defined sub-domains. These conditions imply that a reasonably large number of items is required, and at the same time that not all items will be relevant to each student.

To manage this complexity, 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. In this instance, each student is administered one of three versions of the TECA, each of which covers just two of the three sub-domains. This structure enables robust population estimates to be formed while reducing response burden on individual students.

The TECA is designed to measure students’ capacity to reason and work as an effective engineer. 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 could be giving to each of the sub-domains.

3.2 Item characteristics

3.2.1 *Objective (test) items*

The quality of the items underpins the quality of the instrument and hence of the overall assessment. A number of item types would likely be employed, including multiple choice response, closed-constructed response and open-constructed response. Within each capability, items would be designed to measure varying levels of proficiency. Less demanding items would be designed to measure the kind of competence which is generally associated with reproduction. Higher levels of proficiency would 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 would be assessed by the most demanding items. Language difficulty would need to be set at an appropriate level.

More detailed specification of item characteristics depends on the final specification of capabilities, and comes through the process of operationalising these areas for measurement.

Items that measure technical knowledge, for instance, may use a brief text or information presented graphically and would focus on students’ ability to apply basic technical knowledge in specified areas to solve engineering problems. Such items may involve cognitive processes such as recall, recognition, computation and retrieval.

A combination of item types may be required to measure capabilities related to lifelong learning. Students’ self-reflective capacity and interest in learning, for instance, may be measured using subjective items. The capacity for lifelong learning, however, may be measured by testing whether students are aware of effective approaches for ongoing professional learning.

ACER has developed a range of strategies for assessing people's capacity to solve problems. Items that assess diagnose skills may present novel engineering scenarios and problems in short text passages or graphically, and assess different aspects of problem diagnosis. Students could be presented with a problem and be asked to identify the known and unknown aspects of the problem or situation. They could also be asked to define, redefine and simplify a problem in technical terms or represent the problem graphically.

Items that test students' design skills could be a mix of short-answer and multiple choice questions that are related to either a passage of short text or a graphical stimulus. Students would answer items that ask them to compare different design specifications, identify the steps to take to design an effective solution, and analyse, interpret and evaluate the suitability of proposed design solutions.

To assess engineering students' environmental awareness, students could be presented with novel engineering scenarios and asked to identify contexts that are important and that should be taken into account in the scenario. Items could also ask students to make comparisons between different contexts, evaluate and rank the importance of different considerations, show an understanding of sustainable design and development, and rate different solutions to engineering problems in terms of sustainable development.

The items testing students' ability to apply knowledge of maths, science and engineering in practice would most likely assume basic knowledge, but would require students to apply this knowledge to more complex and higher-level engineering problems.

To assess student understanding of professional conduct and ethical practices, they might answer a series of items that require an understanding and appreciation of ethical practice. They could also be asked to compare and rate different scenarios in terms of their ethical standing.

Particular items in the assessment may be required to assess students' understanding of basic economics and business practices. Students may, for instance, conduct a cost analysis of a novel engineering project, conduct a break-even analysis and analyse the expected value and risk of a real-life engineering project. Items may assess students' interpretation of project management, contingency planning and risk assessment, and time management.

Items to assess students' interpersonal understanding and skills could involve scenarios in which students would be asked to evaluate, identify or infer appropriate strategies and behaviours.

Particular items in the assessment could be used to probe students' ability to identify possible sources from which to access relevant information on a novel engineering problem, their ability to logically organise information, evaluate the reliability and robustness of different sources of information, use the information from research, and how to cite and give credit to information sources.

Items that assess communication may focus on the assessment of written communication skills and include items that require students to locate appropriate material within a particular context, group and sort different materials, order materials logically, synthesise ideas, and write a short argument text and report.

3.2.2 *Context items*

The assessment would 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.

The context items could be based on the indicator framework shown in Figure 2. This framework covers inputs, processes and outcomes at institution, teacher and student levels. It helps identify specific areas of policy interest, define required measures, and develop items to capture required data.

The specific factors in the framework are indicative, and have been taken from the Engineers Australia Accreditation Criteria Summary (EA, 2008b). Appropriate elements would need to be selected and then operationalised for use in this particular assessment.

	Outputs and outcomes	Contexts and processes	Antecedents or constraints
Learners	Graduation numbers and rates Graduate satisfaction Graduate destinations Learning outcomes	Student engagement in learning Retention and progress Year of study Industry experience	Demographics Entry levels and pathways Enrolment characteristics Prior qualifications
Teachers	Curriculum resources Assessment resources Teaching evaluation	Teaching approaches Assessment practices Research and teaching links Educational environment Student support arrangements	Staff numbers and profiles Facilities and equipment
Institutions	Alumni networks	Quality improvement arrangements Support for teachers Industry engagement	Institutional characteristics Faculty characteristics Program characteristics

Figure 2 TECA contextual framework

3.3 Development and validation

The following quality-assured approach would need to be used to develop items:

- item drafting and submission
- expert panelling
- cognitive testing
- revision and proofing
- pilot administration, and
- resource production.

3.3.1 Item drafting and submission

To ensure that the assessment is well grounded in the context of engineering and has as much input from the profession as possible, items would be drafted and submitted by professional item writers at ACER, members of engineering education expert groups, and members of participating countries. Where feasible, appropriate items from existing assessments would also be identified.

A comprehensive set of guidelines for the submission of TECA items would need to be produced. These guidelines would include an overview of the development process and timeframe, detailed descriptions of the requirements for items, how these items should be related to the assessment framework and a brief discussion on item difficulty and the issues that can affect it.

This process would deliver a variety of items that assess different capabilities which are at various stages of their item development. This would provide a basis for further development and validation.

3.3.2 Expert panelling

The development of the assessment items would require each of the items to go through particular steps, and in the case of some of the items, to go through these steps a number of times. Before the items pass through these steps, a professional item writer would prepare the items for development by rewriting each item in a standard way, including the item stimulus, the questions for that item and a proposed coding guide for each question.

Typically, the first step taken to develop the items is expert panelling. For this, each of the items would be distributed to members of the expert group and professional item writers during a meeting, at which each item would be thoroughly examined and scrutinised. After the expert panel has scrutinised and analysed the potential items, and the items have been revised, they would proceed to next stage of development.

3.3.3 Cognitive testing

Cognitive testing would be conducted by providing small groups of engineering students from a variety of institutional and national contexts with a number of revised items.

The students would be asked to complete the items while thinking aloud, or be interviewed either individually or in small groups to ascertain their views about the items and how they went about answering them. This stage is particularly useful for the item writers, as it gives them information that can be used to clarify wording of the items and provide some insight into potential responses that students will give which can help improve the coding guide.

3.3.4 Revision and proofing

Once all of the feedback from cognitive testing and expert panelling has been made and the items have been revised, they may need to be resubmitted for expert discussion, and may also need to be tested with students once more.

After revision and proofing has been completed, the items would be tested with students more thoroughly through a pilot test.

3.3.5 Pilot administration

Pilot administration is essential to assure the construct validity of the assessment. As part of this a range of differential item functioning analyses will be conducted using Rasch item response modelling. Running a pilot would also allow for testing of the mechanics of the assessment, including online delivery, data capture, coding and analysis procedures. The dimensionality of the TECA would be tested.

Every item that has been developed would be tested in an online pilot study with a substantial number of students from a representative range of institutions in all participating countries. Multiple versions of the test containing different items, and different rotations of the items would need to be used during the pilot. Multiple versions of the same test items may be field tested in order to determine which version is superior.

After the pilot testing has been completed, student responses to each question would be available to inform coding and analysis.

3.3.6 Resource production

As well as producing items for the assessment, a range of complementary resources and materials would need to be produced to assist with the administration, coding and data analysis of the assessment. The resources to be produced are likely to need to include an administration guide, a coding guide, a data analysis guide, as well as a document containing frequently asked questions. For quality assurance purposes it is also likely that independent supervisors would need to be trained to manage the assessment in each institution.

4 IMPLEMENTING THE ASSESSMENT: POSSIBLE STEPS

A well-designed administration methodology would be developed to inform assessment administration. This would 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.

This concept design does not provide a detailed description of the administration process, which would need to be developed with greater reference to contexts in participating institutions and countries and technical characteristics. Rather, a few general comments are provided on sampling, administration, reporting and evaluation.

4.1 Sampling

The target population of the AHELO feasibility is bachelor-degree qualifications at tertiary institutions. Depending on the country and institutions, these programs may be of three, four or five years' duration.

Sampling students in large-scale objective assessments in higher education involves a range of general considerations that need to be factored into assessment design. These include designing and managing a representative sample of university students, engaging teaching staff in the assessment process, and engaging learners in the assessment. While a full sampling specification would need to take these and other matters into account, it is helpful at this stage to offer a few general statements.

The level of analysis for the assessment would need to be clearly specified in advance. The most feasible and useful level is likely to be the field of engineering within each institution. For operational purposes, this could be defined in terms of specific departments, faculties or schools which are defined by an institution as reflecting their total effort in engineering education. It is important to stress that individual student is not the level of analysis. The test is low stakes for students.

The number and spread of institutions, programs and students to be sampled, and response rates, would need to be clearly specified in terms of the types of population estimates that are required and their necessary level of precision. Experience with international assessments at school level has shown it is vital to have an independent sampling design and verification process, and rigorous standards for reporting of results.

4.2 Administration

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.

Each test version would likely be designed for about 120 to 180 minute delivery, incorporating 100 to 160 minutes testing, 10 minutes for context questions, 5 minutes setup and 5 minutes to close the assessment. This time band is necessary given the content to be assessed and the way in which computer laboratories are timetabled at institutions.

As the assessment would be designed to test much more than recall of factual content, students might be able to use source materials as well as dictionaries and calculators.

The assessment could be administered in the final semester before graduation, as part of the examination period (which helps target 'batches' of students), or in the mid-year break.

In the design of the administration consideration would be given to ways in which the assessment could be linked with other sources of data that could provide a criterion for cross-validating test results. Examples of such data might include graduation rates, academic performance, industry expectations, graduate destinations, or teacher ratings.

4.3 Reporting

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 projects, graduate employment and routine assessment.

In terms of some operational characteristics of the reporting process, Rasch item response modelling would be used to link the rotated forms of the instrument and compute standards-referenced scores that underpin reports to key stakeholders. These would be designed to support a range of continuous improvement activities, and to help engage key stakeholders in the assessment.

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. Given the matrix structure of the instrument and sampling design, no student would receive individual scores. The assessment is low stakes for students. 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 with no relation to metrics used for grading student performance.

Each institution would receive a 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 identification 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.

4.4 Formative evaluation

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 AHELO Feasibility Study, it would examine the science of the assessment as well as the practicality of implementation. There would also be value in considering the substantive educational implications that arise from such work.

Thus the evaluation would consider areas such as: the sampling regime; the practicalities associated with engaging students in the assessment; the psychometric performance of the instrument; administration and fieldwork; the relationship to other data; costs, benefits and overall value that is added by the assessment; how TECA results could be used by institutions; and the overall quality and integrity of the process. Performance expectations in these areas would be set with reference to other large-scale assessment studies. In certain areas it will be necessary to design new frameworks for the unique operating context of higher education.

5 REFERENCES

- 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, vol. 7, no. 1, pp 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', *Creativity, challenge, change: partnerships in engineering education: proceedings of the 17th Annual Conference of the Australasian Association for Engineering Education, 10-13 December 2006, Auckland*, accessed October 13 from: <http://eprints.qut.edu.au/archive/00005899/01/5899.pdf>
- 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, 29 September to 1 October 2003, Melbourne*, Australasian Association for Engineering Education, pp. 65-76.
- CDIO Initiative (2008) *The CDIO Initiative*. Accessed 1 November from: <http://www.cdio.org>
- ENAAEE (2008). *European Accreditation of Engineering Programmes (EUR-ACE)*. Brussels: European Network for Accreditation of Engineering Education.
- Engineers Australia (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 (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 (2008a). *Accreditation Management System*. Accessed 15 October 2008 from: <http://www.engineersaustralia.org.au/education/program-accreditation/accreditation-management-system>
- Engineers Australia (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', *Program and proceedings of the 4th ASEE/AaeE Global Colloquium on Engineering Education: 26-29 September 2005, Sydney*.
- Global Reporting Initiative (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', *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, 29 September to 1 October 2003*, Australasian Association for Engineering Education, Melbourne, pp. 77-81.

- Johnston, S (2003). 'Sustainability and globalization: a positive role for engineering', *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, 29 September to 1 October 2003*, Australasian Association for Engineering Education, Melbourne, pp. 442-449.
- 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.engineersagainstopoverty.com
- OECD (2008). *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
- OECD (2008). *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', *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, 29 September to 1 October 2003*, Australasian Association for Engineering Education, Melbourne, pp.319-326.
- Reid, M (2006). 'A post-modern engineering education challenge: developing an effective values-based engineering decision-making methodology', *Creativity, challenge, change: partnerships in engineering education: proceedings of the 17th Annual Conference of the Australasian Association for Engineering Education, 10-13 December 2006, Auckland*.
- The Institution of Engineers, Australia (1996), *Changing the culture: Engineering education into the future*, The Institution of Engineers, Australia, Barton, ACT.
- 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>
- UK QAA (2006). *Subject benchmark statement: Engineering*. Accessed 2 October 2008 from: <http://www.qaa.ac.uk/academicinfrastructure/benchmark/statements/engineering06.pdf>
- 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*, vol. 9, no. 2, pp. 127-135.
- Walther, J, Mann, L & Radcliffe, D (2005). 'Global engineering education: Australia and the Bologna Process', Program and proceedings of the 4th ASEE/AaeE Global Colloquium on Engineering Education: 26-29 September 2005, Sydney.

Washington Accord (2005). *Graduate attributes and professional competencies*. Accessed 1 October 2008 from: [http://www.washingtonaccord.org/IEM_Grad_AttrProf_Compencies_v11\(2\).pdf](http://www.washingtonaccord.org/IEM_Grad_AttrProf_Compencies_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', *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, 29 September to 1 October 2003*, Australasian Association for Engineering Education, Melbourne, pp.117-125.



Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:

COATES, HAMISH; Radloff, Alexandra

Title:

Tertiary engineering capability assessment: concept design

Date:

2008

Citation:

Coates, H., & Radloff, A. (2008). Tertiary engineering capability assessment: concept design. Camberwell, Vic.: Australian Council for Educational Research.

Publication Status:

Published

Persistent Link:

<http://hdl.handle.net/11343/28875>

File Description:

Tertiary engineering capability assessment: concept design