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Group of National Experts on the AHELO Feasibility Study

ENGINEERING ASSESSMENT FRAMEWORK

AHELO Feasibility Study

**8th meeting of the AHELO GNE
Paris, 18-19 November 2011**

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Engineering Assessment Framework

January 2012



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INTRODUCTION

1. Over the past few decades, the profession of engineering and the roles of engineers have changed rapidly. The problems faced by engineers in today's world are increasingly complex and require engineers to have both strong technical knowledge and skills, and understanding of relevant environmental, social, economic and cultural contexts. In addition, as for other professions, engineers are expected to be good communicators, be able to work effectively in interdisciplinary teams, to conduct themselves ethically and professionally, and to be able to constantly update and improve their technical and personal skills. The required engineering flavour of these generic skills areas are well covered in the engineering education and professional literature (e.g. Bons & McLay, 2003; Walther, Mann & Radcliffe, 2005; Gill, Mills, Sharp & Franzway, 2005).
2. Such changing requirements are continuous, but they are also identified formally in reviews that are undertaken periodically by national professional peak bodies. The past decade or so has seen such reviews in the United States (National Academy of Engineering, 2005), the United Kingdom (Royal Academy of Engineering, 2007), and Australia (Institution of Engineers Australia, 1996; King, 2008). The recommendations in such reviews are usually focussed on changing university-level engineering curricula and pedagogy, revising professional accreditation requirements, and intensifying connections to both professional practice and to school education.
3. The common trend in modernising engineering education is to increase the focus on graduates' competencies in project work, communication, and collaborative skills, and increase their understandings of ethical practice in the contexts in which engineering problems and projects exist (Boles, Murray, Campbell & Iyer, 2006; Walkington, 2001; West & Raper, 2003). Underpinning much of the curriculum redesign and revision are the agreed graduate outcomes as required by national engineering accreditation processes. Over the past decade, these have increasingly been framed in terms of graduates' learning outcomes and competencies, rather than focusing on input measures. Thus, engineering curricula are specified in terms of expected outcomes, rather than subject content. There is also substantial commonality in the statements of these terms as used internationally by bodies concerned with both professional and education accreditation: Washington Accord, 2009; 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).
4. While educational processes and outcomes in engineering are relatively well defined, a need remains to produce robust data on learning outcomes and graduates' potential for subsequent success in work and further study. An assessment of engineering capability undertaken as part of the AHELO Feasibility Study provides an opportunity to contribute to a more evidence-based approach to ascertaining quality in higher education. In collaboration with teams leading other areas of the study, therefore, the work undertaken in the engineering strand explores the feasibility of directly measuring learning outcomes in engineering across different cultural, linguistic and institutional contexts.

5. In addition to this, 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. 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.
6. This AHELO Engineering Assessment Framework describes and illustrates the domain of engineering competency that is used in the AHELO Feasibility Study. The framework: gives an organisational structure for the domain in terms of engineering knowledge, processes and contexts; describes the types of assessment items that have been developed; and details how reporting will be carried out.

DEFINING THE DOMAIN

7. A cornerstone of any assessment framework is an agreed definition of the domain to be tested and on which instrument development can be based. The aim of this study is to measure what tertiary engineering students in the last year of their 'first-cycle' or bachelor degree 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. Knowledge, skills, attitudes and motivation all play a role in this performance and so must be taken into account in defining the domain.
8. Based on the above considerations, the domain to be tested is **first-cycle engineering competency**, which is defined as follows:

First-cycle engineering competency is the demonstrated capacity to solve problems by applying basic engineering and scientific principles, engineering processes and generic skills. It includes the willingness to engage with such problems in order to improve the quality of life, address social needs, and improve the competitiveness and commercial success of society.

9. In the following paragraphs, each part of this definition is considered in turn, to help clarify its meaning in relation to the assessment.

First-cycle engineering competency...

10. A competency involves far more than the basic reproduction of accumulated knowledge. It involves a mobilisation of cognitive and practical skills, creative abilities and other psychosocial resources such as attitudes, motivation and values (OECD, 2003). The assessment of engineering competency does not test reproduction of factual knowledge for final year first-cycle engineering students: this is already done as part of the courses of study being undertaken by students. Instead, it complements this by focusing on the 'above content' knowledge and skills that need to be applied in solving engineering problems in concrete and novel situations. Accordingly, a deal of creativity is required when completing some test items.

...is the demonstrated capacity to solve problems...

11. Coates & Radloff (2008) affirm that "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". Engineering competency entails the demonstrable capacity to solve problems constrained by "technical, economic, business, political, social, and ethical issues" (National Academy of Engineering, 2004).

...by applying basic engineering and scientific principles, engineering processes and generic skills.

12. In OECD (2009a) the first-cycle engineering program learning outcomes were determined to be Generic Skills, Basic and Engineering Sciences, and the three engineering processes of Analysis, Design and Practice. Generic Skills includes effective communication and awareness of the wider Engineering context. Basic and Engineering Sciences includes knowledge and understanding of the scientific and mathematical principles underlying engineering. Engineering Analysis includes using analytical methods to identify, formulate and solve Engineering problems. Engineering Design includes understanding and application of design methodologies to meet specified requirements. Engineering Practice includes the practical skills and knowledge required for solving problems, conducting investigations, and designing engineering devices and processes.
13. Basic and Engineering Sciences, and the three engineering processes, have been used as the main organisers in developing the test instrument, in addition to those generic skills that are peculiar to engineering. The capacity to apply the learning gained in these areas is the basic construct that is measured in this feasibility study. The next section discusses domain organisation.
14. For the purposes of this assessment a distinction is made between engineering generic skills and non-engineering generic skills. The latter are applicable outside engineering, and include team-work and recognition of the importance of life-long learning. These non-engineering generic skills are assessed in another AHELO strand.

It includes the willingness to engage with such problems...

15. Research has shown that all problem solving is personal and directed, that is, the problem solver's processing is guided by their personal goals (Mayer & Wittrock, 2006). In fact many psychological factors affect the operation of relevant knowledge and skill in solving problems. Person traits such as motivation, self-efficacy and persistence influence an individual's success in finding a solution path. This particularly applies in the engineering context, since engineers have to be willing to tackle "complex and challenging modern societal problems such as food, health, energy, water, and the environment" (OECD, 2009a; National Academy of Engineering, 2008).
16. In addition to purely psychological factors, the novelty of a problem (whether it is familiar and easily understood), the external resources available to the solver (such as computer access), and the environment in which the solver operates (e.g. in a laboratory, in the field or in a test situation) affects the way the solver approaches and engages with the problem.
17. It is not possible in a test situation to control for all the psychological and environmental variables mentioned. A variety of contexts, item types and presentation formats (e.g. interactive items made possible by computer-based assessment) help to mitigate this in an effort to explain variations in student performance in terms of key construct characteristics.

...in order to improve the quality of life, address social needs, and improve the competitiveness and commercial success of society.

18. Rychen & Salganik (2003) argue that competence is a critical factor in the ways that individuals help to shape the world. They say that “key competencies can benefit both individuals and societies”. Indeed, individuals exercise their engineering competency for a wider purpose, not just for personal benefit. The primary goal of engineering is to “improve the quality of life, address social needs, and improve the competitiveness and commercial success of society” (OECD, 2009a). Issues such as these are tapped in some assessment items.
19. The next section identifies the main elements on which the assessment of first-cycle civil engineering competency is based. These elements are placed into a unifying structure and their significance is elaborated.

ORGANISING THE DOMAIN

Framework components

20. How the domain is represented and organised determines the assessment design and, ultimately, the evidence about student proficiencies that can be collected and reported. Many elements are part of the construct, not all of which can be taken into account and varied in an assessment such as this. It is necessary to select the most important elements that can be varied to ensure construction of an assessment that contains tasks which have an appropriate range of difficulty and provide a broad coverage of the domain (see: OECD, 2009b).
21. Arguably the most important aspect of assessing engineering competency is the evaluation of how a student performs when measured against pre-defined objectives of achievement. These objectives are encapsulated in what is known as “learning outcomes”, for example as defined in the Tuning report (González & Wagenaar, 2008):

Learning outcomes are statements of what a learner is expected to know, understand and/or be able to demonstrate after completion of a process of learning.

22. The first-cycle engineering learning outcomes as agreed in the “Tuning-AHELO conceptual framework of expected/desired learning outcomes in engineering” study (OECD, 2009a) serve to circumscribe the engineering knowledge and skills that are the focus of this study. These learning outcomes have explicitly been used in designing the assessment instrument.
23. An assessment instrument must tap into the different aspects of a test taker’s proficiencies. Engineering competency entails applying relevant skills and knowledge in solving problems of interest to an engineer. Recognising that engineering problems occur in a diverse array of situations, a representative sample of engaging contexts for items have been chosen to exercise the constituent components of engineering competency.
24. The key components described in the previous paragraphs are summarised below in Figure 1. This provides an overview of how the domain is organised, showing the elements of importance for the assessment of first-cycle engineering competency.

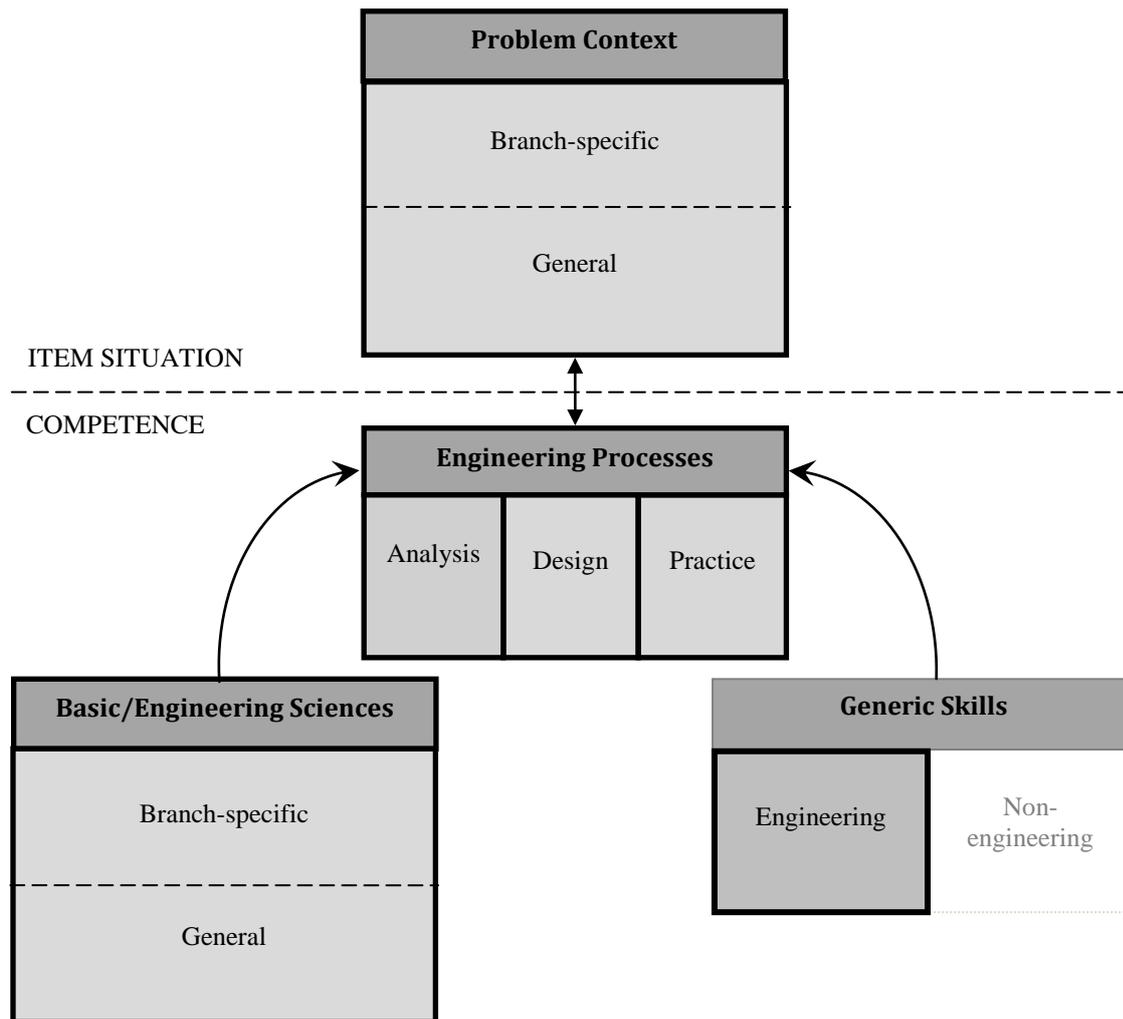


Figure 1: AHELO Engineering Assessment Framework: Key Components

25. The upper half of Figure 1 shows the problem context as presented in an assessment item. Contexts may be suitable for a specific branch of engineering, or may be more generally applicable to two or more branches of engineering. For this study, scenarios are used that pertain to civil engineering. Future studies may be carried out using other branches of engineering, and it may be possible to use some of the general material from the current study for these. The lower half of the diagram shows the important aspects of engineering competency activated when a student tackles an assessment item, including Engineering Processes, engineering Generic Skills, and Basic and Engineering Sciences. Similar to context, the content of Basic and Engineering Sciences can be specific to a particular branch of engineering or it can be knowledge that all engineers would be expected to possess.
26. Contexts have been varied to cover as wide a range as possible in a short assessment. Items have been constructed within each context to measure how well students perform when each of the three engineering processes of analysis, design and practice are exercised, supported by the application of fundamental scientific and engineering knowledge together with engineering generic skills. As discussed above, non-engineering generic skills – whilst playing an important role in an engineer’s arsenal – are not part of this assessment. The features of competency and context pertaining to the assessment are described in detail in the following subsections.

Competence

27. The components of engineering competency are derived from the OECD statements of learning outcomes (OECD, 2009a). These are reiterated below, noting that some minor re-alignment has been made in the interests of streamlining the assessment. In all cases a level of knowledge and understanding to be expected at the end of a first-cycle engineering course is assumed.

Engineering Generic Skills

28. The OECD study (OECD, 2009a) describes generic skills in these terms: “Graduates should possess generic skills which are necessary for the practice of engineering and are applicable more broadly. Among these are the identified capacity for analysis and synthesis, capacity for applying knowledge in practice, capacity to adapt to new situations, concern for quality, information management skills and capacity for generating new ideas (creativity).”
29. The following engineering generic skills are explicitly included in the assessment:
- a. The ability to use diverse methods to communicate effectively with the engineering community and with society at large (EGS1); and
 - b. The ability to demonstrate awareness of the wider multidisciplinary context of engineering (EGS2).

The capacity to generate new ideas, or think innovatively, are not explicitly measured in the assessment, however, some items involving novel or unfamiliar situations require such a capacity to the extent expected of an engineer.

Basic and Engineering Sciences

30. This part of the assessment has been drawn from the following specific learning outcomes:
- a. The ability to demonstrate knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering (BES1);
 - b. The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering (BES2);
 - c. The ability to demonstrate comprehensive knowledge of their branch of engineering including emerging issues. For civil engineering in this assessment, this comprises the following five specialised areas: materials and construction (BES3(i)), structural engineering (BES3(ii)), geotechnical engineering (BES3(iii)), hydraulic engineering (BES3(iv)), and urban and rural planning (BES3(v)).

Engineering Analysis

31. Analysis assessment has been drawn from the following specific learning outcomes:
- a. The ability to apply knowledge and understanding to identify, formulate and solve engineering problems using established methods (EA1).

- b. The ability to apply knowledge and understanding to analyse engineering products, processes and methods (EA2).
- c. The ability to select and apply relevant analytic and modelling methods (EA3).
- d. The ability to conduct searches of literature, and to use databases and other sources of information (EA4).
- e. The ability to design and conduct appropriate experiments, interpret the data and draw conclusions (EA5).
- f. The ability to demonstrate workshop and laboratory skills (EA6).

Engineering Design

32. Design may be of processes, methods or artefacts. The assessment of design has been drawn from the following specific learning outcomes:
- a. The ability to apply knowledge and understanding to develop designs to meet defined and specified requirements (ED1).
 - b. The ability to demonstrate an understanding of design methodologies, and an ability to use them (ED2).

Engineering Practice

33. Practical skills and knowledge are important for solving problems, conducting investigations, and designing engineering devices and processes. The assessment of engineering practice has been drawn from the following specific learning outcomes:
- a. The ability to select and use appropriate materials, equipment and tools (EP1).
 - b. The ability to combine theory and practice to solve engineering problems (EP2).
 - c. The ability to demonstrate understanding of applicable techniques and methods, and their limitations (EP3).
 - d. The ability to demonstrate understanding of the non-technical implications of engineering practice and commitment to professional ethics, responsibilities and norms of engineering practice (EP4).
 - e. The ability to demonstrate understanding of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a global, economic, societal and environmental context (EP5).
 - f. The ability to demonstrate knowledge of project management and business practices, such as risk and change management, and be aware of their limitations (EP6).

34. In addition to all the above knowledge and skills, engineering competency involves considerations beyond narrow fields of specialisation. Societal, ethical, legislative, regulatory, commercial and industrial issues may need to be taken into account in a given context. Finally, engineers need to be able to work in cooperation with other engineers (possibly from another branch of engineering) and non-engineers, so this aspect is included in the field to be surveyed.

Context

35. Scenarios have been devised based on realistic contexts for engineering problems. A broad variety of contexts have been sampled in the assessment. Example contexts from

civil engineering are given below. While settings for assessment tasks are not restricted to these, the examples give an idea of the breadth possible.

36. Contexts selected from a range of situations involving environmental, structural, geotechnical, urban/rural, coastal and construction engineering such as: bridges; buildings; construction sites; corrosion; dam design; drainage systems; emergency staircase design; floating wind turbine; gate and lock canal systems; geotechnical structures; “green” building design; harbour engineering and planning; hydraulic works; hydroelectric power generation; inland navigation design; irrigation; ports and harbours; road and railroad constructions; soil testing and investigations; surveying applications; traffic flows and control in freeways; transport and traffic engineering and planning tunnels; and water supply.

ASSESSING ENGINEERING COMPETENCY

Structure of the AHELO Engineering Assessment

37. The duration of the Engineering Assessment is 90 minutes. The assessment includes a broad sample of items covering a range of difficulty that will enable the strengths and weaknesses of populations and key subgroups to be determined with respect to the components of engineering competency.
38. Two types of assessment tasks have been developed. The first type of task has a constructed response format. Constructed response (CR) tasks have been designed to comprehensively assess four key competencies defined in the Engineering Assessment Framework: engineering generic skills, engineering analysis, engineering design, and engineering practice.
39. The CR tasks introduce an authentic engineering scenario structure, design, situation or problem in a specific context and present students with a set of items related to that context. The scenario is introduced through the use of a range of stimuli including photographs, diagrams, tables and charts and students then respond to a number of items requiring both short answers and longer responses.
40. Each constructed response task is designed to take students 40 minutes to complete, with the Engineering Assessment including one of these tasks. In Phase 2 of AHELO, three constructed response tasks are included and these will be rotated.
41. The second type of task has a multiple choice format. Multiple choice items have been designed to assess the fifth key competency defined in the Engineering Assessment Framework – Basic and Engineering Sciences. They have been included to provide a fast and efficient way to collect data on students' engineering knowledge, understanding and skills and to compliment the constructed response tasks. They cover a wide range of basic engineering knowledge, along with specific above content competencies. The multiple choice items are also included as a means of verifying the robustness of competencies assessed by the constructed response tasks. Since application of basic engineering and scientific principles requires their mastery, results from multiple choice items should indicate whether students have in fact developed the fundamentals that underlie competencies required to analyse and synthesise solutions to complex engineering problems.
42. To respond to multiple choice items, students need to select one correct response out of four possibilities. In total, 30 multiple choice items have been developed, grouped in six sets of five. They are designed so that students can respond to 25 items in 50 minutes, and will be rotated in Phase 2 of AHELO, with students completing five of the five-item sets.
43. There are a number of rotations for Phase 2 of the Engineering Assessment, as indicated in Table 1. Data can be obtained from students' responses to all the materials, however, across any given institution.

Table 1: Phase 2 Engineering Assessment rotations

| Rotation | Constructed response task | Multiple choice set | | | | |
|----------|---------------------------|---------------------|--------|--------|--------|--------|
| | | ENGMC1 | ENGMC2 | ENGMC3 | ENGMC4 | ENGMC5 |
| 1 | CRTM1 | ENGMC1 | ENGMC2 | ENGMC3 | ENGMC4 | ENGMC5 |
| 2 | CRTM1 | ENGMC2 | ENGMC3 | ENGMC4 | ENGMC5 | ENGMC6 |
| 3 | CRTM1 | ENGMC3 | ENGMC4 | ENGMC5 | ENGMC6 | ENGMC1 |
| 4 | CRTM1 | ENGMC4 | ENGMC5 | ENGMC6 | ENGMC1 | ENGMC2 |
| 5 | CRTM1 | ENGMC5 | ENGMC6 | ENGMC1 | ENGMC2 | ENGMC3 |
| 6 | CRTM1 | ENGMC6 | ENGMC1 | ENGMC2 | ENGMC3 | ENGMC4 |
| 7 | CRTM2 | ENGMC1 | ENGMC2 | ENGMC3 | ENGMC4 | ENGMC5 |
| 8 | CRTM2 | ENGMC2 | ENGMC3 | ENGMC4 | ENGMC5 | ENGMC6 |
| 9 | CRTM2 | ENGMC3 | ENGMC4 | ENGMC5 | ENGMC6 | ENGMC1 |
| 10 | CRTM2 | ENGMC4 | ENGMC5 | ENGMC6 | ENGMC1 | ENGMC2 |
| 11 | CRTM2 | ENGMC5 | ENGMC6 | ENGMC1 | ENGMC2 | ENGMC3 |
| 12 | CRTM2 | ENGMC6 | ENGMC1 | ENGMC2 | ENGMC3 | ENGMC4 |
| 13 | CRTM3 | ENGMC1 | ENGMC2 | ENGMC3 | ENGMC4 | ENGMC5 |
| 14 | CRTM3 | ENGMC2 | ENGMC3 | ENGMC4 | ENGMC5 | ENGMC6 |
| 15 | CRTM3 | ENGMC3 | ENGMC4 | ENGMC5 | ENGMC6 | ENGMC1 |
| 16 | CRTM3 | ENGMC4 | ENGMC5 | ENGMC6 | ENGMC1 | ENGMC2 |
| 17 | CRTM3 | ENGMC5 | ENGMC6 | ENGMC1 | ENGMC2 | ENGMC3 |
| 18 | CRTM3 | ENGMC6 | ENGMC1 | ENGMC2 | ENGMC3 | ENGMC4 |

44. The assessment includes a broad sample of items covering a range of difficulty that enables the strengths and weaknesses of populations and key subgroups to be determined with respect to the components of engineering competency.
45. As far as is practicable, each item focuses on a single component of competency. Accordingly, some items test understanding of mathematics and science, some of engineering sciences. Others test methods of engineering analysis, others the ability to realise engineering designs, and others the capacity to apply engineering knowledge and understanding to realistic problems. Engineering generic skills play a part in many of these and so are not assessed independently.
46. Items have been designed to measure varying levels of proficiency. Less demanding items are designed to measure the kind of competence which is generally associated with reproduction. Higher levels of proficiency are 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 are assessed by the most demanding items.
47. Language difficulty has been set at an appropriate level for final-year first-cycle engineering students. Photographs and diagrams have been used where appropriate to avoid excessively long passages of text.
48. The features which determine item difficulty include (but are not limited to): context including familiarity and concreteness of context; engineering processes; complexity of system; familiarity of representations used; number of constraints present; amount/complexity/coherence of information; and complexity/difficulty of computations required.
49. Care has been taken to ensure a range of contexts is employed as one means of controlling for students' interests and prior knowledge. Real world situations are often

extremely complex and a balance has been struck in constructing items between authenticity of a context and practicality of assessment.

50. Table 2 indicates the approximate distribution of score points across the domain components. The engineering processes have been given equal weight. A small number of score points have been allocated to engineering generic skills. Given the relatively limited number of items, the figures and percentages are approximate only.

Table 2: Distribution of score points in the AHELO Engineering Assessment

| | Engineering Generic Skills | Basic/ Engineering Sciences | Analysis | Design | Practice | Weighting |
|-----------|---|--|-----------------|---------------|-----------------|------------------|
| Weighting | 10% | 45% | 15% | 15% | 15% | 100% |

Response formats and scoring

51. Item response formats include:
- a. multiple choice: simple and complex multiple-choice items that are answered by selecting an option from each list of choices;
 - b. constructed response: either short constructed-response, e.g. numerical or short text; or extended constructed response, e.g. creation of flow charts, designs, dot-pointed specifications, and longer written responses.
52. Multiple-choice items can provide a fast and efficient way to collect data on students' engineering knowledge, understanding and skills.
53. Constructed response tasks in the engineering context may, for example, require students to complete short engineering designs (typically in their specialty branch), describe analytic processes or evaluate and make use of complex data to make recommendations or suggest solutions to engineering problems.
54. Scoring rubrics for evaluating student responses to items are given in the Engineering Scoring Guide. The rubrics are constructed based on the components of engineering competency identified above. In the case of Basic and Engineering Sciences – which are tested using items with a multiple choice format – the rubric is very simple. For Engineering Analysis, Design and Practice the rubric is more complex, containing criteria for achievement based on the specific constituent learning outcomes of each component. For example, for Engineering Analysis one criterion would be “Selects and applies relevant analytic and modelling methods”. The rubrics allow the recognition of different levels of attainment in the test-takers' work of each (relevant) criterion. (Note that these criteria can be further used in reporting – see below.)
55. In the rubrics, the highest level of scoring reflects a complete understanding of the problem, is tied to a correct solution, rewards thought that shows considerable insight, and reflects work that is clear, appropriate, and fully developed. Such responses should be logically sound, clearly written and contain no errors. Any examples given should be well chosen and fully developed.
56. At a slightly lower score level, one might encounter work that demonstrates a clear understanding of the problem, shows some insight and provides an acceptable approach,

but still contains minor weaknesses in the development. Examples are provided, but they may not be fully developed.

57. At an even lower level, one may see work that contains evidence of an understanding of the problem at a conceptual level evidenced by the logical approach taken or representation chosen. However, on the whole, such a response is not well developed. While there may be serious logical errors or flaws in the reasoning, the response does contain some correct work. The examples provided may be incorrect or incomplete.
58. Finally, there is a no credit level, for scoring completely incorrect or irrelevant responses. Within the scoring at this level, there is allowance made for distinguishing between students who attempt a given problem and those who submit a blank response. The latter may signal either lack of time or a motivational problem.
59. It should be noted that the majority of items do not attract all of the three positive credit levels described above. Collectively for the assessment, however, there are items tapping into different levels of student performance.

Functionality provided by computer delivery

60. The assessment will be administered via computer. Doing so has several benefits, as outlined in the next few paragraphs.
61. While not possible in the feasibility study, a broader benefit of measuring engineering competency by computer is that, dynamic stimulus material can be produced, including: visuals such as video clips and animations; environments where students interact with features to explore or control a situation; simulations where students can enter parameters and run models; and on-line tools for performing calculations and searches, and for drawing graphs and diagrams.
62. A further benefit is the opportunity to capture and measure data that relate to processes and strategies. It is possible to record data such as the type, frequency, length and sequence of actions performed by students.
63. Another benefit is that the time students spend on any particular item can be restricted, where it is consider appropriate. This is particularly useful in contexts where students are exploring stimulus material interactively.
64. It is possible to deliver items in a fixed order, or 'lockstep' fashion if desired. The lockstep procedure means that students are not able to return to an item or unit once they have moved to the next one. Each time students click the 'Next' button a dialog box displays a warning that they are about to move on to the next item and that it is not possible to return to the previous item. At this point, students can either confirm they want to move on or cancel the action and return to the current item. An advantage of this approach is that it maximises the independence of items within and across units, since students cannot find clues in later tasks that might help them to answer earlier ones. Put more positively, later items can reveal the answers to earlier items without enabling previous answers to be changed.

65. With a computer-based assessment, multiple choice items are scored automatically (by computer). In some instances it may also be possible to automatically score short answer responses.
66. Any responses that cannot be scored automatically are collected by the computer-delivery system and saved in an appropriate format. An online scoring system facilitates scoring (by experts) of these saved files. This eliminates the need for separate data entry, minimises the need for data cleaning, and allows scoring to take place 'off site' if desired.
67. Detailed scoring operations are detailed in the International Scoring Manual.
68. While engineering graduates are expected to be familiar with various software packages, detailed knowledge of particular software is not assumed in the assessment. Only basic ICT skills are assumed, such as keyboard use, manipulating a pointer (via a mouse), clicking option buttons, drag-and-drop, scrolling and use of pull-down menus and hyperlinks.

Calculators

69. This assessment does not focus on students' ability to perform calculations. As such, all students participating in the assessment are allowed to use any hand-held calculators they routinely use in their regular learning environments. The decision of whether or not to use calculators should rest with the individual students based on their knowledge of when a calculator is appropriate and how it might add to the solution of a given problem. No item has been constructed so that its solution is dependent solely on whether a calculator is used or not, or is of such a length or complexity that students not using a calculator are severely disadvantaged in performing any calculations required.

REPORTING ENGINEERING COMPETENCY

70. Similar to the PISA reporting practice (OECD, 2009b), results are reported on a scale constructed using a generalised form of the Rasch model. Underlying the construction of a scale are several assumptions: that there is a latent trait (as specified in the assessment framework) that can be represented by a continuous variable and is possessed by test-takers; that test items can be constructed that require the test-taker to use this trait in responding to items; and that the amount of the trait possessed by test-takers is a function of the score they receive on the test.
71. The form of the Rasch model that is used employs the scores obtained by students to produce estimates for both the difficulty of items and the ability of students on a single real-valued scale. The scale is constructed so as to have a mean score of 500 and standard deviation of 100. Accordingly, about two-thirds of the test-takers would score between 400 and 600 points.
72. The scale is divided into levels (bands) of equal width, with an unbounded region at each end. Each band corresponds to a student proficiency level (or alternatively an item difficulty level). Information about the items at each level is then used to develop descriptions characterising typical student performance at each level. The specific constituent learning outcomes of the competency components (e.g. “Selects and applies relevant analytic and modelling methods”) form the basis of these descriptors.
73. Five levels of proficiency are able to be identified and described to show individuals’ engineering competency. The model and scaling methods allow the linking of measures of student performance with data collected in the contextual instrument, such as gender, socioeconomic standing, geographical location and institution attended. This enables statistical comparisons of population means between students grouped by these background factors. For example, comparisons of performance between participating institutions are possible.

APPENDIX A: ENGINEERING EXPERT GROUP

The AHELO Feasibility Study's Engineering Expert Group (EEG) was drawn from participating countries and key international organisations. The EEG has supported the development of the Engineering Assessment Framework and Engineering Assessment. The work of the EEG builds on that of the Tuning-AHELO Expert Group (TAEG). Table 3 lists members of these groups, affiliations, and periods of service.

Table 3: Engineering Expert Group membership

| Expert Group member | Group | Affiliation | Service |
|--|-----------|---|---------|
| Professor Robin King (Chair) | TAEG, EEG | University of Technology Sydney, Australia | 2009-12 |
| Professor Giuliano Augusti | TAEG, EEG | Universita 'La Sapienza' , Italy | 2008-12 |
| Professor Michael Hoffman | EEG | University of Ulm, Germany | 2009-12 |
| Professor Kikuo Kishimoto | TAEG, EEG | Tokyo Institute of Technology, Japan | 2008-12 |
| Professor Johan Malmqvist | TAEG, EEG | Chalmers University of Technology, Sweden | 2008-12 |
| Professor Jim Melsa | TAEG, EEG | Iowa State University, United States | 2008-12 |
| Professor Lueny Morell | EEG | Hewlett Packard, United States | 2009-12 |
| Professor Nobotoshi Masuda | EEG | Tokyo City University, Japan | 2009-12 |
| Professor Alfredo Soeiro | TAEG | University of Porto, Portugal | 2008-09 |
| Professor Andrew Downing | TAEG | University of South Australia, Australia | 2008-09 |
| Professor Edwin Jones Jr | TAEG | Iowa State University, United States | 2008-09 |
| Professor Eric van der Geer-Rutten-Rijswijk | TAEG | Eindhoven University of Technology, Netherlands | 2008-09 |
| Professor Francesco Maffioli | TAEG | Politecnico di Milano, Italy | 2008-09 |
| Professor Iacint Manoliu | TAEG | Technical University of Civil Engineering, Romania | 2008-09 |
| Iring Wasser | TAEG | ASIIN, Germany | 2008-09 |
| Professor Jim Birch | TAEG | Engineering Council UK, United Kingdom | 2008-09 |
| Professor Mats Hanson | TAEG | KTH- Royal Institute of Technology, Sweden | 2008-09 |
| Professor Patricia Daniels | TAEG | Seattle University, United States | 2008-09 |
| Professor Paulino Alonso | TAEG | President of the Council of Engineering Deans of Chile, Chile | 2008-09 |
| Professor Peter Wieringa | TAEG | Delft University of Technology, Netherlands | 2008-09 |
| Professor Philippe Wauters | TAEG | FEANI Secretary General, Belgium | 2008-09 |

| Expert Group member | Group | Affiliation | Service |
|-----------------------------|--------------|--|----------------|
| Professor Pierre Compte | TAEG | Commission des titres d'ingénieur, France | 2008-09 |
| Professor Yinghe He | TAEG | James Cook University, Australia | 2008-09 |
| Professor Rob Best | TAEG | London South Bank University, United Kingdom | 2008-09 |
| Professor Roger Hadgraft | TAEG | University of Melbourne, Australia | 2008-09 |

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