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Group of National Experts on the AHELO Feasibility Study
(7/1)
PROGRESS REPORT ON THE ENGINEERING SPRAND
6th meeting of the AHELO GNE
Paris, 28-29 March 2011
This document was prepared by the ACER Consortium.
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OVERVIEW

1. This progress report provides an update of work undertaken between September 2010 and February 2011 in Module C of the AHELO Feasibility Study, *i.e.* the development of a provisional assessment framework and instrument for the Engineering strand. This document provides background information that will be elaborated with a verbal report at the sixth AHELO GNE meeting being held in Paris on March 28 and 29, 2011.

2. The Module C team comprises the Australian Council for Educational Research (ACER), Japan's National Institute for Educational Policy Research (NIER) and the University of Florence in Italy, working with colleagues in the Academic Network of European and Global Engineering Education (EUGENE).

3. Figure 1. provides an overview of Module C schedule and progress. As this shows, work is progressing as planned and is on track for completion. In this diagram 'C' stands for 'Completed'.

		2010			2011									
Phase	Activity	6	7	8	9	10	11	12	1	2	3	4	5	6
	Finalise methodology													
	Audit existing resources	С	С	С	С									
	Framework development	С	С	С	С									
	Consultation and validation		С	С	С	С	С	С						
	Develop instrument specification		С	С	С	С	С	С						
	Evaluation and review of framework					С	С	С	С	С	С			
Framework Deliver framework and specifications														
	Submissions from networks	С	С	С										
	Search for existing materials		С	С										
	Item development	С	С	С	С	С	С							
	Cognitive labs with source version						С	С						
	Finalise source versions						С	С						
	Produce source version of instrument							С						
	In-country adaptation/translation								С	С	С			
	Revise, validate and map items									С	С			
Deliver verified translated instruments														
Instrument	Develop coding guides					С	С	С	С	С	С			
	Contribution to analysis plan	С	С	С	С									
	Contribution to reporting		С	С	С	С	С	С	С	С	С			
	Deliver summary report													
Analysis	Deliver report mapping items and framework									С	С			

Figure 1. Module C schedule and progress

FRAMEWORK DEVELOPMENT

4. The Module C team will develop a provisional framework for the field of Engineering. The Engineering strand framework will be developed to include one of the three branches of Engineering articulated in the AHELO Feasibility Study Tuning Framework, namely Civil Engineering, as advised by the Engineering Expert Group and OECD. (Contract M09/57)

5. The Module C team drafted the Engineering Assessment Framework, drawing together the AHELO Tuning document ('Tuning-AHELO Conceptual Framework of Expected/Desired Learning Outcomes in Engineering') with other relevant materials. The Engineering Assessment Framework explicates the skills and knowledge which students will need to demonstrate in order to indicate that they have acquired the following five key areas:

- 1. Engineering Generic Skills
- 2. Basic and Engineering Sciences
- 3. Engineering Analysis
- 4. Engineering Design
- 5. Engineering Practice

6. The draft AHELO Engineering Assessment Framework was posted on the AHELO Exchange for review by the Engineering Expert Group in September 2010. The Engineering Expert Group consists of nine discipline experts drawn from countries participating in the AHELO Feasibility Study. The list of expert group members is provided in Annex A of the Engineering Assessment Framework.

7. In October 2010 the Engineering Expert Group met for an intensive two-day meeting in Singapore. At this time the Engineering Assessment Framework was discussed in detail and a number of revisions were suggested. After revisions were incorporated, the framework was again posted on the AHELO Exchange for a second round of comments/revisions from the Engineering Expert Group.

8. Feedback from participating countries was fed into draft versions of the framework throughout its development. In particular, a series of teleconferences and meetings were scheduled with Swedish GNE and National Project Managers (NPM) delegates, instrument developers and Engineering experts to seek alignment between the international specification of Civil Engineering and the curriculum structure in Swedish institutions. These meetings helped examine resolve a number of definitional and technical matters of broader relevance to the study.

9. The final Engineering Assessment Framework was posted on the AHELO Exchange for countries in February 2011. The draft working version is included in Appendix 1 of this Module C Progress Report. The Engineering Assessment Framework will be finalised by the consortium and Engineering Expert Group for delivery in 2011.

EDU/IMHE/AHELO/GNE(2011)4

INSTRUMENT DEVELOPMENT

10. ACER and Module C partners will develop an instrument to test one branch of Engineering (Civil Engineering). (Contract M09/57)

11. With input from a consultant engineer (Professor Roger Hadgraft, University of Melbourne), the Module C team created twelve constructed response tasks for the AHELO Engineering Assessment. In addition, a large number of multiple choice items from the Japanese Licensing Exam for Civil Engineers were translated. All draft assessment items were posted on the AHELO Exchange for review by the Engineering Expert Group in October 2010.

12. At the October 2010 meeting of the Engineering Expert Group, all draft engineering items were discussed in detail and revisions, deletions and additions suggested. Results from initial qualitative testing at the University of Melbourne were reviewed. Once changes were incorporated, the revised items were posted on the AHELO Exchange for further input from the Engineering Expert Group, and went through a further period of revision by the Module C team.

13. It is important to note how the Engineering instrument positions alongside the Generic Skills and Engineering instruments. The Generic Skills consists entirely of open constructed response with no multiple choice. The Economics instrument consists of a balance of open constructed response and multiple choice items. The Engineering instrument consists of a number of different question types, including open constructed response, short response, and multiple choice. The deployment of this variety of item types across instruments in the AHELO Feasibility Study enables testing of various technical, practical and educational considerations.

14. The final AHELO Engineering Assessment will be composed of two hybrid (constructed and short response) tasks, and 20 multiple choice questions, which together will take students 90 minutes to complete. For qualitative testing, the Module C team prepared four constructed response tasks and 40 multiple choice questions. These tasks and questions will be administered in an alternated manner in focus groups to be conducted in March and April by participating countries. The choice of the tasks and questions best suited to the final AHELO Engineering Assessment will take place based on feedback collected from students during the qualitative testing phase. The Module C team has also created scoring guides for each of the items.

15. All English source versions of the items in the AHELO Engineering Assessment were posted on the AHELO Exchange in January 2011 in preparation for translation and adaptation by countries. Information about adaptation, translation and verification is provided in the Module E Progress Report. Participating countries are expecting to finalise the adaptation, translation and verification process by the end of April 2011.

16. A brochure on the AHELO Engineering Assessment is included in Appendix 2 of this Module C Progress Report. This brochure was created to assist NPMs promote the assessment with institutions and students.

CONTRIBUTE TO PROJECT MANAGEMENT

17. The Module C team will assist with broader aspects of the study's planning, implementation, analysis and reporting. (Contract M09/57)

18. The Module C team has been involved in overall management of the AHELO Feasibility Study, working closely with colleagues in other consortium partners. They have been involved in several key meetings:

- Presenting a Module C Progress Report to the Group of National Experts in October 2010;
- Participating in a two-day face-to-face meeting of NPMs in Paris in October 2010;
- Arranging and running a two-day meeting with the Engineering Expert Group in October 2010;
- Participating in teleconferences with all NPMs in December 2010;
- Participating in the March 2011 meeting of the AHELO GNE; and
- Participating in the April 2011 meeting of the AHELO TAG.

19. The Module C team has also contributed to the revision of the AHELO Assessment Design and the drafting and revision of the AHELO Analysis Plan, as well as reviewing AHELO Reporting Guidelines. Contribution has been multifaceted and provided on an ongoing basis during the development and finalisation of these materials.

20. The Module C team has also worked closely with cApStAn on the creation of the AHELO Translation, Adaptation and Verification (ATAV) guide for all Engineering Assessment items, and has contributed to the development of translation and adaptation guidelines.

PROGRESS TOWARDS DELIVERABLES

21. The Module C team acknowledges and accepts the deliverables stated in the AHELO Terms of Reference: the framework and test specifications for the Engineering assessment; the instrument for the Engineering assessment including the scoring/coding guides; and a mapping of the items in the 'mini assessment' to the provisional framework. (Contract M09/57)

22. The following materials are being produced and finalised for delivery:

- The framework and test specifications for the Engineering assessment;
- The instrument for the Engineering assessment including scoring/coding guides;
- A mapping of the items in the 'mini assessment' to the provisional framework; and
- A summary framework and instrument development report including details of the development process, the pretest outcomes and a mapping of test items to the assessment framework for the Engineering instrument.

APPENDIX 1:

ENGINEERING ASSESSMENT FRAMEWORK (DRAFT)





AHELO ENGINEERING STRAND ASSESSMENT FRAMEWORK

Doc: AHELOENG_AF

Version: 1.0

ANNEX 1 OF EDU/IMHE/AHELO/GNE(2011)4

23 December 2010

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AHELO Engineering Strand Assessment Framework

TABLE OF CONTENTS

PRE	AMBLE
I.	INTRODUCTION
II.	DEFINING THE DOMAIN
III.	ORGANISING THE DOMAIN
a b c	Framework Components10Competency12Engineering Generic Skills12Basic and Engineering Sciences13Engineering Analysis14Engineering Design14Engineering Practice14Context15
IV.	ASSESSING ENGINEERING COMPETENCY
a b c d	 Structure of the Assessment
V.	REPORTING ENGINEERING COMPETENCY
VI.	SAMPLE TASKS
а	. Civil Engineering25
VII.	REFERENCES
ΑΝΙ	NEX A: EXPERT GROUP

PREAMBLE

- The original draft of this document was based on the AHELO-Tuning document (OECD 2009a), the AHELO Engineering Strand Assessment Workshop held at ACER in Melbourne in January 2010, the TECA document (Coates & Radloff, 2008), and the consortium technical proposal document. It is informed by the processes and practices adopted in the PISA literacy surveys (e.g. OECD 2009b), and the combined expertise of consortium staff.
- 2. Subsequent drafts incorporated review comments from consortium members and engineering expert group members.
- 3. This version clarifies the section on the structure of the assessment.

I. 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 curriculum 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

5

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

- 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 modules, therefore, the work undertaken in Module C will explore the feasibility of directly measuring learning outcomes in Engineering and 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 framework describes and illustrates the domain of engineering competency that will be used in the AHELO Feasibility Study. It gives an organisational structure for the domain in terms of engineering knowledge, processes and contexts; describes the types of assessment items that will be developed; and details how reporting will be carried out. For the present study, Civil Engineering competency will be assessed in a paper-and pencil instrument.

II. 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 will be **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 will 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 will complement 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 will be required when completing some test items.

7

... 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 programmes 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; and *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 will be 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 will be measured in this feasibility study. See chapter III below for a discussion of domain organisation.
- 14. For the purposes of this assessment a distinction will be 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 will be 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) will affect 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 will 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 will be tapped in some assessment items.
- 19. The next chapter identifies the main elements on which the assessment of firstcycle Civil Engineering competency will be based. These elements will be placed into a unifying structure and their significance elaborated.

9

III. ORGANISING THE DOMAIN

a. 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 (c.f. 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 will be the focus of this study. These learning outcomes will be explicitly 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 will be chosen to exercise the constituent components of engineering competency.
- 24. The key components described in the foregoing paragraphs are summarised below in figure 4.1. 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. 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 will be 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 & Engineering Sciences. Similar to context, the content of Basic & 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 will be varied to cover as wide a range as possible in a short assessment. Items will be 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 in the previous section, *non-engineering* generic skills – whilst playing an important role in an engineer's arsenal – will not be part of this assessment. The features of competency and context pertaining to the assessment are described in detail in the following subsections.

b. Competency

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 will be explicitly included in the assessment:
 - *i.* The ability to use diverse methods to communicate effectively with the engineering community and with society at large;
 - *ii.* The ability to demonstrate awareness of the wider multidisciplinary context of engineering.

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

Basic and Engineering Sciences

- 30. This part of the assessment will be drawn from the following specific learning outcomes:
 - *i.* The ability to demonstrate knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering including:
 - Mathematics: Real & complex analysis, linear algebra, differential equations, Fourier series, Laplace transforms, numerical methods, vector calculus, probability and statistics.
 - Sciences: general physics (including fields, waves, mechanics, matter, forces) electrical technology, electronics, material science and strength of materials, fluid mechanics.
 - Chemistry, engineering geology, technical mechanics, statics and continuum mechanics, structural mechanics, hydraulics.
 - *ii.* The ability to demonstrate a systematic understanding of the key aspects and concepts of their branch of engineering. For Civil Engineering in this assessment, this includes:
 - Building materials, environmental sciences, building physics, surveying, fundamentals of planning, structural theory, engineering drawing, operations research, introduction to GIS, architectural drawings, electro-mechanics for civil engineering, introduction to environmental engineering
 - iii. 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*, including: science of materials; steel, timber and masonry wall construction; construction operation and management; construction informatics; building services engineering
 - *Structural Engineering*, including: structural statics; earthquake engineering; maintenance management
 - *Geotechnical Engineering*, including: foundation engineering; dam and tunnel remediation & construction; slope stabilisation
 - *Hydraulic Engineering*, including water engineering and management; design of components and systems such as water supply systems and sewer networks

• *Urban and Rural Planning* including: land planning; irrigation; traffic engineering; road and railway engineering; transportation networks; ecology and the environment; economics and sustainability; irrigation engineering; inland navigation engineering

Engineering Analysis

- 31. Analysis assessment will be drawn from the following specific learning outcomes:
 - *i.* The ability to apply knowledge and understanding to identify, formulate and solve engineering problems using established methods;
 - *ii.* The ability to apply knowledge and understanding to analyze engineering products, processes and methods;
 - *iii.* The ability to select and apply relevant analytic and modelling methods;
 - *iv.* The ability to conduct searches of literature, and to use databases and other sources of information;
 - v. The ability to design and conduct appropriate experiments, interpret the data and draw conclusions;
 - vi. The ability to demonstrate workshop and laboratory skills.

Engineering Design

- 32. Design may be of processes, methods or artefacts. The assessment of design will be drawn from the following specific learning outcomes:
 - *i.* The ability to apply their knowledge and understanding to develop designs to meet defined and specified requirements;
 - *ii.* The ability to demonstrate an understanding of design methodologies, and an ability to use them.

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 will be drawn from the following specific learning outcomes:
 - *i.* The ability to select and use appropriate materials, equipment and tools;

- *ii.* The ability to combine theory and practice to solve engineering problems;
- *iii.* The ability to demonstrate understanding of applicable techniques and methods, and their limitations;
- *iv.* The ability to demonstrate understanding of the non-technical implications of engineering practice and commitment to professional ethics, responsibilities and norms of engineering practice;
- v. 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;
- vi. The ability to demonstrate knowledge of project management and business practices, such as risk and change management, and be aware of their limitations including:
 - Project planning, labour, contracts, safety and health, cost analysis and control, professional ethics, subcontracting, environmental issues and information management.
 - Management of construction and public works
- 34. In addition to all the above knowledge and skills, engineering competency involves considerations beyond narrow fields of specialization. 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.

c. Context

- 35. Scenarios will be devised based on realistic contexts for engineering problems. A broad variety of contexts will be sampled from in the assessment. Example contexts from Civil Engineering are given below. Potential settings for assessment tasks are not restricted to these, but 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:
 - bridge collapses structural analysis, including loads, trusses, gusset plates, etc.
 - 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
- harbor engineering and planning
- hydraulic works
- hydroelectric power generation
- inland navigation design
- irrigation (including water pump)
- 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
- water supply

IV. ASSESSING ENGINEERING COMPETENCY

a. Structure of the Assessment

- 37. The Assessment of Engineering Competency will be made up of two types of "module": one type contains multiple-choice items (questions) about basic engineering science; the other stems from context "units". That is, an engineering scenario will be introduced in a specific context, and a set of items relating to that context will follow. In some cases a given scenario may also be suitable for other branches of engineering, and so it might be possible to use items tapping common technical knowledge or engineering generic skills for future studies using other branches of engineering.
- 38. The duration of the Assessment of Engineering Competency will be 90 minutes. It will be composed of three modules, with 30 minutes allocated to each one.
- 39. One of the three modules will assess basic engineering science and will be composed of 20 multiple-choice items. In order to ensure coverage of basic engineering science concepts, the multiple-choice items have been developed in four clusters of 10 items each. These clusters, labelled MC1, MC2, MC3 and MC4, will be rotated so that each candidate receives two clusters.
- 40. In addition to the multiple-choice items, each participant will complete two unitbased modules, each consisting of around 7-8 items. Some of the items in these modules require extended responses and each module will require 30 minutes to complete. During the development of the final Assessment of Engineering Competency, four unit-based modules will be trialled. After the focus groups have been conducted the best two unit-based modules will be retained and the other two will be discarded. Since the unit-based modules mainly consist of Constructed Response items, the final two unit-based modules selected will be labelled CR1 and CR2.
- 41. This will result in a number of combinations in the final version of the Assessment of Engineering Competency, as indicated in the table below:

		Multip	Constru	cted		
			response			
Booklet	MC1	MC2	MC3	MC4	CR1	CR 2
1	•	•			•	•
2	•		•		•	•
3	•			•	•	•
4		•	•		•	•
5		•		•	•	•
6			•	•	•	•

Table 1. Booklet distribution.

- 42. The assessment will include 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.
- 43. As far as is practicable, each item will focus on a single component of competency. Accordingly, some items will test understanding of mathematics and science, some of engineering sciences; others will test methods of engineering analysis; others the ability to realise engineering designs; in yet others, the capacity to apply engineering knowledge and understanding to realistic problems. Engineering generic skills will play a part in many of these and so will typically not be assessed independently.
- 44. Items will be designed to measure varying levels of proficiency. Less demanding items will be designed to measure the kind of competence which is generally associated with reproduction. Higher levels of proficiency will be measured by items that assess the extent to which individuals make connections between different aspects of knowledge and skill. Higher-order reflective forms of reasoning will be assessed by the most demanding items¹.
- 45. Language difficulty will be set at an appropriate level for final-year first-cycle engineering students. Photographs and diagrams will be used where appropriate to avoid excessively long passages of text.

¹ See the PISA mathematics assessment framework for an elaboration of the terms *reproduction, connection,* and *reflection.* (OECD, 2009b)

- 46. Care will be 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 will need to be struck when constructing items between authenticity of a context and practicality of assessment.
- 47. The following table indicates the recommended distribution of **score points** across the domain components. The basic and engineering sciences will be assessed in the two multiple choice clusters. The three process components analysis, design and practice will be assessed in the unit based modules. The processes have been given equal weight. A small number of score points will be allocated to engineering generic skills. Given the relatively limited number of items, the figures in the table, and the percentages, are approximate only.

	Engineering Generic Skills	Basic and Engineering Sciences	Analysis	Design	Practice	
MC	0	20	1	1	1	50%
CR	4	0	6	6	6	50%
	10%	45%	15%	15%	15%	100%

Table 2. Recommended distribution of score points

48. The rows represent the different available response formats: Multiple Choice and Constructed Response. A full discussion of response formats and coding (marking) of responses now follows.

b. Response Formats and Coding

- 49. Item response formats will include:
 - multiple choice simple and complex multiple-choice items that are answered by selecting an option from each list of choices;
 - constructed response either short constructed-response (such as numerical or short text); or extended constucted-response – e.g. creation of flow charts, designs, dot-pointed specifications, and longer written responses.
- 50. Multiple-choice items can provide a fast and efficient way to collect data on students' engineering knowledge, understanding and skills.
- 51. Constructed-response items 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.

- 52. Marking guides or rubrics for evaluating student responses to items will be constructed based on the components of engineering competency identified in Section III b, above. In the case of basic and engineering sciences – which are tested using items with a multiple-choice format – the rubric will be very simple. For analysis, design and practice the rubric will be 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 will 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 chapter V below.)
- 53. In the rubrics, the highest level of scoring will reflect a complete understanding of the problem, be tied to a correct solution, reward thought that shows considerable insight, and reflect 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.
- 54. 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.
- 55. 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.
- 56. Finally, there will be a no credit level, for coding completely incorrect or irrelevant responses. Within the scoring at this level, there will be 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.

- 57. It should be noted that the majority of items will not attract all of the three positive credit levels described above; however, collectively for the assessment, there will be items tapping into different levels of student performance.
 - c. Functionality Provided by Computer Delivery
- 58. Due to budgetary constraints the initial pilot study will take the form of a penciland-paper instrument administered in participating countries. It is planned that for future studies the assessment will be administered via computer. Doing so has several benefits, as outlined in the next few paragraphs.
- 59. Both units and items within units will be delivered in a fixed order, or "lockstep" fashion. 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 will display a warning that they are about to move on to the next item and that it will not be possible to return to the previous item. At this point, students can either confirm they want to move on to the next item or cancel the action and return to the current item.
- 60. 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.
- 61. A principal 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. With appropriate authoring, it will be possible to record data such as the type, frequency, length and sequence of actions performed by students.
- 63. Another possible benefit is that the time students spend on any particular item can be restricted, where it is considered appropriate. This is particularly useful in contexts where students are exploring stimulus material interactively.

- 64. With a computer-based assessment, around 40% of the items will be multiple choice to enable their automatic (computer) coding. In some instances it may also be possible to automatically code short answer responses.
- 65. Any responses that cannot be coded automatically will be collected by the computer-delivery system and saved in an appropriate format. An Online Coding System will be developed to facilitate the coding (by experts) of these saved files. This eliminates the need for separate data entry, minimises the need for data cleaning, and allows coding to take place "off site" if desired.
- 66. Whilst engineering graduates would be expected to be familiar with various software packages, detailed knowledge of particular software will not be assumed in the assessment. Only basic ICT skills will be 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.

d. Calculators

67. This assessment does not focus on students' ability to perform calculations. As such, all students participating in the assessment should be 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 should be 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 would be severely disadvantaged in performing any calculations required.

V. REPORTING ENGINEERING COMPETENCY

- 68. Similar to the PISA reporting practice (OECD, 2009b), results will be 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.
- 69. The form of the Rasch model that will be 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.
- 70. The scale will be 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) will be very useful as the basis of these descriptors.
- 71. It is expected that five levels of proficiency will be 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 background data (where available) 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 would be possible.
- 72. In assessments with a large enough number of items responded to, it is sometimes possible to collect enough data to create subscales based on independent components within a domain. It is unlikely that there will be enough such items to

report on potential engineering subscales associated with, for example, the engineering process sub-domains.

73. What features will determine item difficulty? Some possibilities are:

- Context including familiarity and concreteness of context
- Engineering process
- Complexity of system
- Familiarity of representations used
- Number of constraints present
- Amount / complexity / coherence of information
- Complexity / difficulty of computation required

VI. SAMPLE TASKS

a. Civil Engineering

74. A sample civil engineering unit will be made available during the course of the validation phase.

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ANNEX A: EXPERT GROUP

A group of experts drawn from participating countries and key international organisations will be supporting the team in developing the assessment framework and instruments. The membership comprises the following experts:

Expert Group Member	Affiliation
Professor Robin King (Chair nominee)	University of Technology, Sydney
Professor Giuliano Augusti	Universita "La Sapienza" , Italy
Professor Michael Hoffman	University of Ulm, Germany
Professor Kikuo Kishimoto	Tokyo Institute of Technology, Japan
Professor Johan Malmqvist	Chalmers University of Technology, Sweden
Professor Jim Melsa	Iowa State University, USA
Professor Lueny Morell	Hewlett Packard, USA
Professor Nobotoshi Masuda	Tokyo City University, Japan

APPENDIX 2: AHELO ENGINEERING ASSESSMENT BROCHURE

Engineering Generic Skills

Effective communication and awareness of the wider civil engineering context.

Basic and Engineering Sciences

Knowledge and understanding of underlying scientific and mathematical principles – general sciences; materials and construction; structural engineering; geotechnical engineering; hydraulic engineering; and urban and rural planning.

Engineering Analysis

Using analytical methods to identify, formulate and solve problems.

Engineering Design

Understanding and application of design methodologies to meet requirements.

Engineering Practice

Practical competencies required to solve problems, conducting investigations, and designing engineering devices and processes. Covers non-technical elements of civil engineering practice like professional ethics, responsibilities and the impact of engineering solutions in a global, economic, societal and environmental context.

Further information: www.oecd.org/edu/ahelo





Engineering Assessment

Engineering Assessment

The Organisation for Economic Cooperation and Development (OECD) is conducting the Assessment of Higher Education Learning Outcomes (AHELO) to test the feasibility of assessing bachelor degree learning outcomes in civil engineering across different cultural, linguistic and institutional contexts. The **Engineering Assessment** measures civil engineering learning outcomes. The test assesses whether students close to graduating have the capabilities required for effective professional practice as global engineers.

This test has been internationally developed and validated for OECD by the Australian Council for Educational Research (ACER), Japan's National Institute for Educational Policy Research (NIER), the EUropean and Global ENgineering Education (EUGENE) network, supervised by globally recognised experts on engineering education.

Test format

The test is a online instrument of 90 minutes duration, composed of two modules.

Module one: Two engineering scenarios, each based on authentic engineering problems. Materials are presented to introduce the context, and students are asked to solve engineering problems by applying their knowledge and skills. Completion time is 60 minutes. Module two: Basic engineering science module with 20 multiple choice items. Completion time is 30 minutes.

Test focus

AHELO's **Engineering Assessment** focuses on 'above content' knowledge and skills. Rather than assess achievement against curriculum this test looks at whether students have the capacity to use acquired knowledge and skills to solve concrete, novel and real-world problems.

The test incorporates important aspects of engineering competency activated when a student tackles an assessment item: engineering processes, engineering generic skills and basic engineering sciences.

