**Accreditation and Competence in the Context of World Wide Engineering Mobility- the International Engineering Alliance Experience**

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**Summary**

The International Engineering Alliance IEA has developed exemplar graduate attributes as a foundation for both educational course design and accreditation and international benchmarking, as well as developing competencies for professional engineers, engineering technologists and engineering technicians. This paper examines the principles and basis for the attributes and the differentiation between various categories of engineer and explains the purpose, rationale and the IEA approach to mobility through recognition of educational attainment and professional competence and reflects on the experience to date and possible future developments.

**Background**

What is the IEA- who are the members and how they fit together?

The IEA is a group of self regulating educational accords and professional competence agreements which have a substantially common view of what constitutes an acceptable professional engineering education and professional competence.

The educational accords apply to qualifications to enter practice. They comprise the:

*Washington Accord* for professional engineering education,

*Sydney Accord* for engineering technologist education, and

*Dublin Accord* for engineering technician education.

The professional competence recognition agreements currently comprise the :

*Engineers Mobility Forum* for professional engineers (to become the International Professional Engineers Agreement (IPEA) from 1 Jan 2013)

*Engineering Technologists Mobility Forum* for Engineering Technologists (to become International Engineering Technologists Agreement (IETA))

*APEC Engineer* (to become APEC Engineers Agreement APEC EA) which is open to any of the national professional engineering organisations from the 21 countries belonging to the Asia Pacific Economic Cooperation Agreement. APEC is thus a regional agreement whereas the other Accords and Agreements are intended to be able to have worldwide coverage.

Thus there is recognition that mobility of engineers is important and therefore there is a need for recognised standards of education and professional expertise to facilitate that movement and optimise the utilisation of professional engineers worldwide. **(slide 3)** Hence the overarching purpose of the IEA could be said to be:

**To increase the benefits of authoritative engineering education and competence standards through promoting globally their wider recognition and adoption.**

So what are educational accords and competence agreements and the principles underlying them?

**Principles underlying educational accords and competence agreements**

The primary aim is to improve mobility of engineers between jurisdictions. This mobility is facilitated by mutual recognition that the standards of educational qualifications and competence are equivalent and that the processes for assessment of these are agreed to be robust, repeatable and substantially equivalent. Thus mobility is or should desirably be primarily a consequence of mutual recognition and trust in standards and processes rather than specific mobility agreements between countries such as bilateral mobility agreements. Negotiation of bilateral agreements is too expensive and cumbersome for many to achieve true internationalism, particularly small countries.

But what is the nature of engineering? Engineering is an art supported by science and thus competence is not determined solely by education but requires a period of post graduate experiential learning to develop competence and judgment to a professional level through a process of mentoring. In addition one of the criteria is that the level of competence must be that required for independent practice. Therefore the fundamental principle underlying the IEA competence agreements is that competence is understood to comprise knowledge plus experience plus mature personal qualities.

But engineering is complicated because unlike some professions where work has traditionally been divided into separate and distinct roles and categories (for example medicine where doctors and nurses have distinctly different roles) engineering work is not so clearly divided, but is rather an activity generally undertaken by a team in which the roles and qualifications more or less comprise a continuum with sometimes blurred boundaries. For example it has been commonly observed that in some countries where there are insufficient engineering technologists or their equivalent that professional engineers have sometimes ended up by working in technologist roles. Historically engineering is a profession where it is possible to move from one category of engineer to another by on the job learning supplemented by formal study. In addition engineering is a profession in which often only inadequate or approximate information is available, risks abound and the potential impacts on societal safety can be large. Hence it is necessary to understand societal values and risk management and to develop sound judgment at all levels. In addition the required skills range from practical manufacturing or fabrication skills to the need for deep theoretical understanding of the fundamental physical and mathematical laws on which designs may be based. In general not all these attributes are present within any one individual and it necessary to distinguish between the competencies required for each class of engineer.

Therefore we must define the nature of the various levels of engineering

**The Requirements of a Profession**

If the highest level of engineer is the professional engineer what is a profession? In deciding the requirements of a profession the following definition has been helpful

*A profession is an occupational group which specialises in the performance of such highly developed skills for the meeting of complex human needs that the right use of them is achieved only under the discipline of an ethic developed and enforced by peers and by mastery of a broader contextual knowledge of the human being, society, the natural world, and historical trends"* (Reeck 1982)

This definition has as key elements: knowledge, skills and contextual knowledge, peer discipline, effects on humanity and ethics and implies that complexity and judgment are essential components

The knowledge component and some skills are initially acquired by education but this is only part of the development of a professional, the basic knowledge and skill must be further developed by supervised practice to the level of professional competence for independent practice.

In this integration of education with the longer term development of professional competence it is important the essential features of both the education and subsequent development are built upon a common base. In 2002 work commenced in New Zealand on developing elements and methodologies for assessing high level educational outcomes and professional competence (IPENZ 2002, 2009) and in 2004 the IEA developed the initial Graduate Attributes and Professional Competencies subsequently adopting them in 2005, with successive refinements resulting in the current version being adopted in 2009. (IEA 2009)

Therefore professional competence comprises:

* An agreed educational base - in this case an Accord recognised degree, or equivalent, plus
* Experience after graduation to develop both professional and personal maturity. For the IEA this requires a minimum of seven years including two years responsible experience and ongoing continuing professional development (CPD) plus
* Meeting an agreed competence typically measured by evaluation against 13 elements defined by the IEA (IEA 2009); that is competence in the ‘art of doing engineering.’ A critical element among these is that of ethical behaviour, which will become increasingly important as mobility continues to expand.

The matrix of elements to be considered in designing criteria to assess competence is multidimensional and must allow for variation in the importance of the various elements to describe the various types of engineer. Any system of elemental description of attributes of competence must also be able to describe the full range of engineering required.

For the purpose of definition of graduate attributes the IEA has adopted three categories of engineer namely professional engineer (Washington Accord), engineering technologist( Sydney Accord) and engineering technician (Dublin Accord).(IEA 2009)

We can debate whether we have defined these correctly or indeed even whether the names are entirely suitable.

The 12 elements describing the educational outcome (graduate) attributes for the Accords are identical for each category: engineering knowledge, problem analysis, design and development of solutions, investigation, modern tool usage, the engineer and society, environment and sustainability, ethics, individual and team work, communication, project management and finance and lifelong learning.

The elements are differentiated between the engineer categories by the complexity of problem solving and engineering activities in terms of a range of attributes. A part example for just two of the elements for Washington and Sydney Accords is shown in Table 1(IEA 2009).

Table 1 Graduate Attribute Profiles

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Element** | **Differentiating**  **Characteristic** | **… for Washington Accord Graduate** | **… for Sydney Accord Graduate** |
| **1.** | **Engineering**  **Knowledge** | Breadth and depth of education and type of knowledge, both theoretical and practical | Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of **complex** engineering problems | Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to ***defined*** and applied engineering procedures, processes, systems or methodologies. |
| **2.** | **Problem**  **Analysis** | Complexity of analysis | Identify, formulate, research literature and analyse ***complex***engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences. | Identify, formulate, research literature and analyse ***broadly-defined***engineering problems reaching substantiated conclusions using analytical tools appropriate to their discipline or area of specialisation. |

In addition it is necessary to define the levels of complexity in problem solving and engineering activities as well as the knowledge profile required for each Accord. These are summarised In Appendix 1 for the professional engineer (WA) and the engineering technologist (SA) Another factor is the quantum and relationship of theoretical and contextual knowledge as analysed further by Hanrahan (2012)

**Professional competency**

The 13 elements describing professional competency are not exactly the same as the graduate attribute elements but are built upon them and similarly differentiated between professional engineer, engineering technologist and technician on the basis of the range statements and knowledge profiles in Appendix 1.

Examination of these elements above and the range statements and knowledge profiles shows several features:

1. The elements are outcome focussed rather than input or content focussed and thus for any particular programme there is required to be a mapping of the outcomes against the outputs sought by course assessments.
2. Not all elements are of equal importance or weighting. For example fundamental technical knowledge is of paramount importance (Element 1) as it underpins other elements so a further knowledge profile has been developed for each of the Accord programmes. Hence it is not simply an arithmetical exercise to determine whether a programme meets the criteria: holistic professional judgment is required not only in the accreditation of individual programmes but also in quality assurance and mutual recognition of accreditation systems.
3. It is clear that much of engineering work can and should be done by engineering technologists and technicians particularly in well established industries, with perhaps relatively fewer graduates in the professional engineering category operating at the complex forefront of the profession.
4. The definition of a profession quoted earlier implies that it must be subject to self discipline and self regulation by peers. At what level this should apply within the wide range of engineering activities is a matter for debate but clearly applies at the Washington Accord/professional engineer level operating at the forefront of the profession.
5. In respect of any programme there are some aspects that are not dealt with by elemental analysis such as robustness or security of outcomes and this must be evaluated during the accreditation process.

**Evaluation in Practice**

The IEA graduate attributes exemplars are intended to be of assistance in the design of both particular courses and national accreditation systems and, of course, evaluation of national systems by each of the accords.

The extent to which national systems have adopted outcome based accreditation varies around the world but the nature of the elemental criteria does allow evaluation of the outputs. In addition to the evaluation of outcomes one aspect that must be evaluated is the robustness or security of the outcomes and this clearly includes evaluation of such input aspects as staffing, facilities, finance and connection with industry. Among the IEA Accord members this complete evaluation of national accreditation systems is initially done for any jurisdiction by a multinational three person panel on initial application for signatory status and subsequently revaluated every six years.

The internally similar and consistent design of the elemental criteria can allow concurrent evaluation of adjacent accord programmes in a single institution depending on individual institutional arrangements e.g. concurrent evaluation of WA and SA programmes or SA and DA programmes within a single institution.

The logical extension of the evaluation of academic programmes and national accreditation systems is the evaluation of professional competence in the various categories of engineer. It is clear that around the world the concept of professional competence varies in the extent to which it is developed and/or the formal expression of it. Indeed some countries have not yet developed the understanding of professionalism or the framework for assessing this which has led in some cases to significant disadvantages in attempting to up-skill the engineering workforce through international construction contracts. There is also the concurrent change from historical input measures ie years of mathematics, science, experience etc to the greater emphasis on assessment of professional and personal attributes.

**Experience to Date**

The experience to date of both individual countries (IPENZ 2002, 2009) and within the Accords has demonstrated the validity of the approach. This has resulted in increasing interest and uptake from a wide range of countries who perceive both internal and mobility benefits. The use of the range statements and concepts of variable complexity have enhanced the ability to distinguish between different classes of engineer and the educational programmes that underpin them.

One significant advantage of the Accords is that they evaluate national systems rather than individuals and thus achieve considerable benefit to individuals. There is however a somewhat uneven understanding of the differences between the various categories of engineer particularly between professional engineer and engineering technologist and their associated accords. The name ‘engineering technologist’ may be an unattractive title to those who think of themselves primarily as engineers.

The related competency agreements, which to date have required members to evaluate individuals for entry onto a national competency register of the appropriate standard, together with a schedule of agreed mobility benefits between the members, has proved more difficult to administer. This has been for a variety of reasons but partly because of the highly variable methodologies and systems for the assessment of professional competence, sometimes even between states within countries, and partly because of very variable benefits. The competency agreements have therefore been changed to a set of agreements on exemplar competency standards in a manner similar to the accords for education. The ultimate objective is that while the agreements describe standards of competence for individuals, in due course national systems may be declared to meet the required standards. This has the significant advantage of greater coverage for those jurisdictions while at the same time also covers individuals who meet the international benchmarks but who belong to jurisdictions whose national standards do not meet the required exemplars.

**Conclusion**

The original purpose of the IEA Accords and Agreements was to foster and ease mobility of graduates and engineers round the world starting with the Washington Accord in 1989. The subsequent experience of the International Engineering Alliance is that the international educational accords based on exemplar elemental graduate attributes have contributed to a wider understanding of the required outcomes of an engineering education and to the development of engineering education in a number of countries while not unduly constraining educational individuality.

The further development of professional competencies defined on an elemental basis has allowed a more robust assessment of individuals and national standards for engineering competence. However while engineering is governed by universal physical laws it is subject to local requirements and affected by cultural, social, environmental and risk considerations. Thus there is still further development work required by regional and global accreditation and competence assessment bodies to obtain a more universal understanding and definition of the various categories of engineer and the extent to which these should be benchmarked against common standards.

One thing that the alliance has taught us is that we must learn that cooperation is recognising those things that are common and give credit for these while we continue to concentrate on the differences, why they are there and perhaps even revisiting the question of whether they are important.

This conversation is not easy and increased understanding will take careful patient discussion over some time.

**References**

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**Appendix 1 Extracts from the IEA Graduate Attributes**

**Range of Problem Solving**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Attribute** | **Complex Problems** | **Broadly-defined Problems** | **Well-defined Problems** |
| 1 | Preamble | Engineering problems which cannot be resolved without in-depth engineering knowledge, much of which is at, or  informed by, the forefront of the professional discipline, and have some or all of the following characteristics: | Engineering problems which cannot be pursued without a coherent and detailed knowledge of defined aspects of a professional discipline with a  strong emphasis on the application of developed technology, and have the following characteristics | Engineering problems having some or all of the following characteristics: |
| 2 | Range of conflicting  requirements | Involve wide-ranging or conflicting  technical, engineering and other issues | Involve a variety of factors which may impose  conflicting constraints | Involve several issues, but with few of these  exerting conflicting constraints |
| 3 | Depth of analysis required | Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models | Can be solved by application of well-proven analysis techniques | Can be solved in standardised ways |
| 4 | Depth of knowledge required | Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first  principles analytical approach | Requires a detailed knowledge of principles and applied procedures and methodologies in defined aspects of a professional discipline with a strong emphasis on the application of developed  technology and the attainment of know-how, often within a multidisciplinary engineering environment | Can be resolved using limited theoretical knowledge but normally requires extensive practical knowledge |
| 5 | Familiarity of issues | Involve infrequently encountered issues | Belong to families of familiar problems which are solved in well-accepted ways | Are frequently encountered and thus familiar to most practitioners in the practice area |
| 6 | Extent of applicable codes | Are outside problems encompassed by standards and codes of practice for  professional engineering | May be partially outside those encompassed by standards or codes of practice | Are encompassed by standards and/or documented codes of practice |
| 7 | Extent of stakeholder  involvement and level of conflicting requirements | Involve diverse groups of stakeholders with  widely varying needs | Involve several groups of stakeholders with  differing and occasionally conflicting needs | Involve a limited range of stakeholders with  differing needs |
| 8 | Consequences | Have significant consequences in a range of contexts | Have consequences which are important locally, but may extend more widely | Have consequences which are locally important and not far-reaching |
| 9 | Interdependence | Are high level problems including many component parts or sub-problems | Are parts of, or systems within complex engineering problems | Are discrete components of engineering systems |

**Range of Engineering Activities**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Attribute** | **Complex Activities** | **Broadly-defined Activities** |
| 1 | Preamble | **Complex activities** means (*engineering)*  activities or projects that have some or all of the following characteristics: | **Broadly defined activities** means (*engineering)*  activities or projects that have some or all of the following characteristics: |
| 2 | Range of resources | Involve the use of diverse resources (and for this purpose resources includes people, money, equipment, materials, information and technologies) | Involve a variety of resources (and for this purposes resources includes people, money, equipment, materials, information and technologies) |
| 3 | Level of interactions | Require resolution of significant problems arising from interactions between wide- ranging or conflicting technical, engineering or other issues, | Require resolution of occasional interactions between technical, engineering and other issues, of which few are conflicting |
| 4 | Innovation | Involve creative use of engineering principles and research-based knowledge in novel ways. | Involve the use of new materials, techniques or processes in non-standard ways |
| 5 | Consequences to society and the environment | Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation | Have reasonably predictable consequences that are most important locally, but may extend more widely |
| 6 | Familiarity | Can extend beyond previous experiences by applying principles-based approaches | Require a knowledge of normal operating procedures and processes |

**Knowledge Profile**

|  |  |
| --- | --- |
| **A Washington Accord programme** provides: | **A Sydney Accord programme** provides: |
| A systematic, theory-based understanding of the **natural sciences** applicable to the discipline (e.g. calculus-based physics) | A systematic, theory-based understanding of the  **natural sciences** applicable to the sub-discipline |
| Conceptually-based **mathematics**, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline | Conceptually-based **mathematics**, numerical analysis, statistics and aspects of computer and information science to support analysis and use of models applicable to the sub-discipline |
| A systematic, theory-based formulation of **engineering fundamentals** required in the engineering discipline | A systematic , theory-based formulation of **engineering fundamentals** required in an accepted sub-discipline |
| engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline. | engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for an accepted sub-discipline |
| knowledge that supports **engineering design** in a practice area | knowledge that supports **engineering design** using the technologies of a practice area |
| knowledge of **engineering practice** (technology) in the practice areas in the engineering discipline | knowledge of **engineering technologies** applicable in the sub-discipline |
| **comprehension of** the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability; | **comprehension of** the role of technology in society and identified issues in applying engineering technology: ethics and impacts: economic, social, environmental and sustainability |
| Engagement with selected knowledge in the **research literature** of the discipline | engagement with the **technological literature** of the discipline |
| A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in  4 to 5 years of study, depending on the level of students at entry. | A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 3 to 4 years of study, depending on the level of students at entry. |