White Paper on an Outcomes-Based Vision for Engineering Program Accreditation
Deans Liaison Committee – National Council of Deans of Engineering and Applied Science (NCDEAS)
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1. Background

Accreditation provides regulators of the engineering profession with public notification that a program meets standards of quality set forth by the Accreditation Board (AB). The accreditation process involves periodic assessment of engineering programs against accepted standards. Thereafter, engineering regulators automatically accept that the graduates from these accredited programs meet the academic requirements for licensure. The accreditation of engineering academic programs is also a key foundation for the practice of engineering at the professional level in each of the countries or territories covered by the Washington Accord.

In general, regulators require that each domestic applicant for a licence shall demonstrate that s/he has obtained a bachelor's degree in an engineering program from a Canadian university that is accredited by AB, or in the case of foreign or Canadian trained engineers who do not have an engineering undergraduate degree, equivalent engineering educational qualifications.

As a process, by achieving recognition by the Accreditation Board, accreditation reflects the fact that the program is committed to self-study and external review by peer evaluators in seeking to not only meet required standards but to also continuously seek ways by which it will enhance the quality of education and training that the program provides. Accreditation is a peer review process undertaken by appropriately trained and independent panels of practicing engineers, both industrial and academic, on behalf of properly constituted agencies. This process involves both scrutiny of data about the program and a structured visit to the Higher Education Institution (HEI) that is responsible for the delivery of the program.

Outcomes-based education shifts the focus of educational activity from teaching to learning; and from teacher instruction to student demonstration. The effective measure of outcomes facilitates the continuous improvement of engineering education. In Canada, the outcomes are measured in the 12 graduate attributes. Graduate attributes form a set of individually assessable outcomes that are the components indicative of the graduate's potential to acquire competence to practise at the appropriate level. These attributes are clear, succinct statements of the expected capability, qualified when necessary for a particular program. The graduate attributes are set out in section 3.1 of the Accreditation Criteria and Procedures Report [1].

The following sections describe the measures used by the Accreditation Board to evaluate Canadian engineering programs for the purpose of accreditation.

The curriculum content and quality criteria are designed to assure a foundation in mathematics and natural sciences, a broad preparation in engineering sciences and engineering design, and an exposure to non-technical subjects that supplement the technical aspects of the curriculum. All students must meet all curriculum content and quality criteria. The academic level of the curriculum must be appropriate to a university-level engineering program.

In addition to the curriculum content and quality requirements, there are four other requirements, shown in the adjacent table, which must be met in order for an engineering program to be accredited. This White Paper is only concerned with the way that Curriculum Content and Quality are measured in 3.4 and does not recommend any changes to the other four requirements.

3.1 Graduate Attributes (required capabilities of graduates)
3.2 Continuous Improvement (student outcomes assessed, learnings applied by program)
3.3 Student Support (policies and procedures that address admission, counseling, promotion, graduation)
3.4 Curriculum Content & Quality (minimum body of knowledge)
3.5 Program Environment (facilities, faculty, financial resources)

The purpose of this paper is to propose the use of an Examination Syllabus as a replacement for Accreditation Units (AUs) as a measure of curriculum content and quality. The Examination Syllabus is a standard form of assessment that is used by regulators for the curriculum content assessment of foreign trained engineers (see Appendix 1). The Syllabus approach to the definition of Curriculum Content is aligned with the overall goal, namely to shift the emphasis from inputs (time allocated to learning activities) to outcomes (what students have learned).

2. Curriculum Content Assessment by Examination Syllabus

The Examination Syllabus is the mechanism used by regulators to check the academic knowledge of those who did not graduate from accredited engineering programs. The Examination Syllabus is a set of topics used by provincial engineering regulators to check that an applicant has the academic knowledge needed to be licensed in Canada. The syllabus is divided into three categories:

- **Basic studies**: These are first-year math and science topics which underlie all accredited engineering programs at Canadian HEIs.
- **Complementary studies**: These are topics including safety, economics, sustainability and engineering management which are required by all accredited engineering programs at Canadian HEIs.
- **Discipline-specific studies**: These are a reflection of typical third- and fourth-year core topics in the engineering disciplines that are offered through accredited engineering programs at Canadian HEIs.

These elements of the Examination Syllabi parallel the existing Curriculum Content and Quality requirements in 3.4, with the exception of the Engineering Design component, which would need to be added. The Examination Syllabi are developed, approved and maintained by Engineers Canada's Qualifications Board (QB). The Qualifications Board looks at the engineering undergraduate programs in Canada and identifies subject topics within the engineering programs. Peers from academia review this information and identify the common core topics for the syllabi. The regulators provide input on the syllabi to ensure that it meets the depth and breadth requirements for licensure. New syllabi are developed when there are new types of engineering practice. More information and the published Examination Syllabi are available at http://www.engineerscanada.ca/examination-syllabus.

In current discussions by the Consultation Group, program content and quality is defined as:

3.4.6 Minimum Program Content

The program must have a minimum of ~~1,950 Accreditation units~~ four years of full-time (or equivalent) appropriate content ~~that are~~ at a university level. An Interpretive Statement on minimum program content is attached as an appendix to this document.

and

3.4.2 Minimum curriculum components:

An engineering program must include the following minima ~~minimum for the entire curriculum and~~ for each of its components.

~~* The entire program must include a minimum of 1,950 AU~~
Engineering science and engineering design: Minimum 900 AU
Which includes a minimum 225 AU in each of Engineering science and Engineering design
Mathematics and natural sciences: Minimum 420 AU
Which includes a minimum 195 AU in each of Mathematics and Natural sciences.
Complementary Studies: Minimum 225 AU
Laboratory experience and safety procedures instruction

For engineering programs at a Canadian HEI that are four years of full-time (or equivalent) of content, at a university level, and that meet the appropriate Examination Syllabus, the regulator would be assured that the program meets the depth and breadth requirements of the academic requirement for licensure.

It is noteworthy that the Examination Syllabus would meet the same requirements as those issued for licensed foreign trained engineers and, in addition, would provide a higher standard whereby graduates will also have demonstrated the 12 graduate attributes from the additional outcome-based assessment in the accreditation process. The accreditation process would assure the minimum path requirement and provide further assurance that every graduate has met the minimum criteria. Regulators would be able to continue to accept the accredited degree without further review.

When an HEI-created program is not covered by the available examination syllabi, one could be developed and approved by the Qualifications Board. The QB would be able to add the new syllabus to the portfolio of syllabi available for regulators which are used to assess international engineering graduates and determine if they meet the academic requirements for licensure. In defining engineering syllabi, care is required to achieve an appropriate balance between essential topics that must be included in all programs and optional topics, so that HEI's can build an appropriate level of distinctiveness into their programs.

There are two potential pathways to this outcomes based vision – either in two steps with an intermediate (transitory) step in which the input requirements are reduced to 1545 AU's as proposed earlier by the Consultation Group, or directly to the syllabus-based approach, in which AU's are replaced by syllabi.

3. Rationale

Regulators currently use examination syllabi to assess approximately 40% of the applicants for licensure. The regulators have excellent experience and data that assessing an applicant against an examination syllabus is a reliable means of determining equivalence to an AB accredited degree.

Since 1989, under the Washington Accord, when a registering body is separate from the signatory, the signatory must make every effort to ensure that the registering body recognises signatories' programs. Engineers Canada provides the regulators with information regarding the Washington Accord Signatories and has established the framework reference and acceptance of a Washington Accord degree without future review. Today, three jurisdictions (BC, PEI, MB) accept a Washington Accord degree without further review. For the other nine regulators, Washington Accord degrees are accepted as being substantially equivalent to an AB degree. Individual applicants are assessed on an exemption basis versus the Examination Syllabus.

Other curriculum measurement methods have been examined previously [2-4] to achieve these objectives of shifting the emphasis from inputs to outcome based assessment. It is worthwhile to compare their relative strengths and weaknesses. Appendix 2 highlights the primary issues to be considered for an outcomes-based education. In Appendix 2, Table 1 presents the advantages and disadvantages of each method. Table 2 summarizes similar information but organized by features in rows and options by column.

Six options are presented in Appendix 2, including Option C (a modified definition of AU), Option D (current proposal) and Option E (no changes – status quo). Based on the comparisons in the tables, it is suggested that Option D (current proposal) is best suited with respect to eight key features of a desired outcomes-based assessment methodology. Some features are relatively subjective and dependent on how the details of each option are implemented. Nevertheless, the tables provide a useful comparison from an overall broad perspective.

Based on the comparisons of available options, it is proposed that the examination syllabus approach be adopted as a measure of curriculum content and quality in order to ensure that engineering programs at Canadian HEIs meet the regulators' academic requirements, while providing significant flexibility to the HEIs for educational innovation and alternate modes of program delivery. It would significantly reduce the workloads of program visitors and HEIs, as committed by Engineers Canada when outcomes-based assessment was originally proposed. The additional rigorous accreditation processes would also enable regulators to continue to accept graduates without further review of their individual academic qualifications.

By specifying what graduates are expected to know, the Examination Syllabus approach to curriculum content and quality measurements aligns well with the overall objective of shifting the emphasis of accreditation from input measures to outcomes. It would ensure that graduates have the necessary knowledge and skills to be productive and successful members of the engineering profession.

References

1) Canadian Engineering Accreditation Board, "Accreditation Criteria and Procedures", Engineers Canada, 2014
2) Isaacson, M., Lynch, W., Peters, R., "Balancing Inputs and Outputs: Moving to Criteria with Graduate Attributes", report of CEAB Task Force, August 2012
3) Isaacson, M., "Graduate Attributes and Accreditation", Canadian Civil Engineer, pp. 19 - 21, Spring 2016
4) Owens, D., Registrar, Engineers Ireland, Outcome-based Education and Engineering Education Accreditation, CAST Innovation and Integration Engineering Education Accreditation International Symposium, Beijing, April 11, 2016

Appendix 1 – Sample Examination Syllabus (Mechanical Engineering)

The ECQB syllabi for 21 engineering disciplines can be found at: www.engineerscanada.ca/examination-syllabus. These are used by provincial regulators to assess the academic qualifications of international engineering graduates (IEGs) and graduates from non-CEAB accredited programs who have applied for licensure in Canada. For example, the examination syllabus for Mechanical Engineering consists of the following groups.

- BASIC STUDIES (7 Mandatory): Mathematics, Probability & Statistics, Statics & Dynamics, Advanced Mathematics, Mechanics of Materials, Mechanics of Fluids, and Properties of Materials.
- TECHNICAL EXAM GROUP A (6 Mandatory): Applied Thermodynamics & Heat Transfer, Kinematics & Dynamics of Machines, System Analysis & Control, Design & Analysis of Machine Elements, Electrical & Electronics Engineering, and Fluid Machinery or Advanced Strength of Materials.
- TECHNICAL EXAM GROUP B (Any 3): Advanced Machine Design, Environmental Control in Buildings, Energy Conversion and Power Generation, Integrated Manufacturing Systems, Product Design & Development, Advanced Fluid Mechanics, Aero and Space Flight, Engineering Materials, Advanced Engineering Structures, Finite Element Analysis, Acoustics and Noise Control, Robot Mechanics, and Biomechanics.
- COMPLEMENTARY STUDIES (Any 2): Engineering Economics, Engineering in Society, Sustainability, Engineering & the Environment, and Engineering Management.
- ENGINEERING REPORT (Mandatory).

Within each course, a list of expected topics is provided. For example, the course "07-Mec-A1 Applied Thermodynamics and Heat Transfer" should have the following components.

- Thermodynamics: Review of the fundamental laws of thermodynamics, introductory psychrometry and analysis of the ideal gas compressor cycle, Rankine cycle, Otto cycle, Diesel cycle, Brayton cycle and the vapour compression refrigeration cycle.
- Heat Transfer: Application of the principles of steady and transient conduction heat transfer, natural and forced convection heat transfer and radiation heat transfer. Thermal analysis of heat.

Appendix 2 – Comparison of Curriculum Measurement Methods

Six options of different curriculum measurement methods are compared in this Appendix with respect to eight key characteristics. The options and characteristics are briefly described. Further details are available in Refs. [2-4]. In each approach, there are several common elements. For example, the curriculum content and quality must make it possible to obtain a foundation in mathematics and natural sciences, a broad preparation in engineering sciences and engineering design, and an exposure to non-technical subjects. The academic level of the curriculum must be appropriate to a university-level engineering program. The degree must comprise at least four years (eight semesters) of full-time study.

<u>Curriculum Measurement Options</u>

A) Option A [2]. A full-time semester typically comprises of a minimum of 225 instruction hours, where an instruction hour is defined as 1 hour of lecture (corresponding to 50 minutes of activity) or a corresponding duration for laboratories, projects and other modes of instruction as deemed appropriate by the institution. The curriculum should contain the following components in the following proportions: Mathematics and natural sciences (at least 23%), Engineering sciences and design (at least 45%, neither less than 12 %), and Complementary studies (at least 12%).

B) Option B [2]. The degree must comprise at least 1,800 instructional hours. Instructional hours are equivalent to Accreditation Units (AUs), except that each institution may define equivalent instruction hours for laboratories, tutorials, projects and other modes of instruction as it considers appropriate. The curriculum should contain the following component AUs: Mathematics and natural sciences (at least 420), Engineering sciences and design (at least 900, neither less than 225), and Complementary studies (at least 225).

C) Option C [3]. The Accreditation Unit (AU) remains as the basis for quantifying the curriculum, but the formal definition of the AU may be simplified in order to reduce institutional effort. The AU or equivalent is retained for a clear measure of curriculum quantity - whether this entails a modified AU definition or some other unit of measurement such as hours or academic credit or semesters suitably defined.

D) Option D. Use of an Examination Syllabus as a replacement for Accreditation Units (AUs) and for a measure of curriculum content and quality. The Examination Syllabus is a standard form of assessment that is used by regulators for the curriculum content assessment of foreign trained engineers.

E) Options E and F - Status quo. The entire program must include a minimum of either: 1,950 AUs (Option E) or 1,545 AUs (Option F). Engineering science and engineering design: Minimum 900 AUs - which includes a minimum 225 AUs in each of Engineering science and Engineering design. Mathematics and natural sciences: Minimum 420 AUs - which includes a minimum 195 AU in each of Mathematics and Natural sciences. Complementary Studies: Minimum 225 AUs.

Significant Characteristics

1) *Shift of emphasis to outcomes based assessment*. As outlined in the last Washington Accord review, the accreditation system needs to shift the focus of educational activity from teaching to learning; and teacher instruction to student demonstration. In addition to technical skills, employers need graduates to have other “enabling” skillsets as per the graduate attributes, with a broader knowledge of the world, as more well-rounded individuals, who can be integrators of complex systems, and multi-disciplinary in addition to being technically proficient.

2) *Workloads for program visitors and HEIs*. In 2008, Chantal Guay, former CEO of Engineers Canada, made the following commitment to NCDEAS. “Engineers Canada is committed to working with the NCDEAS during the transition into the new accreditation criteria, which is not intended to add more work, but to streamline the accreditation process.” The workload to prepare for accreditation (both AUs and graduate outcomes) has been drastically increased beyond the workload required historically with the AU system.

3) *Flexibility for educational innovation*. There is a need for better flexibility for educational innovation and alternative forms of program delivery such as active learning, experiential learning, project based learning, MOOCS, etc. Also, there is a need for a better ability to complement technology-focused studies with other studies (e.g., management, social sciences, entrepreneurship, research) to better prepare students to enter the global marketplace.

4) *Risks of pursuing alternate learning modes*. Many engineering schools view K-factors as too risky to use for introducing substantive program changes or alternative learning modes since the AB does not provide approvals of such use prior to an accreditation visit. Programs also find it too risky for contact-time based measurement of curriculum via AUs to be mapped onto objectives of educational innovation, flexible learning styles, and inquiry-based learning, using a K-factor.

5) *Program completion times*. Most of the other developed countries around the world have moved to 4-year undergraduate degrees with outcomes based assessment. It is important to consider getting in line with the rest of the world where the norm is a 4-year degree with outcomes based assessment.

6) *Foreign trained engineers*. The QB syllabi for engineering disciplines are used by provincial regulators to assess the academic qualifications of foreign trained engineers and graduates from non-CEAB accredited programs who have applied for licensure in Canada.

7) *New programs and emerging pedagogies*. The QB develops and approves the Examination Syllabus for any new program that is developed by an HEI which is not currently covered within the portfolios of syllabi. Any new syllabus added to the portfolio by the QB would be available for regulators to assess international engineering graduates and determine if they meet the academic requirement for licensure.

8) *Shift of emphasis to quality over quantity*. The overall quality of the engineering degree and its value to society should improve under any proposed changes. Students spending time in classrooms is just one of many learning environments, and not necessarily the most effective to get the skills needed by employers in the global marketplace. The amount of emphasis placed on quantitative measures should be balanced with program content and quality.

Table 1: Comparison of Curriculum Assessment Methods by Option Type

Options of Curriculum Measurement Methods	**Disadvantages**	**Advantages**
Option A [2] - 4 years and 225 instruction hours per year minimum with specified proportions of curriculum components	• lack of specificity introduces risk that causes HEIs to avoid substantive program deviations • larger programs can be unfairly constrained by specified percentages	• flexibility of HEI to modify curriculum and components to meet guidelines • for a program longer than 4 years, the proportions of program components can be adjusted so individual components are not unfairly constrained
Option B [2] - 1800 instructional hours as defined by the HEI as equivalent to AUs	• lack of specificity and inherent risk causes HEIs to avoid substantive deviations • does not adequately reduce workloads for program visitors and HEIs as committed by Engineers Canada in 2008 in moving toward graduate attributes	• flexibility of HEI to define effective instructional hours for labs, tutorials, projects, other modes of instruction • no longer constraints associated with "qualified AUs" • interim step from B to A to gain confidence in moving to outcomes based assessment
Option C [3] - Alternative modified AU definition or other unit of measurement such as hours, academic credit, or semester suitably defined	• depending on the details it may lead to insignificant overall change from existing AUs or shift of emphasis to outcomes based assessment • inconsistent with method of assessment by regulators of foreign trained engineers	• opportunity for a relatively straightforward simplification such as a proportionality factor between AUs and commonly used credit hours • builds upon well-known existing AU system that has been used for several decades
Option D (current proposal) - 4 years of full-time study minimum and examination syllabus	• challenge of curriculum assessment of new programs where a syllabus is not available through the QB • restricts program and course content as defined through the QB's program syllabus	• consistency with current approach of assessing foreign trained engineers • flexibility for educational innovation and alternate modes of learning • potential to significantly reduce workloads
Option E - Status quo (1950 AUs minimum)	• constrains educational innovation and alternate modes of course delivery • does not adequately address issues of workload and shift of emphasis to outcomes based assessment • AUs do not measure learning	• most well understood by stakeholders • familiarity means no disruptive change is required • tight control of programs through AUs means a high degree of uniformity across the country

Option F - Status quo with reduced AUs (1545 AUs minimum)	• continued reliance on AUs for curriculum content which do not measure learning • does not address workload issues	• non-disruptive change • less constrained from the point of view of educational innovation and alternate modes of course delivery • creates space for efficiencies associated with outcomes based assessment

Table 2: Comparison of Curriculum Assessment Methods by Feature

Features of Curriculum Measurement	**A**	**B**	**C**	**D**	**E**	**F**	**Comments**
1) Significant shift of emphasis to outcomes based assessment				■		■	Shift to learning outcomes and other qualitative measures
2) Significant reduction of workloads for program visitors and HEIs			■ ?	■			Dependent on how modified AU is defined and measured in (C)
3) Enables flexibility for educational innovation and alternate modes of learning				■		■	
4) Certainty of approval, a priori, of alternate learning modes to support risk taking by HEIs	■			■			K-factors too risky as approval not granted prior to site visit
5) Program completion times (4 years) that are consistent with other countries	■		■	■		■	Increasingly sustained trend of 4 year completion times
6) Consistent with curriculum assessment by regulators of foreign trained engineers				■			Foreign trained engineers not assessed against AUs
7) Available mechanisms for new programs and emerging technologies and pedagogies	■	■	■	■	■	■	
8) Rigorous and readily understood assessment by stakeholders	■	■	■	■	■	■	