IEA Graduate Attributes: A Guide to Demonstration and Evaluation

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CACEI

Consejo de Acreditación de la Enseñanza de la Ingeniería, A.C.

CACEI: Accreditation Council for Engineering Education, Mexico, June 1, 2022

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Disclaimer

The expressed views and suggestions on how to demonstrate and how to evaluate the graduate attributes are personal suggestions and should not be taken as binding to any organization I am affiliated with!

DEFINITION AND RELEVANCE OF GA

Graduate attributes is a set of individually assessable outcomes that are indicative of a **graduate's potential** to acquire competence to practice at the appropriate level. The attributes are clear, succinct statements of the expected capability.

Among the Requirements of Rules and Procedures Documents of IEA:

"The *graduate outcomes standard* applied for accreditation [by a signatory] is substantially equivalent to that of the Accord graduate attributes exemplar."

TABLES THAT DEVELOP GAPC

1) **Range of Problem Solving Capabilities**: problem solving capabilities that distinguish the 4-5-year programs with engineer graduates from those that have a teaching duration of 3-4 years for technologists or 2 years for graduating technicians

2) **Range of Engineering Activities**: complex activities for an engineer, broadly-defined activities for a technologist, and well-defined activities for a technician

3) **Knowledge and Attitude Profile**: can be viewed as describing what the curriculum of an engineering program must contain at a minimum

4) **Graduate Attribute Profiles**: the qualifications (assimilated knowledge, skills, and attitudes) of an engineer or technologist or technician at the time of graduation

5) **Professional Competence Profiles**: the competences for a qualified engineer/technologist/technician attained, not only during school education but also, through lifelong learning and professional development.

Example on Ethics

(Table 4: Graduate Attributes**)** **Ethics:** Understanding and level of practice	**WA7:** Apply ethical principles and commit to professional ethics and norms of engineering practice and adhere to relevant national and international laws. Demonstrate an understanding of the need for diversity and inclusion (WK9)
(Table 3: Knowledge and Attitude Profile**)**	**WK9: Ethics, inclusive behavior and conduct.** Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitudes
(Table 1: Range of Problem Identification and Solving**)** Range of conflicting requirements	**WP2:** Involve wide-ranging and/or conflicting technical, non-technical issues (such as ethical, sustainability, legal, political, economic, societal) and consideration of future requirements

- **The entry in "Ethics" row** includes engineering codes, standards, specifications, diversity, and anti-discrimination legislation.
- Table 3 stipulates that professional ethics and norms are acquired as **knowledge** and ''diversity and inclusion'' as **awareness.**
- The items of Table 3 and Table 4 are based upon Table 1, where **problem identification and solving** are indicated to involve ethical, legal, societal requirements.

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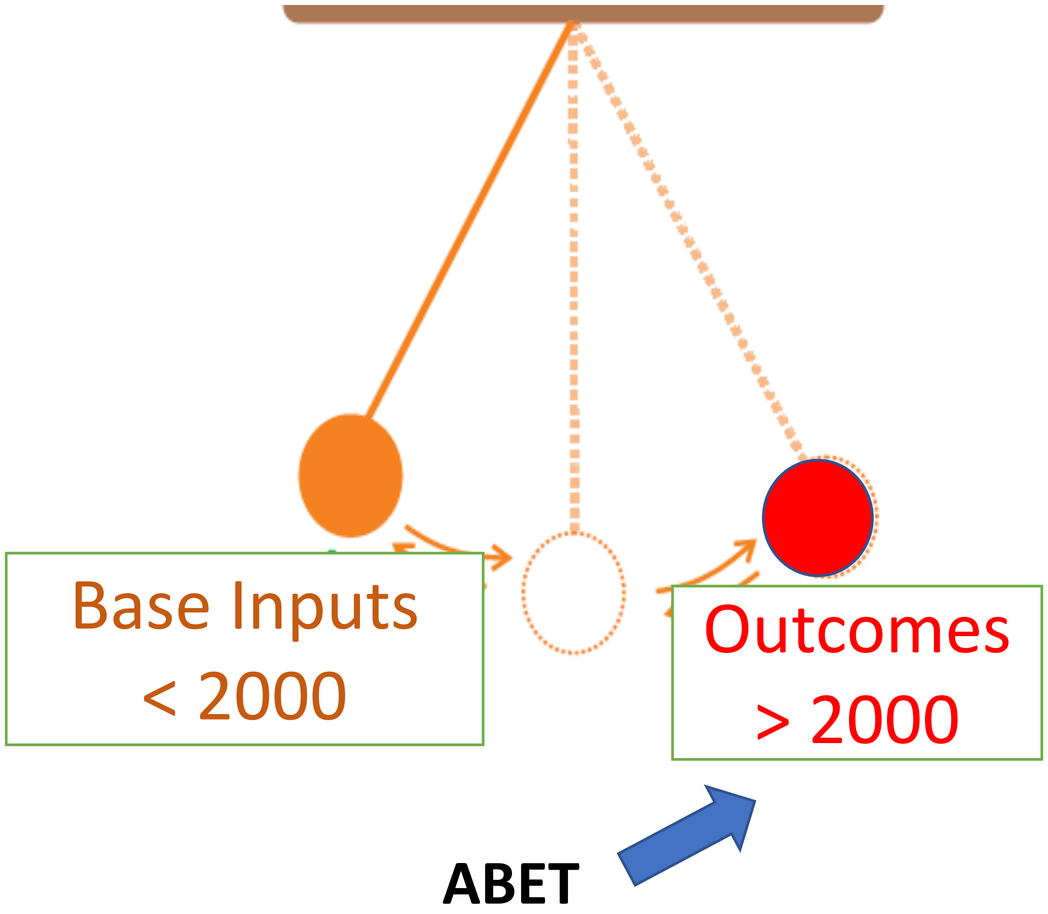
Two Orientations for Educational Accreditation

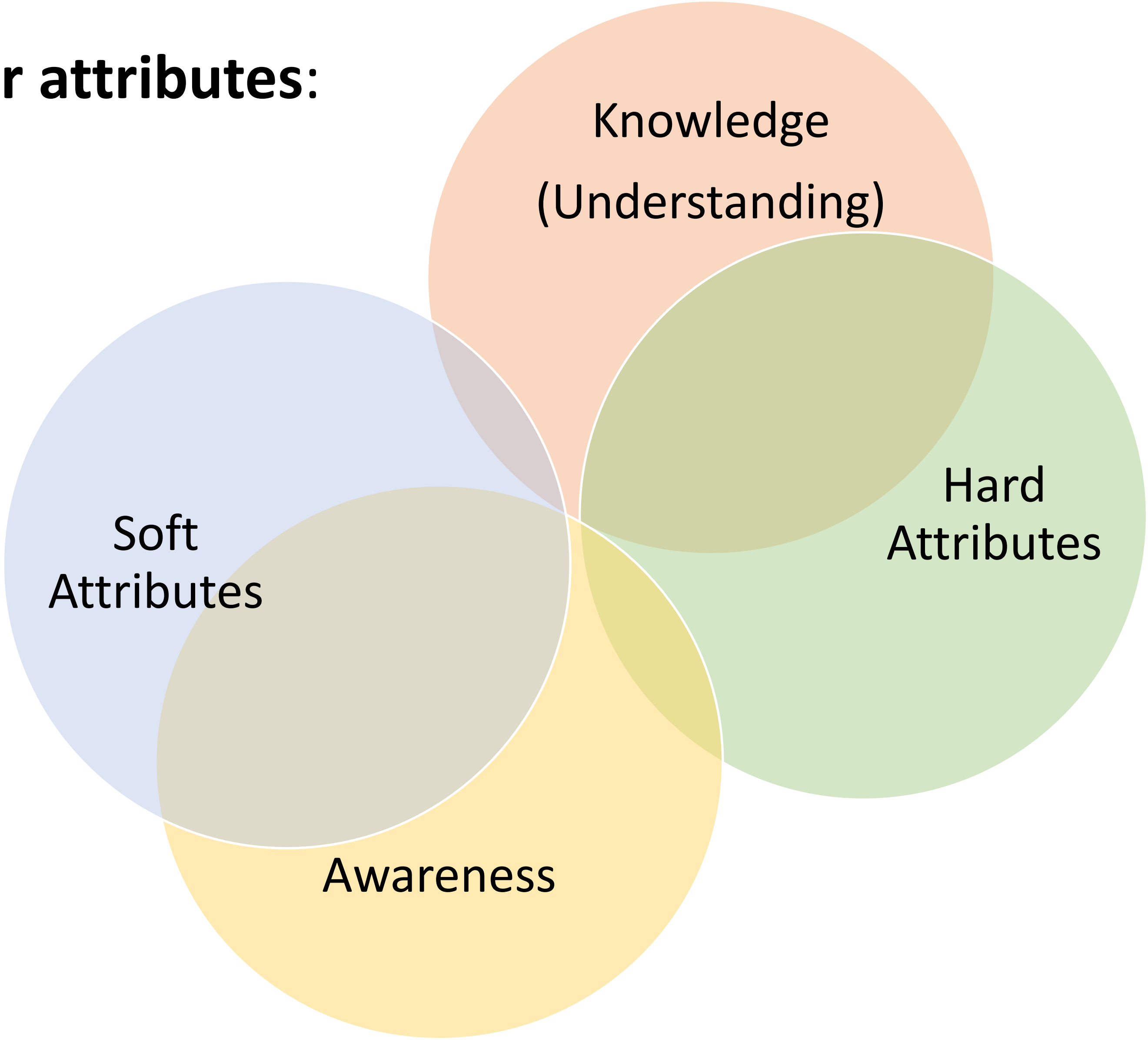
- Inputs ensure that the outcomes have a **chance** to be achieved.
- They are important and occur as integral parts of all «outcome based criteria».
- Will pendulum swing back?



Two subset decompositions for attributes:

1) Hard vs. soft attributes
2) Knowledge (understanding) vs awareness
3) Look at the intersections!

''It is easier to assess knowledge and practical skills than higher level cognitive or social skills and competences or, even more, attitudes and values,'' ***ENAEE Label Committee Investigation***.



Knowledge and Awareness: Operational Definitions

Knowledge: Recognizing and comprehending terminology, facts, methods, trends, classifications, structures, or theories. It involves learning as well as demonstrating what has been learned. The demonstration of a specific knowledge is invariably by means of work done based on that knowledge.

Awareness: Recognizing the context and implications while using or applying what has been learned. The demonstration of awareness can be more varied than a demonstration of knowledge. Asking the right questions, including among the assumptions made, complying with or respecting when faced with a situation may be acceptable demonstrations.

Knowledge (Understanding) and Awareness

Table 3 Knowledge and Attitude Profile

A Washington Accord program provides:	
WK1: A systematic, theory-based understanding of the **natural sciences** applicable to the discipline and awareness of relevant **social sciences**	"Awareness" is less than "knowledge" and more than "acquaintance" or "familiarity." An example to distinguish "knowledge" and "awareness": **Awareness**: Limit the social sciences electives to a restricted pool of courses that are relevant to the discipline and make sure that every student takes course(s) and discusses some «social aspects or implications» in a major work (HW, term paper, ...). **Knowledge** (if it were required): The courses would have been must courses and the HEI program must have shown additional student work in which student displays the learning and understanding of the main subject matters.

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Awareness: Inclusion among Assumptions Made

Knowledge and Attitude Profile, WK1 contains "awareness of relevant social sciences."

Demonstration by way of " including among assumptions made "

A robot is designed to answer questions by the visitors of a museum. The museum is on Central Anatolian civilizations. The engineer points out that the robot is programmed to understand only i) *such and such current dialects* and ii) *does not understand vocabulary that refer to the ancient Urartu civilizations* (Eastern Anatolian). The first points out to an assumption on speech recognition capability of our robot, and the second, to the technical vocabulary database of the robot.

The design engineer need not completely understand either the various Anatolia dialects or the kind of ancient civilizations but he is aware of them.

A LOOK AT THE GRADUATE ATTRIBUTES: EXAMPLES OF IMPLEMENTATION AND INDICATORS OF ACHIEVEMENT

Renewed emphasis is on:

DIGITIZATION, AUTOMATION, SUSTAINABILITY,
CONTINUOUS DEVELOPMENT, CREATIVITY, BROADER VIEW, DIVERSITY/INCLUSION

IEA respects the uniqueness of every engineering program, many of which display better practices than those suggested here

RESEARCH, CREATIVITY, CRITICAL THINKING

WA2: Identify, formulate, research literature

WA4: Investigate ... problems using research methods including research-based knowledge The "research" here consist of learning how to find out what is already known about a particular problem (*anything more than this would be unrealistic for a four-year curriculum*).

WA3: Design creative solutions Bring forth (extra credit, reward, honorable mention, etc.) unique solutions in any student assignment.

WA5: Create ... techniques, resources, ... and IT tools Confront the student with problems that need selection of a tool, including some that necessitate the creation of a new tool. «Creation» need not be comprehensive *(adding a feature to an existing software, synthesis of two separately available tools, an alteration of an existing model).*

WA11: ... ability for ... critical thinking add an item among the evaluation criteria of any major student work to assess whether the student applied a questioning and logical process while making assumptions and decisions.

COMPUTING , REMOTE SETTINGS, EMERGING TECHNOLOGIES

WA1: Apply knowledge of ... computing and engineering fundamentals Knowledge of ''computing fundamentals" are knowledge of "algorithms, numerical analysis, basic optimization approaches (*not: Computing Tool Usage!).*

WA8: Function effectively ... in ... remote and distributed settings Requires that a meeting or presentation by a student is also transmitted to an audience and its effectiveness is evaluated.

WA11: ... adaptability to new and emerging technologies ... 1) Make students attend (and submit its proof) to one or two lessons or seminars in which they listen to real experiences of adaptability and change management of a professional engineer. 2) Encourage students to engage with professional and intellectual communities.

ETHICS, DIVERSITY & INCLUSION

WA7: ... commit to professional ethics and norms ... Demonstrate an understanding of the need for diversity and inclusion

WA9: Communicate effectively and inclusively ...

WA8: Function effectively ... as a member or leader in diverse and inclusive teams

1) If a devoted course to ethics is not feasible, then design, as parts of some appropriate courses, a number of case studies.
2) For the demonstration of D&I as an "attitude," design one or two case studies on "*workplace ethics problem on non-discrimination*."
3) Form any lab or project team among students **randomly,** as a principle.

ETHICS: A POSSIBLE CLASSIFICATION

Rules that Regulate Human-to-Human and Human-to-Institution Relationships

Laws: Lawful (Legal) vs Unlawful (Illegal)

Obey laws

Norms: Normal (Appropriate) vs Abnormal (Inappropriate)

Listen while the other is talking, Unplug while repairing (even if very low power), Dress appropriate to the occasion

Ethics: Right vs Wrong

Be accountable, Keep promise, Do not endanger anything/anybody

Morals:Good (Virtue) vs Bad (Vice)

Help the needy, Be just

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DESIGN

WA3: Design creative solutions for complex engineering problems and design systems, components or processes Confront students with a complex problem

i) that is *incompletely defined, not amenable to a deductive resolution*, and *requires an innovative or creative approach* and

ii) admits differing and equally acceptable solutions.

WA4: ... design ... experiments

1) Discipline dependent: *"finding bugs in a code" in computer engineering, "measuring elasticity" in mechanical engineering, "determining the bandwidth by measurement" in electrical engineering*.
2) The word "design" necessitates that a student (or a group of students) devises which experiment would be suitable without guidance.

SUSTAINABILITY

WA2: Investigate ... with holistic considerations for sustainable development
WA3: Design ... solutions ... with appropriate consideration for public health and safety, whole-life cost, net zero carbon as well as resource, cultural, societal, and environmental considerations
WA6: ...evaluate sustainable development impacts ...

1) The sustainable development outcomes must be considered at problem definition, analysis, design, and evaluation stages, **all**.
2) Students must be made aware of what these considerations are and learn how to identify those that are relevant to a particular problem.
3) *To implement: i) Carefully design the **motivational and application examples** given throughout the curriculum* and ii) Include UN-SDG in the check-list of capstone design project!
4) The observance of these aspects in each major student work on analysis and design may be sufficient *(although, in some disciplines, a full course for a particular aspect may be necessary, for instance, health and safety in chemical engineering).*


SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS

UN SDG: ALL ARE RELEVANT

1. NO POVERTY: In India, more than 100 million low-income users have access to mobile phones that cost less than US$25.

2. ZERO HUNGER: Communications technology for weather monitoring, forecasting and disaster

3. GOOD HEALTH: A rubber-based leg prosthetic enables thousands of people with disabilities to become more mobile

10. REDUCED INEQUALITIES: The 'Chotukool' fridge, which costs US$69 and keeps food cool, enable women to spend more time on economic activities

A CLOSER LOOK!

Differentiating Characteristic	**... for Washington Accord Graduate**	
Engineering Knowledge: Breadth, depth and type of knowledge, both theoretical and practical	**WA1:** Apply knowledge of mathematics, natural science, computing and engineering fundamentals, and an engineering specialization as specified in WK1 to WK4 respectively to develop solutions to complex engineering problems	1) Each component of "knowledge" would require inclusion of a number of full semester-courses in the 4 year curriculum (usually, many in the first two years). 2) Some Engineering Accreditation Criteria (EAC) stipulate that there must be 30 semester-credit hours (approximately corresponding to a total of 10 courses) to satisfy mathematics and natural sciences together. 3) Similarly, some EAC require 45 semester-credit hours of courses to satisfy computing and engineering fundamentals knowledge requirement. 4) The new addition "computing" here does not mean"Tool Usage, " that occurs in WA5 below. It rrefers to knowledge of computing fundamentals" such as "algorithms, numerical analysis, basic optimization approaches," whichever is appropriate to the discipline.

Differentiating Characteristic	… for Washington Accord Graduate	
Problem Analysis: Complexity of analysis	**WA2:** Identify, formulate, research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences with holistic considerations for sustainable development* (WK1 to WK4)	1) Qualitative statements of problems are usually already there. The students should learn how to go from there to a **quantitative** (mathematical, model-based, physical, computational) **description**. 2) Students should learn how to judge the **validity of assumptions** made at the formulation and analysis stages. 3) The **sustainable development outcomes** must be considered also at **problem definition and problem analysis stages.** To be able to do this, students must be first made aware of what these considerations are and learn how to identify those that are relevant to a particular problem under analysis. This, in turn, requires a careful design of motivational as well as application examples given throughout the curriculum.

COMPLEX vs WELL-DEFINED: MAKE A WIRE TURN

Engineering Problem: Make a wire turn when excited by voltage:

Solution: Wring (twist) a copper wire into a loop and place it in a magnetic field after applying voltage at its ends.

Complex Engineering Problem: Explain why a wire excited by voltage turns when placed in a magnetic field.

Solution: Explain via Faraday's or Lorentz or Maxwell's laws. This requires a knowledge of *vector fields* (Mathematics), *magnetic flux* (Physics), and *partial differential equations* (Mathematics), all of which are available in a third year electromagnetics book.

Both are engineering problems but require different knowledge and skills, neither superior to other.

Differentiating Characteristic	... for Washington Accord Graduate	
Design/ development of solutions: Breadth and uniqueness of engineering problems i.e., the extent to which problems are original and to which solutions have not previously been identified or codified	**WA3:** Design creative solutions for complex engineering problems and design systems, components or processes to meet identified needs with appropriate consideration for public health and safety, whole-life cost, net zero carbon as well as resource, cultural, societal, and environmental considerations as required (WK5)	1) A **design solution** is distinguished as i) its problem is *incompletely defined, not amenable to a deductive resolution*, and *requires an innovative or creative approach*. ii) its problem *admits differing and equally acceptable solutions*. 2) Some HEI's present a list of ''appropriate considerations'' as an integral part of the capstone design project. In order to guarantee that the solution takes a most relevant subset into account. It is highly recommended to **include a reference to UN-SDG** in this list or directly form a list based on it. 3) The significance of "**creative solutions**" can be taught (and measured) by bringing forth (extra credit, reward, honorable mention, etc.) unique solutions in student assignment.

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Differentiating Characteristic	… for Washington Accord Graduate	
Investigation: Breadth and depth of investigation and experimentation	**WA4:** Conduct investigations of complex engineering problems using research methods including research-based knowledge, design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions (WK8)	1) The "research methods" here consist of learning how to find out what is already known about a particular problem (anything more than this would be unrealistic for a four-year curriculum) 2) The teaching of "design of experiments" is obviously dependent on the engineering discipline: "finding bugs in a code" in computer engineering, "measuring elasticity" in mechanical engineering, "determining the bandwidth by measurement" in electrical engineering, and so on. The word "design" necessitates that a student (or a group of students) devises which experiment would be suitable without guidance. 3) Design of experiments, analysis and interpretation of data, synthesis of information are all methods of investigation that can be implemented as *parts* of suitable courses, ***not*** in separate courses.

Differentiating Characteristic	… for Washington Accord Graduate	
Tool Usage: Level of understanding of the appropriateness of technologies and tools	**WA5:** Create, select and apply, and recognize limitations of appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering problems (WK2 and WK6)	1) The attribute is to be able to **select and apply** the appropriate **tool** from among those that the recent (modern) technology offers; and, to be able to **create one** when none of the existing tools answer the present need. 2) The implementation not only requires to confront the student with problems that need selection of a tool but also with some that necessitate the creation of a new tool. 3) To expect a creation that is comprehensive (a new software!) is not realistic; **adding a feature to an existing software**, synthesis of two separately available tools, an **alteration of an existing model** (from linear to nonlinear, from time-invariant to slowly time-varying, from polynomial to exponential etc.) would be examples that can be introduced in a four-year curriculum.

Differentiating Characteristic	… for Washington Accord Graduate	
The Engineer and the World: Level of knowledge and responsibility for sustainable development	**WA6:** When solving complex engineering problems, analyze and evaluate sustainable development impacts* to: society, the economy, sustainability, health and safety, legal frameworks, and the environment (WK1, WK5, and WK7)	1) This attribute can **partly be acquired by** its implementation in the **capstone design** experience.. 2) An **awareness of social sciences** is one requirement to the attainment of this attribute. An example implementation in the curriculum may be to limit the social sciences electives to a restricted pool of courses that are relevant to the discipline. (Sociology and Psychology may support Computer and Industrial Engineering; Economy supports all traditional engineering disciplines, and so on). 3) In some disciplines, a full 3-semester-credit course for a particular aspect may be feasible. (For instance, health and safety in chemical engineering and so on.) Otherwise, the **observance of these aspects in each major student work on analysis and design** may be sufficient.

Differentiating Characteristic	... for Washington Accord Graduate
Ethics: Understanding and level of practice	**WA7:** Apply ethical principles and commit to professional ethics and norms of engineering practice and adhere to relevant national and international laws. Demonstrate an understanding of the need for diversity and inclusion (WK9)

1) This row is about understanding and practicing ethics. The additions are detailing what aspects ethics encompasses. D&I, as an "attitude" is very much a part of ethics. Team work is an instance where D&I is important. Communication is another.
2) If a devoted course to ethics is not feasible, then the best way to implement this attribute in the curriculum would be to design, as parts of some appropriate courses, a number of case studies.
3) An example of implementation for the demonstration of D&I as an "attitude" may be to design one or two (of these) case studies on "workplace ethics problem on non-discrimination."
4) Professional ethics is more than"not to cheat on specs of a product," it is more embracing and includes all aspects indicated in this row.

Differentiating Characteristic	**... for Washington Accord Graduate**	
Individual and Collaborative Team work: Role in and diversity of team	**WA8:** Function effectively as an individual, and as a member or leader in diverse and inclusive teams and in multi-disciplinary, face-to-face, remote and distributed settings (WK9) .	1) "inclusive" draws attention that teams must learn to function with individuals of different backgrounds and different levels of learnings, etc. One implementation in the curriculum is to form any lab or project team among students randomly, as a principle. 2) The teamwork attribute, especially multidisciplinary one, is a major challenge of implementation in any engineering discipline, not only to realize but even to sustain after having started. This is, however, one attribute almost every employer of engineers puts at the top of the "must be'' list. 3) The "remote and distributed settings" component will continue to be the primary setting for any group to work together. An implementation example may be to require that a meeting or presentation by a student is also transmitted to an audience and its effectiveness is evaluated. 4) If most major student projects are done in groups, then a measurement of individual contributions becomes necessary.

Differentiating Characteristic	... for Washington Accord Graduate	
Communication: Level of communication according to type of activities performed	**WA9:** Communicate effectively and inclusively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, taking into account cultural, language, and learning differences.	1) This attribute has potentially many important components. The choice is shaped by specific scenarios in mind. The present priorities are on "reports and documentation" and "language and learning differences." 2) The implementation would require that every student not only writes a comprehensive report, makes a formal presentation, and faces a diverse audience at least once during the education period but that all these activities are evaluated by instructor(s) using appropriate performance criteria, with feedback to the student, and with "repeat" a viable option.

Differentiating Characteristic	**… for Washington Accord Graduate**	
Project Management and Finance: Level of management required for differing types of activity	**WA10:** Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects in multidisciplinary environments.	1) Many EACs implement this attribute via a must or elective course, although this is neither sufficient nor necessary. 2) Knowledge of *systems engineering and/or project management tools* and *processes to the planning and execution of project work* are required. 3) The correct implementation strongly depends on the engineering discipline as well as the program educational objectives. 4) One possible solution may be to implement (form) the capstone design experience as a major collaborative project, which requires management and has economic dimensions.

Differentiating Characteristic	... for Washington Accord Graduate	
Lifelong learning: Duration and manner	**WA11:** Recognize the need for, and have the preparation and ability for i) independent and life-long learning ii) adaptability to new and emerging technologies and iii) critical thinking in the broadest context of technological change (WK8)	1) This row concerns both continuity and aspects (types) of learning. 2) Critical thinking can be understood as an "active, logical, and questioning process of accepting facts or beliefs." 3) An example implementation for (i) and (ii): Students attend (and can submit its proof) to one or two lessons or seminars in which the students listen to real experiences of adaptability and change management of a professional engineer. 4) A student's engagement with a professional and intellectual community may be a further demonstration of (i). 5) Critical thinking can be learned. An example: add an item among the evaluation criteria of any major student work to assess whether the student applied a questioning and logical process while making assumptions and decisions.

SOURCES

- **IEA GAPC** (https://www.ieagreements.org/assets/Uploads/Documents/IEA-Graduate-Attributes-and-Professional-Competencies-2021.1-Sept-2021.pdf)
- **UN SDG** (https://www.undp.org/)
- **UNESCO Engineering Report**, *March 2021 (*http://worldengineeringday.net/wp-content/uploads/2021/03/UNESCO-Engineering-Report-Engineering-for-Sustainable-Development -EN.pdf)
- **ENZ: Accreditation Standards** (https://d2rjvl4n5h2b61.cloudfront.net/media/documents/ACC_02_Accreditation_Criteria_V3.1_20201030.pdf)
- **UK-Spec third edition**.pdf (https://www.engc.org.uk/standards-guidance/standards/uk-spec/)

Thank You

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