Graduate Attributes 101

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What we will cover in this workshop

Canadian Engineering Accreditation Board (CEAB)

- **CEAB** - a standing committee to "Engineers Canada"
- **Engineers Canada** - a national federation of all the provincial licensing organizations (i.e. PEO)
- **Accreditation** - performed to ensure that graduates of an engineering program are academically qualified to be licensed as a professional engineer
- Accreditation is critical to our success!

What does the CEAB look at? (Six key areas)

1. Graduate attributes – *we will come back to this*
2. Continual improvement – *will come back to this*
3. Students – policies, procedures, quality, counselling, …
4. Curriculum content and quality – inputs based assessment (counts AU – accreditation units)
5. Program Environment (faculty, labs, libraries, financial resources …)
6. Additional criteria (program options, weakest link, program name, …)

Critical to our success

- Become a P.Eng.
- Must have your P.Eng. to participate in design courses!
- Faculty has workshops to help you prepare for the law and ethics exam.

McMaster Accreditation Status

- All programs underwent CEAB review in 2015 when GA/CI was in early stages of development
- All programs received 6 year of accreditation
- Next review is in 2021
- Graduate Attributes assessment and continuous improvement is ON-GOING effort.
- CEAB will have higher expectations on GA/CI at the next review.

Sample of PEO Current Expectations:*

- It is expected that suitable committee and reporting structures are in place to assure the sustainable development and measurement of graduate attributes.
- **All faculty members** of the relevant academic unit are expected to be aware of and engaged in outcomes-based assessment.

*from *Accreditation Criteria and Procedures 2016*

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WHAT ARE “GRADUATE ATTRIBUTES”?

What are the 12 “graduate attributes” (GAs)?

Attributes/skills that graduates of a program must have include:

1. Knowledge base for engineering
2. Problem analysis
3. Investigation
4. Design
5. Use of engineering Tools
6. Individual and Team Work
7. Communication Skills
8. Professionalism
9. Impact on society and environment
10. Ethics and equity
11. Economics and Project management
12. Life-Long learning

Background/Language – **Outputs** Based Assessment

- We need to some way to assess the degree to which our students have attained these **attributes**.
- We start by defining "**indicators**" of the attributes.
- Each **attribute** has a number of '**indicators**' associated with it.
- The indicators describe the various elements of an attribute.
- Indicators must be "measurable".

Example – Attribute/Indicators

Attribute: 1. A knowledge base for engineering

Description of the attribute (from CEAB):

Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.

Four Indicators for "Knowledge base for engineering":

1.1 Competence in Mathematics

1.2 Competence in Natural Sciences

1.3 Competence in Engineering Fundamentals

1.4 Competence in Specialized Engineering knowledge

Another Example: Attribute/Indicators

Attribute #6: Individual and team work

Description of the attribute (from CEAB):

An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

Three Indicators for "Individual and team work":

6.1 Manages time and processes effectively, prioritizing competing demands to achieve personal and team goals and objectives.

6.2 Develops and implements processes and methodologies to manage the effectiveness of a team both in terms of the quality of the work produced by the team as well as the inter-personal relationships within the team.

6.3 Works in a group, taking a leadership role as appropriate and relinquishing the leadership role as appropriate.

Structure of Attributes/Indicators:

(we are measuring learning outcomes that relate to the 'indicators')

- Graduate Attribute #1
  - Indicator 1.1
  - Indicator 1.2
- Grad Attribute #2
  - Indicator 2.1
  - Indicator 2.2
  - Indicator 2.3
- …
- Graduate Attribute #12
  - Indicator 12.1
  - Indicator 12.2

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CURRICULUM MAPPING

Curriculum Mapping

- You will need to assess which indicators are relevant to the courses that you teach.
- You will need to come up with a list of "**learning outcomes**" for your course (*more on this later*).
- Need to complete a "Course Information Sheet" (or possibly an excel file provided by dept administrator)
- For each indicator, you need to state if:
  - Not relevant
  - I – **I**ntroduced in your course
  - D – **D**eveloped in your course
  - A – **A**pplied in your course
  - (We previously used a scale of 0 (not relevant), 1, 2, 3)

Curriculum Mapping

I D A mapping of indicators (from CEAB website 2019):

https://www.engineerscanada.ca/sites/default/files/draft_program_visitor_guide_v1.25.pdf

p. 6 of the visitor guide

- **Introductory:** … the students **learn the working vocabulary of the area of content**, along with some of the major underlying concepts. Many of the terms need defining and the ideas are often presented in a somewhat simplified way.

- **Development:** …the students **use their working vocabulary and major fundamental concepts** to begin to probe more deeply, to read the literature, and to deepen their exploration into concepts.

  At this level, students can begin to appreciate that any field of study is a complex mixture of sub-disciplines with many different levels of organization and analysis.

- **Application:** … the students **approach mastery in the area of content**.
  They explore deeply into the discipline and experience the controversies, debate and uncertainties that characterize the leading edges of any field.
  An advanced student can be expected to be able to relate course material across different courses, to begin to synthesize and integrate and achieve fresh insights.
  Students at this level are working with the knowledge very differently, perhaps even creating new knowledge through independent investigation.

Curriculum Mapping

- All faculty members provide a description of how relevant the indicators are to their courses
- This is put together into a large excel file to see an overall mapping for the program
- Helps to identify any “gaps” that may exist
- You will likely be asked to measure the extent to which the students have mastered the relevant indicators for your course.

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LEARNING OUTCOMES

Indicators/Course Learning Outcomes

- Indicators can be broad statements that apply across departments.
  Example “Competence in Mathematics”
- Learning outcome statements are more precise and contain detailed information about what a student will learn.
- We are measuring how well the students mastered the learning outcomes from your course that pertain to the indicators.

Example #1: Indicator and Associated Learning Outcome

- Indicator:
  - 1.1 Competence in Mathematics
- Example of an associated learning outcome for a specific course:
  - "A demonstrated ability to solve a linear homogeneous differential equation with associated boundary conditions."

Example #2: Indicator and Associated Learning Outcome

- Indicator:
  - 1.4 Competence in specialized engineering knowledge
- Example of an associated learning outcome for a specific course:
  - "A demonstrated ability to describe the basis of the heat and momentum transfer analogy and perform heat transfer calculations on thermal boundary layers."

Example #3 – Indicator is already a learning outcome

- Indicator:
  - 8.1 Demonstrates an understanding of the role of the engineer in society, especially in protection of the public and public interest.
    - This is an indicator for the attribute: “Professionalism”
    - This indicator is already specific enough to be a learning outcome for a course (example: ENGINEER 1P03 – “Introduction to Professional Engineering”)

Measurement Goals:

1. To determine the extent to which our students are attaining specific *learning outcomes* associated with the 'indicator' that we are measuring.
2. To use this information to improve our program in subsequent years. Need to satisfy the "continuous improvement" requirement of CEAB.

High level description of measurement procedure

- Want to get a sense of how well our students are attaining the *learning outcomes* associated with the indicator and determine what they are struggling with.
- We use tests, assignments, presentations, reports in our measurement process.
- We use rubrics to measure the student learning outcomes.
- Four levels of grading are used:
  1. Does not meet expectations
  2. Marginal
  3. Meets expectations
  4. Exceeds expectations

What is a learning outcome?

Simply stated, a learning outcome is:

1. What faculty members want students to know at the end of the course

AND

2. What faculty members want students to be able to do at the end of the course

Reference: Pauline Smiley, Fleming College, Symposium on Learning Outcomes Assessment, Toronto, 2012.

Characteristics of Learning Outcomes

1. They specify an action by the students that is observable.
2. They specify an action by the students that is measurable.
3. They specify an action that is done by the students (rather than the faculty members).

Reference: Pauline Smiley, Fleming College, Symposium on Learning Outcomes Assessment, Toronto, 2012.

Writing learning outcome statements

- Must include verbs!
- Example of a bad learning outcome statement:
  - "Differential equations"
- Example of a good learning outcome statement:
  - "A demonstrated ability to solve a linear homogeneous differential equation with associated boundary conditions."
  - Note: verbs are included and detail is given.

Aside: Bloom's Taxonomy

- Taxonomy is: Remember, Understand, Apply, Analyze, Evaluate, Create.
- It provides useful words for developing learning outcome statements.
- How does Bloom's fit into our process?
  - It tends to confuse us.
  - Don't get caught up in using Bloom's to determine your learning outcomes.
  - Upshot: Don't worry about Bloom's! – Just think of it as providing useful verbs!

REMEMBER	UNDERSTAND	APPLY	ANALYZE	EVALUATE	CREATE
Count	Associate	Add	Analyze	Appraise	Categorize
Define	Compute	Apply	Arrange	Assess	Combine
Describe	Convert	Calculate	Breakdown	Compare	Compile
Draw	Defend	Change	Combine	Conclude	Compose
Identify	Discuss	Classify	Design	Contrast	Create
Label	Distinguish	Complete	Detect	Criticize	Drive
List	Estimate	Compute	Develop	Critique	Design
Match	Explain	Demonstrate	Diagram	Determine	Devise
Name	Extend	Discover	Differentiate	Grade	Generate
Outline	Extrapolate	Divide	Discriminate	Interpret	Group
Point	Generalize	Examine	Illustrate	Judge	Integrate
Quote	Give examples	Graph	Infer	Justify	Modify
Read	Infer	Interpolate	Outline	Measure	Order
Recall	Paraphrase	Manipulate	Point out	Rank	Organize,
Recite	Predict	Modify	Relate	Rate	Plan
Recognize	Rewrite	Operate	Select	Support	Prescribe
Record	Summarize	Prepare	Separate	Test	Propose
Repeat		Produce	Subdivide		Rearrange
Reproduce		Show	Utilize		Reconstruct
Select		Solve			Related
State		Subtract			Reorganize
Write		Translate			Revise,
		Use			Rewrite
					Summarize
					Transform
					Specify

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INDICATOR MEASUREMENTS

Overall Measurement Procedure

1. Decide on which student work will be used for measurement (i.e., tests, exam, presentations, project reports…)
2. Develop a rubric to describe desired student learning outcomes (more detail on this to come)
3. While you are marking, keep track of how the student did by ticking the appropriate box
4. Analyze results to provide information for continuous improvement (i.e., identify learning outcomes that the students are struggling with)
5. Document measurement results

Example: Measurement of the Indicator "Competence in Specialized Engineering Knowledge" using MECH ENG 4S03 (Incompressible Flows)

1. Student work used for measurement:
   - Final exam
2. Development of rubric (example to follow):
   - Think about what you wanted the students to learn
   - Link those learning outcomes to the exam questions
   - Decide on what the students needed to be able to do to demonstrate that they "met expectations"
   - Then define learning outcomes for "exceed expectations", "marginal", "does not meet expectations"

Example Rubric – MECH ENG 4S03 (Incompressible Flow)

Topic (exam questions used)	Below Expectations	Marginal	Meets Expectations	Exceeds Expectations
Topic #1: Heat and momentum transfer analogy (Question 4 of final exam)	-Does not understand the concept of the analogy	-Able to use the correlations. - Understands that there is an analogy, but cannot explain the math behind it.	- Can explain the math. basis of the analogy. - Can determine appropriate correlation to solve for heat transfer or drag	-"meets expectations" plus: - Can explain why analogy does not hold if there is pressure gradient
	Comments on Topic #1 performance:			

Example Rubric – MECH ENG 4S03 (Incompressible Flow)

Topic (exam questions used)	Below Expectations	Marginal	Meets Expectations	Exceeds Expectations
Topic #2: Boundary layers (Question 3 of final exam)	-Cannot use correlations correctly -Unable to explain separation	-Can draw velocity profile -Can calculate local shear and total drag -Doesn't understand separation	-Can draw boundary layer velocity profile - can calculate local shear and total drag -Can say whether flow will separate or not	-"meets expectations" plus: - Can explain (based on physics in near wall region) why sep. cannot occur for fav. pressure grad.
	Comments on Topic #2 performance:			

POOR Example Rubric

Topic (exam questions used)	Below Expectations	Marginal	Meets Expectations	Exceeds Expectations
Topic #3: (Question 4 of final exam)	Student does not answer question or does poorly on question 4 [< 4.5 / 10]	Student has problems with question 4. [4.5 – 6 / 10]	Is able to answer question 4 satisfactorily [6-8 / 10]	Does really well on question 4 [>8 / 10]
	Comments on Topic #3 performance:			

Example Rubric – MECH ENG 4S03 (Incompressible Flow)

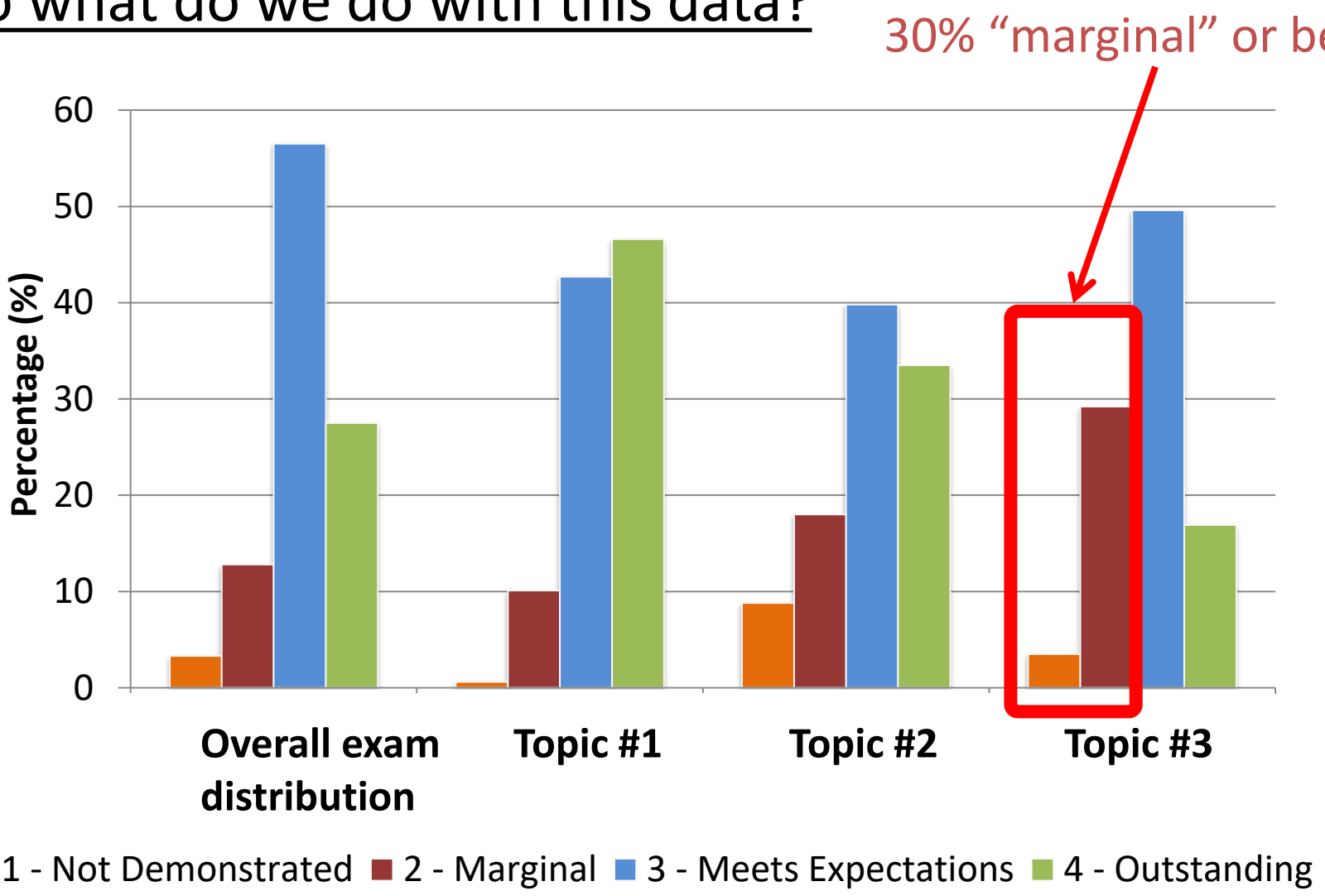
Topic (exam questions used)	Below Expectations	Marginal	Meets Expectations	Exceeds Expectations
- Keep adding rows until you have covered topics you wish to measure - remember to leave blank space for 'ticks' when measuring - remember to leave area to write in comments while you are marking				
- If all the elements of the exam or test pertain to the indicator being measured (i.e., 'Competence in specialized engineering knowledge' as in this example), then add a row with the overall mark distribution on the exam or test:				
Overall exam performance	% that did not meet expectations (i.e., grade of less than 48% on exam)	% that were marginal (grade of roughly 48% to 59%)	% that met expectations (grade of roughly 60% to 79%)	% that exceeded expectations (top students: 80% and above)

Measurement Logistics:

As you mark a question that is on the rubric, tick off the appropriate box. Add comments as appropriate.

Topic #1: Heat and momentum transfer analogy (Question 4 of final exam)	**-Does not understand the concept of the analogy** ///	**-Able to use the correlations.** **- Understands that there is an analogy, but cannot explain the math behind it.** ~~////~~ ////	**- Can explain the math. basis of the analogy.** **-Can choose appropriate correlation to solve for heat transfer or drag** ~~////~~ ~~////~~ ~~////~~ ~~////~~ ~~////~~ ~~////~~	**-"meets expectations" plus:** **- Can explain why analogy does not hold if there is pressure gradient** ///
	Comments on Topic #1 performance: -Students were generally good at using correct correlation -Some had trouble explaining the mathematics behind the analogy (need to spend more lecture time on that next year)			

So what do we do with this data?



Topic #1 – many are exceeding expectations (could reduce lecture time on it)
Topic #3 – more than 30% of class is marginal or below (struggling with this)

*Plot is from Brian Frank from Queen’s

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GRADUATE ATTRIBUTE DOCUMENTATION

Documentation of Measurement Results

- Need to write a short document summarizing results. It should include:
  - Rubric used for measurement
  - Corresponding exam or test
  - Distributions for each learning outcome area
  - Identified areas for continuous improvement
  - Sample exam papers with performance in each area (below expectations, marginal, …)
  - Suggestions for how to improve measurement procedure (if any)
- VENA: Faculty of Engineering has invested in database software to “store” these data.

Follow-up

- Continual Improvement:
  - Incorporate areas identified as needing improvement into your lectures the next time you teach this course
- Keep track of the changes made to your course since we will likely need to incorporate them into the next CEAB report.
- Subsequent measurement of the same learning outcomes should hopefully show improvement in those areas where we found the students were struggling.

Continual Improvement*

- At the program level, CEAB will be assessing:
  - Improvement process:
    - Suitable committee structure
    - Engagement of relevant stakeholders
    - Well-defined timetable
  - Stakeholder engagement:
    - Consultation with broadly-based set of stakeholders (internal and external to the program and institution)
  - Improvement Actions:
    - Expectation of curriculum or other program improvements
    - improved achievement of graduate attributes
    - Improvements in assessment process

*From “Accreditation Criteria and Procedures 2016 – Appendix 10”

If you need help with this:

- Each department has a graduate attributes (GA) committee
- Committee responsible for:
  - Developing a GA measurement plan for the department
  - Organizing stakeholder meetings
  - Communicating expectations to faculty members
  - Assisting faculty members with GA measurements
  - Reviewing GA measurement reports
  - Keeping track of continuous improvement at course level (via measurement reports)
  - Recommending program improvements based on program level GA measures
    - e.g., which attributes do not meet the threshold or are not well represented in the curriculum.

Graduate Attributes – Key Documents:

Marilyn's website: http://mechfaculty.mcmaster.ca/~lightsm/gradatt/

- List of indicators (revised in 2013)
- This workshop presentation
- Sample measurement report
- Report cover page with checklist of contents

Key Documents from CEAB website:

https://engineerscanada.ca/sites/default/files/accreditation-criteria-procedures-2016-final.pdf

https://engineerscanada.ca/sites/default/files/draft_program_visitor_guide_v1.25.pdf

APPENDIX

LIST of INDICATORS

Appendix – Indicator List

1. A knowledge base for engineering

Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.

- Competence in Mathematics
- Competence in Natural Sciences
- Competence in Engineering Fundamentals
- Competence in Specialized Engineering knowledge

2. Problem analysis

An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.

- Demonstrates an ability to identify reasonable assumptions (including identification of uncertainties and imprecise information) that could or should be made before a solution path is proposed.
- Demonstrates an ability to identify a range of suitable engineering fundamentals (including mathematical techniques) that would be potentially useful for analyzing a technical problem.
- Obtains substantiated conclusions as a result of a problem solution including recognizing the limitations of the solutions.

3. Investigation

An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.

- Recognizes and discusses applicable theory knowledge base
- Selects appropriate model and methods and identifies assumptions and constraints.
- Estimates outcomes, uncertainties and determines appropriate data to collect.

4. **Design**

An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, economic, environmental, cultural and societal considerations.

- Recognizes and follows an engineering design process.
  (This means an iterative activity that might include recognizing the goal, specifying the constraints and desired outcomes, proposing solutions, evaluating alternatives, deciding on a solution, and implementing.)
- Recognizes and follows engineering design principles including appropriate consideration of environmental, social and economic aspects as well as health and safety issues.
- Proposes solutions to open-ended problems.
- Employs appropriate techniques for generation of creative ideas such as brainstorming and structured inventive thinking.
- Includes appropriate health and safety considerations
- Determines and employs applicable standards and codes of practice.

5. Use of engineering tools

An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.

- Evaluates and selects appropriate modern tools.
- Demonstrates an ability to use modern/state of the art tools.
- Creates, adapts, modifies and extends tools and techniques as appropriate to solve problems.

6. Individual and team work

An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

- Manages time and processes effectively, prioritizing competing demands to achieve personal and team goals and objectives.
- Develops and implements processes and methodologies to manage the effectiveness of a team both in terms of the quality of the work produced by the team as well as the inter-personal relationships within the team.
- Works in a group, taking a leadership role as appropriate and relinquishing the leadership role as appropriate.

7. Communication skills

An ability to communicate complex engineering concepts within the profession and with society at large. Such abilities include reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.

- Demonstrates an ability to respond to technical and non-technical instructions and questions.
- Presents instructions and information clearly and concisely as appropriate to the audience
- Constructs effective oral or written arguments as appropriate to the circumstances

8. Professionalism

An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.

- Demonstrates an understanding of the role of the engineer in society, especially in protection of the public and public interest.
- Demonstrates an understanding of legal requirements governing engineering activities (including but not limited to personnel, health, safety, and risk issues).
- Shows an awareness of the PEO and the role of licensing.

9. Impact of engineering on society and the environment

An ability to analyze social and environmental aspects of engineering activities. Such abilities include an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society; the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.

- Identifies and quantifies the full range of short-term, long-term, local and global impacts of their engineering projects on society, including: economic aspects; social, cultural, and human health aspects, and; ecosystem integrity aspects.
- Addresses uncertainties in the prediction of interactions on society and the environment in a structured and transparent manner.
- Assesses possible options and design configurations from a sustainability engineering perspective, which emphasizes environmental stewardship, life-cycle analysis, and long-term decision-making principles.

10. Ethics and equity

An ability to apply professional ethics, accountability, and equity.

- Applies the engineering code of ethics, understanding of the stakeholders: the individual, the employer, and the public.
- Applies ethical frameworks and reasoning in situations where there may be conflicting interests among the stakeholders
- Applies knowledge of law and principles of equity to ensure equitable treatment of others.

11. Economics and project management

An ability to appropriately incorporate economics and business practices including project, risk and change management into the practice of engineering, and to understand their limitations.

- Applies economic principles in decision making
- Plans and effectively manages time, resources, and scope
- Understands the business processes for implementing engineering ideas
- Identifies, characterizes, assesses, and manages risks to project success

12. Life-long learning

The ability to identify and to address their own educational needs in a changing world, sufficiently to maintain their competence and contribute to the advancement of knowledge.

- Critically evaluates and applies knowledge, methods and skills procured through self directed and self identified sources, including those that lie outside the nominal course curriculum.
- Shows an awareness of the wide range of engineering societies, literature, conferences, and other information sources.