Graduate Attributes 101

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Worksop Agenda

1. Some background on the CEAB
2. What are “Graduate Attributes”?
3. Curriculum mapping
4. Learning outcome statements
5. Indicator measurements
6. GA Documentation

1 - Some Background on the CEAB

A little context never hurts, right?

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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 Investigate? (Six key areas)

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

McMaster Accreditation Status

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- Most recent review was November 2021
  - 2020-2021 was our “capture” year
- Included our iBioMed programs (obtained the 3-year max for new programs)
- Next accreditation (iBioMed programs only) – November 2024
- Graduate Attributes assessment and continuous improvement is an ONGOING effort

2 – What are Graduate Attributes?

Lists are fun.

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What are the 12 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

Language - Outcomes Based Assessment

- We need to some way to assess the degree to which our students have attained **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 Attribute 1:

1.1 Competence in Mathematics

1.2 Competence in Natural Sciences

1.3 Competence in Engineering Fundamentals

1.4 Competence in Specialized Engineering knowledge

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.

Two Indicators for Attribute 6:

6.1 Actively contributes to the planning and execution of a team project

6.2 Manages interpersonal relationships, taking leadership responsibilities as needed

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
- *… And so on…*
- Graduate Attribute #12
  - Indicator 12.1
  - Indicator 12.2

3 – Curriculum Mapping

It helps to have a map!

Curriculum Mapping

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- Courses in each program have been mapped to relevant indicators
- Each course has a list of "**learning outcomes**"
- Relevant indicators map to the learning outcomes
- For each indicator, there are three levels:
  - I — Introduced in your course
  - D — Developed in your course
  - A — Applied in your course

I D A mapping of indicators

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

- **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.

4 - Learning Outcomes

"I know nothing, except that I know nothing"

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Indicators/Course Learning Outcomes

- Indicators can be **broad statements** that apply across departments.
- **Learning outcome** statements contain detailed information about what a student will know and be able to do at the end of the course.
- We are measuring how well the students mastered the learning outcomes.

- Good learning outcomes:
    1. Specify an ***action by the students*** that is **observable**.
    2. Specify an ***action by the students*** that is **measurable**.
    3. Specify an ***action*** that is ***done by the students*** (not the instructors).

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

Writing Learning Outcomes

- Must include verbs!
- Example of a <u>bad</u> learning outcome statement:
  - *Differential equations*
- Example of a <u>good</u> learning outcome statement:
  - Analytically solves a linear homogeneous differential equation with associated boundary conditions in 1 and 2 dimensions.

Four sin words in learning outcome statements: **know, understand, learn, appreciate**

Bloom’s Taxonomy

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INCREASING COGNITIVE LOAD AND EDUCATIONAL FULFILLMENT

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

Examples: Indicator and Associated LO

- Indicator:
  - 1.1 Competence in Mathematics
- Example of an associated learning outcome for a specific course:
  - Analytically solves a linear homogeneous differential equation with associated boundary conditions in 1 and 2 dimensions.

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

Example: Learning Outcomes in Syllabus

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Learning Objectives

After completing this course, the student should be able to:

L.1. Recognize when numerical methods should be applied as a part of a solution to a variety of chemical engineering (and other) problems or opportunities.

L.2. Formulate mathematical models of common engineering unit operations and processes.

L.3. Identify the appropriate algorithm or numerical method suitable for the solution.

L.4. Break down how an algorithm works based on fundamental mathematical concepts.

L.5. Implement algorithms using calculators and (more importantly) software tools.

L.6. Derive algorithms for new problems based on a fundamental understanding of the objective.

L.7. Use a numerical solution to help solve the original problem of interest.

L.8. Identify the critical differences, advantages, and disadvantages of numerical versus analytical techniques.

Example: GA Mapping in Syllabus

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C.E.A.B. Graduate Attributes

Certain courses in the chemical engineering curriculum collect indicator data related to the development of the attributes deemed critical for engineers according to the Canadian Engineering Accreditation Board (CEAB). These indicators will be assessed throughout the course and redacted samples of student work may be collected for submission to the CEAB during McMaster Engineering's accreditation cycle. The indicators assessed in ChE 2E04 are as follows:

1.1 – Competence in mathematics.
1.3 – Competence in engineering fundamentals.
5.1 – Evaluates engineering tools, identifies their limitations, and selects, adapts, or extends them appropriately.
5.2 – Successfully uses engineering tools.
7.1 – Demonstrates comprehension of technical and non-technical instructions and questions.

The CEAB indicators listed above are mapped to the course learning outcomes as shown in the table at right. The CEAB accreditation process is an important component to curriculum design in engineering. If you have any questions or wish to be involved in the accreditation process, please let me know at neasej@mcmaster.ca.

Indicator	Mapped Learning Outcomes
1.1	L.2 L.4 L.5
1.3	L.1 L.2 L.3 L.7 L.8
5.1	L.3 L.4 L.6 L.8
5.2	L.3 L.5
7.1	L.1 L.7 L.8

5 – Indicator Measurements

Pass me the grade stick, will ya?

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Measurement Goals

1. Determine the extent to which students are attaining specific *learning outcomes* associated with the indicator

2. Use this information to improve programs in subsequent years (as required by CEAB).

Measurement Collection

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- We use tests, assignments, presentations, reports etc. in our measurement process.
- We use rubrics to measure the student learning outcomes demonstrated in those assessments.

- Four levels of performance are used:
  1. Does not meet expectations [BE]
  2. Marginal [MA]
  3. Meets expectations [ME]
  4. Exceeds expectations [XE]

Measurement Procedure

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1. Decide on which student work will be used for measurement (i.e., tests, exam, presentations, project reports…)
2. Develop a rubric to measure indicator performance based on the relevant learning outcome
3. Bin students according to rubric performance
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: MECH ENG 4S03

Measurement of the Indicator 1.4: **Competence in Specialized Engineering Knowledge**

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:			

Measurement Logistics

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- 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)			

6 – Graduate Attribute Documentation

Home stretch

Documentation of Measurement Results

- Need to write a short document summarizing results. It should include:
  - Rubric used for measurement
  - Corresponding assessment (e.g., exam question)
  - Distributions for each indicator measurement
  - Identified areas for continuous improvement
  - Possibly examples of student performance in each area e.g., below expectations, marginal, … (consult with your Associate Chair)
  - Suggestions for how to improve measurement procedure (if any)
- VENA: Faculty of Engineering has invested in database software to store data

Following Up

- Continual Improvement:
  - Incorporate areas identified as needing improvement the next time you teach this course
  - This tracking ensures legacy for the next instructor of the course

- It is important to be accountable for your suggested improvements – they are recorded in GA reports and reported to the CEAB

- 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 2022 - Appendix 10”

If You Need Help

- 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

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Key Documents from CEAB website (update July 2023):

https://engineerscanada.ca/sites/default/files/accreditation/Manual-of-Accreditation-Procedures-Accreditation-Visit-Cycle-2020-2021-e.pdf

https://engineerscanada.ca/sites/default/files/2021-03/General%20_Visitor_Manual_0.pdf

See Appendix for Detailed List of Indicators

APPENDIX

List of Indicators

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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.

- 1.1 Competence in Mathematics
- 1.2 Competence in Natural Sciences
- 1.3 Competence in Engineering Fundamentals
- 1.4 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.

- 2.1 Identifies and states reasonable assumptions and suitable engineering fundamentals, before proposing a solution path to a problem.
- 2.2 Proposes problem solutions supported by substantiated reasoning, recognizing the limitations of the solutions

Appendix – Indicator List

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.

- 3.1 Selects appropriately from relevant knowledge base to plan appropriate data collection methods and analysis strategies.
- 3.2 Synthesizes the results of an investigation to reach valid conclusions.

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, and economic, environmental, cultural and societal considerations.

- 4.1 Defines the problem by identifying relevant context, constraints, and prior approaches before exploring potential design solutions.
- 4.2 Explores a breadth of potential solutions, considering their benefits and trade-offs as they relate to the project requirements.
- 4.3 Develops models/prototypes; tests, evaluates, and iterates as appropriate.
- 4.4 Justifies and reflects on design decisions, giving consideration to limitations, assumptions, constraints and other relevant factors.

Appendix – Indicator List

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.

- 5.1 Evaluates engineering tools, identifies their limitations, and selects, adapts, or extends them appropriately.
- 5.2 Successfully uses engineering tools.

6. Individual and Teamwork

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

- 6.1 Actively contributes to the planning and execution of a team project.
- 6.2 Manages interpersonal relationships, taking leadership responsibilities as needed.

Appendix – Indicator List

7. Communication Skills:

An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes 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.

- 7.1 Demonstrates comprehension of technical and non-technical instructions and questions.
- 7.2 Composes an effective written document for the intended audience.
- 7.3 Composes and delivers an effective oral presentation for the intended audience.

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.

- 8.1 Describes the duty of a Professional Engineer to the public, client, employer, and the profession.
- 8.2 Integrates appropriate standards, codes, legal and regulatory factors into decision making.

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9. Impact of Engineering on Society and the Environment:

An ability to analyze social and environmental aspects of engineering activities. Such ability includes 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.

- 9.1 Evaluates the environmental impact of engineering activities, identifies uncertainties in decisions, and promotes sustainable design.
- 9.2 Evaluates the social impact of engineering activities, including health, safety, legal, cultural, and other relevant factors, and identifies uncertainties in decisions.

10. Ethics and Equity

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

- 10.1 Applies ethical frameworks and reasoning, including in situations where there are possible conflicting interests among the stakeholders.
- 10.2 Applies the principles of equity and universal design to ensure equitable treatment of all stakeholders.

Appendix – Indicator List

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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.

- 11.1 Applies economic principles in decision making.
- 11.2 Plans and effectively manages a project's time, resources, and scope, following business practices as appropriate.
- 11.3 Identifies, characterizes, assesses, and manages risks to project success.

10. Life-Long Learning

An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.

- 12.1 Reflects on one's own educational needs and opportunities for growth.
- 12.2 Seeks and acquires appropriate external information as required, including showing awareness of sources of information and ability to critically evaluate them.