A Shift to Outcomes-Based Assessment in Engineering

How changes in the national accreditation requirements in professional engineering are changing the way we evaluate our programs.

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1 Canadian Engineering Accreditation

Engineering accreditation in Canada has traditionally been input-based, with a focus on metrics such as contact hours, course content, and class sizes. Through international agreements, Canada and other countries have agreed to shift to outcomes-based accreditation systems. By 2014, Canadian universities must demonstrate that graduates of their programs possess attributes in twelve specified areas. Schools across the country, including UBC, are working hard to develop tools and processes to meet these requirements.
2 CEAB Graduate Attributes

The Canadian Engineering Accreditation Board (CEAB) is responsible for Canadian engineering accreditation. They have adopted 12 Graduate Attributes to specify the knowledge and abilities required of engineers at the time of graduation:

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. Lifelong learning
3 Process Flow Used at UBC

1. Defining Purpose and Outcomes
2. Program Mapping (Identifying Assessment Points)
3. Identifying and Collecting Data
4. Analysis and Interpretation
5. Create a Program Improvement Plan
6. Program & Course Improvement

Stakeholder input
The *graduate attributes* broadly define the required outcomes, but they are difficult to measure directly. For example:

- **#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.

With inspiration from other schools, we began by defining the attributes in terms of *Indicators*. These are the 4-7 measurable descriptors of what students in UBC Engineering must do to be considered competent in an attribute. For example, the first of five indicators for Problem Analysis was phrased as:

- **2.1 Problem Identification:** Identify known and unknown information, uncertainties, and biases when presented with a complex ill-structured problem.
A survey was sent to faculty teaching in each program. For each course, instructors indicated to what degree each attribute was developed:

- **E** – Emphasized (taught and assessed)
- **U** – Utilized (required for the course but not taught)
- **I** – Introduced (appeared in the course but not assessed)
- **☐** – Not developed
In the survey, instructors also indicated which assessment tools they used for any attributes the emphasized in their course.

With the map and assessment information, several courses were targeted in each program for data collection.
7 Collecting Data

A handful of courses were targeted in each program and data collection is ongoing. Existing course evaluation tools are being used wherever possible. In addition to embedded questions on exams, extensive use is being made of marking rubrics.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Unacceptable</th>
<th>Marginal</th>
<th>Meets Expectations</th>
<th>Exemplary</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Problem Identification</td>
<td>Team is NOT able to identify the parameter they are studying with the prototype.</td>
<td>Parameter studied is NOT directly relevant to project success.</td>
<td>Parameter studied is appropriate for project, AND the team is able to provide some justification why.</td>
<td>Parameter studied is appropriate for project, AND the team is able to provide strong justification why.</td>
<td>0</td>
</tr>
<tr>
<td>3.2 Investigation Design</td>
<td>Team has NOT built a prototype.</td>
<td>Prototyping method is NOT appropriate for the parameter being studied (i.e. will not yield desired data).</td>
<td>Prototyping method is of least somewhat appropriate for the parameter being studied; a simpler approach MAY exist.</td>
<td>Prototyping method is appropriate for the parameter being studied, AND the team is able to clearly justify why the physical prototype used is superior to other physical or virtual prototypes.</td>
<td>1</td>
</tr>
<tr>
<td>3.3 Data Collection</td>
<td>No data collected; prototype does NOT work.</td>
<td>The prototype works BUT data collection / analysis techniques are inappropriate.</td>
<td>Data collection and analysis are done appropriately AND data quality is fair.</td>
<td>Data collection and analysis are done appropriately AND data is of high quality.</td>
<td>2</td>
</tr>
<tr>
<td>3.4 Data Synthesis</td>
<td>No conclusions are drawn, OR inappropriate conclusions are drawn.</td>
<td>Appropriate conclusions are drawn from the data, AND the team is able to explain how the data affects the project.</td>
<td>Appropriate conclusions are drawn from the data, AND the team is able to provide some explanation of how the data affects the project. Some implications are overlooked.</td>
<td>Appropriate conclusions are drawn from the data, AND the team is able to provide strong and complete explanations of how the data affects the project.</td>
<td>3</td>
</tr>
<tr>
<td>3.5 Analysis of Results</td>
<td>The team does NOT consider limitations or errors in the tests, or validity of the conclusions.</td>
<td>The team considers errors, limitations, and validity of the tests, BUT does NOT quantify errors or take appropriate action.</td>
<td>The team quantifies errors, and considers limitations and validity, AND takes action. BUT action is limited or somewhat inappropriate.</td>
<td>The team quantifies errors, and considers limitations and validity. AND is able to justify and take appropriate action.</td>
<td>3</td>
</tr>
</tbody>
</table>

Shown is a rubric for prototype evaluation. Five criteria in the left column map directly to the Indicators used to define the attributes. The results are used in the course as well as documented for accreditation.
8 Collecting Data

To complement the instructor-gathered data from courses (exams, rubrics, etc.) various student surveys are being piloted.

Please indicate how competent you believe you are at this time in the abilities and attributes below.

<table>
<thead>
<tr>
<th>Knowledge of engineering, math, and science fundamentals</th>
<th>Unsure</th>
<th>Not at all competent</th>
<th>Somewhat competent</th>
<th>Competent</th>
<th>Highly competent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to identify, analyze, and solve problems</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Ability to use experiments and analysis to investigate complex problems</td>
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<tr>
<td>Ability to design solutions for complex, open-ended problems</td>
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</tr>
<tr>
<td>Ability to select, apply, and/or create engineering tools and techniques</td>
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<tr>
<td>Ability to work effectively as a member and leader in teams</td>
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<tr>
<td>Ability to communicate complex engineering concepts</td>
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<tr>
<td>An understanding of the roles and responsibilities of engineers in</td>
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</tbody>
</table>

Shown is an example of part of a survey where students self-rate their competency with the different attributes. Similar surveys have been used in courses to gather data at the indicator level.
Data is being summarized by year, indicator, and attribute. At this stage the effort is to identify strengths and weaknesses within the programs.

**Attribute 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.

- Below Expectations: 3%
- Marginal: 28%
- Meets Expectations: 54%
- Exceeds Expectations: 15%

<table>
<thead>
<tr>
<th>Indicator Summary</th>
<th>Courses and elements assessed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Use of Process</td>
<td>MECH 223 Report 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td>MECH 223 Presentation 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td>MECH 223 Final Exam 2</td>
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<td></td>
<td>MECH 325 Assignments 1-5</td>
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<tr>
<td></td>
<td>MECH 45X Report 1, 2, &amp; 3</td>
</tr>
<tr>
<td>4.2 Need Identification</td>
<td>MECH 223 Final Exam 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td>MECH 325 Assignments 1-5</td>
</tr>
<tr>
<td></td>
<td>MECH 328 Project Report</td>
</tr>
<tr>
<td></td>
<td>MECH 45X Report 1</td>
</tr>
</tbody>
</table>
We are at the early stages of this process, and are piloting what we believe to be a workable assessment framework. We have initial data on how our programs are performing, but have not yet begun implementing curriculum changes or program improvements.

We are striving to implement a meaningful yet sustainable process. In particular, we hope to incorporate data collection as part of regular course and program activities (as opposed to the “accreditation scramble” that used to happen every five or six years). In addition, we are working hard to educate students about the coming changes, and to include them and other stakeholders in the process.
UBC is one of seven Canadian schools collaborating on and supporting this process. Reflecting the scale of task ahead of us, we have collectively chosen the acronym “EGAD” based on the “Engineering Graduate Attribute Development Project”. EGAD provides two main support mechanisms:

- **Workshops**: training workshops are offered on a regular basis, and on request. Since 2010, 12 workshops have been delivered in six provinces.

- **Online Resources**: online outcomes-based accreditation training materials and resources are available through the EGAD website: [http://egad.engineering.queensu.ca/](http://egad.engineering.queensu.ca/). Included on the website are vetted resources and examples drawn from the participating institutions.