RECONCILING GRADUATE ATTRIBUTE ASSESSMENT WITH EXISTING OUTCOME-BASED ASSESSMENT

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Abstract – Historically, accreditation of engineering programs has relied on the use of input-based assessment of a program by framing major categories and identifying accreditation unit totals for each category. Beginning in 2014, compliance with an outcomes-based assessment of program quality and implementation of a program improvement process is also required.

The introduction of graduate attributes assessment at BCIT prompted faculty members to question the relationship between existing learning outcomes and indicators of graduate attributes. Since both outcomes and indicators are written to describe competencies, faculty hypothesized that correlation exists between them.

Upon further investigation, faculty, staff, and administrators at BCIT came to understand that there is a relationship between learning outcomes and indicators of graduate attributes, but they are not synonymous. Indicators are required to build a normalizing bridge between outcomes and attributes. They provide a rational relationship between a curriculum's individual course learning outcomes and the twelve graduate attributes mandated by the Canadian Engineering Accreditation Board.. This is especially important for subjective expectations of learning where there is not an obvious one-to-one relationship between learning outcomes and attributes

Keywords: *graduate attributes; learning outcomes; outcome based assessment.*

1. INTRODUCTION

The British Columbia Institute of Technology (BCIT) offers industry-informed programs with a focus on experiential teaching and learning, and outcomes-based assessment. Each course delivered at BCIT is required to develop a comprehensive list of learning outcomes embedded within a course outline. Learning outcomes

specify what learners' new behaviours will be after a learning experience, and state the knowledge, skills, and attitudes that the students will gain through a course.

The establishment of a faculty wide engineering graduate attributes assessment project prompted questions of overlap between learning outcomes and indicators of graduate attributes. Faculty members wondered whether aspects of the graduate attributes project represented a duplication of activity, and they challenged the value of a separate, stand-alone process.

The graduate attributes project leadership group at BCIT embarked on a journey to define the relationship between the two. Faculty buy-in and project success would improve with this reconciliation.

2. QUESTIONS

In 2012 faculty leaders in each engineering department followed the recommendation of the Engineering Graduate Attributes Development Project (EGAD) and commenced the writing of indicators of graduate attributes. Indicators of graduate attributes are written to describe what the student will be able to do, the level of complexity at which they will do it, and the conditions under which learning will be demonstrated [3]. Existing learning outcomes were removed from the conversation and left in their independent and functioning role. Faculty members were lead through a workshop on writing indicators and a draft list of indicators was compiled [7][7].

Early contributors to, and adopters of, the graduate attribute framework recognized many similarities between learning outcomes and indicators of graduate attributes.

Learning outcomes and indicators of graduate attributes describe competencies. Both communicate expectations of learner's, and graduates' skills upon program

completion. Both provide an objective benchmark for assessment. Faculty hypothesized that the extent to which correlation exists between them meant they could, in fact, be synonymous. Therefore, why have both learning outcomes and indicators of graduate attributes?

3. ASSOCIATING LEARNING OUTCOMES AND INDICATORS OF GRADUATE ATTRIBUTES

BCIT Faculty is counselled to write learning outcomes that ‘define coherent units of learning that can be further subdivided or modularized for classroom or for other delivery’ [9]. For a typical course in an engineering program, the recommended number of learning outcomes is 5 to 12. Table 1 summarizes the total number of learning outcomes defined for each program.

Table 1: Program Courses, Learning Outcomes and Indicators

	Number of Courses	Number of Learning Outcomes	Number of Indicators
Civil Engineering	80	609	73
Electrical Engineering	52	546	73
Mechanical Engineering	59	533	73

A specific example, Electrical Engineering’s ELEX 7720 – Linear Feedback Control, has 11 defined course learning outcomes, shown in Table 2.

Table 2: ELEX 7720 Linear Feedback Control Course Learning Outcomes

1	Define what is linear feedback control.
2	Describe the conditions for and limitations of linear feedback control.
3	Prepare a set of control system performance objectives.
4	Propose measures by which performance may be gauged.
5	Recommend an appropriate control strategy to use based on process characteristics and performance objectives.
6	Design a 3-term PID controller using an appropriate choice of empirical, semi-empirical, or analytic approach.
7	Describe practical concepts and limitations of controller implementation such as direct/reverse acting controllers, bump-less transfer, and integrator anti-windup schemes.
8	Justify reducing the order of a system model and approximating nonlinear terms, in order to make

	the problem tractable for linear process control design
9	Analyze implications of making model simplifications on the final system performance.
10	Design controllers using both time domain and frequency domain approaches.
11	Develop facility with tools including Labview, MATLAB, and Simulink for use in process modeling, controller design, and simulation and analysis.

Notice the tight coupling of language used in the expression of the learning outcomes to course content and the technical knowledge that will be gained as a result of taking the course. Also notice that the list of learning outcomes tends to shadow module delivery.

When asked to reflect upon which graduate attributes were being developed in this course, the instructor reported attributes 1-7 of the twelve listed in Table 3.

Table 3: Engineering Graduate Attributes

1. Knowledge base for engineering
2. Problem analysis
3. Investigation
4. Use of engineering tools
5. Design
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

The development of these attributes, in particular attributes 6 and 7, are not at first glance easily recognizable from the listed learning outcomes.

If it is agreed that each learning outcome should exhibit a direct line of sight to one or more graduate attributes, and if the team purports that assessing a learning outcome with an existing assessment tool will help gather direct evidence of mastery of a graduate attribute, then the outline of a relationship has been established.

The graduate attributes leadership team embarked on an exercise to associate learning outcomes and attributes. In some cases, there was an obvious 1:1 relationship, however, in other cases the relationship was 1:many. The graduate attributes leadership team also recognized another truth associated with the identity of these core components. Learning outcomes were used to measure an individual’s performance in a course, whereas indicators

of attributes were used to measure a program's performance and overall effectiveness.

With this information in mind, faculty members began to map learning outcomes to indicators, and to graduate attributes. The initial hypothesis was: if it is possible to show a one-to-one relationship between a learning outcome and an indicator, then it is possible to use the existing assessment tool (or part of it) for that outcome as a direct measure of a graduate attribute.

4. FINDINGS

In practice, indicators provide a bridge between the course-focused learning outcomes and the program-focused attributes. Indicators also provide a leap pad between approximately 1700 learning outcomes and the 12 attributes, making it possible to show direct linkages between outcomes and attributes for the purpose of data collection.

Referring back to the ELEX 7720 example, it is perhaps not surprising that some of the more technically focused graduate attributes, for example '2: Problem Analysis', could clearly be related one-to-one between an indicator of the graduate attribute and a stated course learning outcome, as shown in Table 4.

Table 4: One-to-one mapping of ELEX 7720 learning outcomes and indicators of problem analysis

Learning Outcome	Indicators of Problem Analysis
5. Recommend an appropriate control strategy to use based on process characteristics and performance objectives.	2.2.3 Select the best process to solve an engineering problem.
8. Justify reducing the order of a system model and approximating nonlinear terms, in order to make the problem tractable for linear process control design	2.2.1 Create a process/solution method for solving a problem, including forming justified approximations and assumptions

Furthermore, for example in the case of the graduate attribute '5: Use of Engineering Tools', if the learning outcome was broken down into sub-outcomes, a mapping to indicators of this graduate attribute could be made, as shown in Table 5.

Table 5: One-to-one mapping of ELEX 7720 learning sub-outcomes and indicators of use of engineering tools

Learning Outcome
11. Develop facility with tools including Labview, MATLAB, and Simulink for use in process modeling,

controller design, and simulation and analysis.	
Learning Sub-Outcome	Indicators of Use of Engineering Tools
11.1 The student can combine tools including Labview, MATLAB, and Simulink to take maximum advantage of their use in process modeling, controller design and implementation, and simulation and analysis.	5.2.1 Identify the strengths and limitations of tools for (i) acquiring information, (ii) modeling and simulating, (iii) Monitoring system performance, and (iv) creating engineering designs.
11.2 The student can use Simulink to construct a simulation of a non-linear dynamical system	5.2.2 Demonstrate proficiency in using discipline specific tools
11.3 The student can select the appropriate numerical integration technique to minimize Simulink numerical errors	5.3.2 Verify the credibility of results from tool use; appreciate the accuracy and limitations, and the assumptions inherent in their use.

It turns out that for ELEX 7720, graduate attributes 1 to 5 can be connected one-to-one with the learning (sub)-outcomes defined for this course.

Graduate attributes '6: Individual and Team work' and '7: Communication' do not fit into this framework. The instructor did not have a stated learning objective that could be mapped to an indicator of the graduate attribute. Rather, development of attainment of these attributes is embedded in expectations of formal laboratory reports and oral presentations, and requirement for participation in team project work. In other words, the learning associated with these attributes is woven into the course. Development of these attributes often occurs as a result of *how* the course is delivered: the method, the mode, the model.

We have come to understand that there is a relationship between learning outcomes and indicators of graduate attributes, but they are not synonymous. The graduate attributes provide a comprehensive statement of competency, and are both explicit and implicit expectations in course work. Course learning outcomes are highly specific to course content and always explicit, measurable statements of expectation and competency.

5. GRADUATE ATTRIBUTE INFORMATION FROM LEARNING OUTCOME ASSESSMENT

Where there is a one-to-one relationship between learning outcome (or sub-outcome) and indicator, it is possible to use existing assessments to gather direct evidence of competency. However, if there is no one-to-one relationship between learning outcome and indicator, as is the case for most of the subjective attributes, an assessment tool must be developed to ensure an “apples-to-apples” comparison. A rubric tool where each line of the rubric represents an indicator is a perfect assessment tool for this purpose.

The following is a case study from Civil Engineering CIVL 7090 – Capstone Design Project, demonstrating the use of indicators as a bridge between learning outcomes and graduate attributes. The result is an assessment tool developed for a particular outcome that can be used to collect direct evidence of graduate attribute mastery.

In order to progress in our understanding of the relationship between learning outcomes and indicators of graduate attributes, Civil Engineering faculty members were asked to complete a matrix for each of their courses. In the left column is a list of learning outcomes. The twelve columns on the right represent the twelve graduate attributes. Faculty members were asked to indicate if each learning outcome related to each of the twelve attributes. As shown in Table 6, CIVL 7090, maps its learning outcomes as shown, resulting in formation of a one-to-many relationship between learning outcomes and graduate attributes.

Table 6: CIVL 7090 – Capstone Design Learning Outcome to Graduate Attribute Mapping

CIVL 7090 Course Learning Outcomes	CEAB Graduate Attributes											
	1	2	3	4	5	6	7	8	9	10	11	12
Design a civil engineering project from conception through to a completed plan.	X	X	X	X	X	X	X	X	X	X	X	X
Integrate information, ideas and concepts from previous courses into a comprehensive design effort.	X	X	X	X	X	X	X		X		X	X
Apply civil engineering concepts to real-world engineering practice.	X	X	X	X			X	X	X	X	X	X
Critically assess engineering decisions	X	X	X	X				X	X	X	X	X

with respect to economic implications and environmental and societal impact.												
Work collaboratively as part of a team to complete a project according to pre-determined specifications.	X					X	X	X		X	X	X
Produce a list of references that demonstrate library and internet searches to find specific engineering information.	X	X	X	X	X							X
Write an engineering report to industry standards.	X				X	X	X	X	X	X	X	X
Make formal oral presentations summarizing individual design work.							X	X	X	X		X

In order to manage this one-to-many relationship, the faculty member developed an assessment tool for a single learning outcome with the capability of measuring mastery for several attributes. For example, CIVL 7090 has eight defined learning outcomes, one of which is “Write an engineering report to industry standards”. This learning outcome has association with nine graduate attributes. In the rubric associated with the marking of the final report for the Capstone project, data for seven of the nine graduate attributes are assessed using nineteen indicators of graduate attributes, a portion of which is shown in Table 7. A separate sheet contained descriptors of the five levels of mastery for each project component.

Table 7: CIVL 7090 Capstone Design Project Report Marking Rubric

COMPONENT	LEVEL:	Level of Mastery					Grad Attrib Indicator Ref. #
		Below Expectations	Developing	Competent	Proficient	Exceeds Expectations	
		1	2	3	4	5	
Report Appearance: General appearance, Title page, Table of Contents, disclaimer							
Executive Summary							7.1.2
Writing Skill: organization, spelling, grammar,							7.1.2

clarity, conciseness						
Visual aids: figures, tables						7.3.1
References: correct referencing of information						
Project Description: background, objectives, constraints						7.1.2
Design Problem Definition						4.1.1
Civil Engineering Knowledge Base: Application of Civil Engineering laws and principles						1.4.1
Engineering Resources: Locating and applying library, internet, and software resources						5.2.2
Lifelong Learning: source and comprehend technical literature						12.3.1

The relationship between learning outcomes, indicators, and graduate attributes is complex. Indicators are required to build a normalizing bridge between outcomes and attributes. In other words, indicators provide a rational relationship between the program learning outcomes and the graduate attributes, especially for subjective expectations of learning where there is not an obvious one-to-one relationship between an outcome and an attribute.

6. MOVING FORWARD

The twelve graduate attributes provide an excellent framework to ensure program quality. A clear understanding of the equilibrium-like relationship between learning outcomes and graduate attributes allows faculty members to (a) ensure a direct line of sight between course-based learning outcomes and attributes, and (b) an opportunity to reflect on gaps in the list of indicators.

The graduate attribute project provides an opportunity to revisit learning outcomes to ensure they align with the industry-valued graduate attributes. Over time, direct evidence of learning, modification of assessment tools, and edited lists of indicators will help ensure all stakeholders keep program quality front of mind.

Initially, the graduate attributes project leadership group anticipates an overlap of learning outcomes and indicators of graduate attributes, shown in Figure 1, that allows for some outlying outcomes. We will be challenged to consider whether these learning outcomes are relevant. For example, application of the rubric for CIVIL 7090 led to the realization that there was no indicator (providing linkage to graduate attributes) for one line in the rubric that the instructor deemed important to assess. If the learning outcome is deemed relevant, we will be motivated to modify our indicators to ensure we include what's important.

Fig. 1: Current Learning Outcome to Graduate Attribute Mapping

As the graduate attributes project progresses, we anticipate an alignment between learning outcomes and graduate attributes represented by a set of circles where the learning outcome set is completely enclosed by the graduate attributes but not perfectly superimposed, as shown in Figure 2. The gap where there are no learning outcomes, but still graduate attribute development and assessment required, will prompt the need for assessment tools, such as the rubric for CIVIL 7090.

Fig. 2: Learning Outcome to Graduate Attribute Mapping

Over time, as the data analysis guides program review, we expect that explicit learning outcomes will be written to cover previous gaps, eventually resulting in a two perfectly superimposed circles, Figure 3.

Fig. 3: Learning Outcome to Graduate Attribute Mapping

En route to two perfectly aligned circles, the process will be iterative and organic. This prompts a review of the relevant indicators and the cyclical process of program improvement continues.

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