The Process of Continual Improvement of Engineering Programs at the University of Manitoba: Now and Next

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Abstract- *This paper describes the process that has been implemented for continual improvement of the Engineering programs at the University of Manitoba. The continuous improvement process developed is founded on: (i) assessment of graduate attributes, (ii) evaluation of student success, and (iii) further improvement of the programs. Graduate attributes are assessed both directly and indirectly. The direct assessment of attributes is through course-embedded procedures, while the indirect assessment is through compilation of many activities at both the Program, Department and Faculty levels, as well as via effective feedback from the students and the external engineering community. Together these assessments provide important information for the newly-established Curriculum Management Committee (CMC) to identify/prioritize needs, make recommendations and oversee the implementation of improvements. We describe steps taken to ensure a sustainable continuous program improvement process.*

Keywords: *Faculty-wide curriculum; graduate attributes; curriculum assessment; curriculum improvement.*

1. INTRODUCTION

In July 2010, a *Curriculum Management Committee* (CMC) was set up to study and establish an implementable process, acceptable to all Departments involved in the education of our Engineering students, aimed at ensuring that the curricula of the BSc (Engineering) programs improves continuously. The committee consisted of Heads of four Engineering Departments, Associate Heads responsible for five Engineering programs, and the Associate Dean, Undergraduate Programs. The committee met more than thirty-five times and consulted with University Teaching Services, as well as the Faculties of Education and Pharmacy at the University of Manitoba who have similar interests in attribute-based teaching and learning. This committee has developed a faculty-wide continuous improvement process for the BSc (Engineering) programs. Moreover, the committee has proven very

effective in forming an inclusive community in which all academics and staff, involved in educating our Engineering students, are equally aware of the needs and are able to share the responsibility of improving the curriculum on a continuous basis. This structure is also independent of personnel changes in the educational units.

This continuous improvement process is built upon the belief that the evolution of any curriculum involves changes at many different levels, and the impact of these changes is often not obvious until long after the course is over, and when there is a need to reuse/recall fundamentals/information to solve a problem in a subsequent course, or at the job site. Therefore, the continuous improvement process adopted at the University of Manitoba provides a rigorous assessment of curricula changes through numerous feedback mechanisms over an extended period of time.

2. DIRECT ASSESSMENT OF ATTRIBUTES

The direct assessment (course-embedded) of the attributes is at the course level, coordinated by the corresponding departments. In addition to quantifying student learning, direct assessment also involves modification of the mapping of course content to attributes to better reflect the true contribution of each learning outcome to attaining each attribute, establishment of effective indicators and assessment tools for measuring competency levels associated with attributes, and examination of different assessments in reflecting performances of similar outcomes. Fundamental questions related to the direct assessment data are to determine: (i) how much does each attribute need to be assessed, (ii) how well these assessments measure what students are supposed to be learning, and (iii) do the assessments show the extent to which student learning exceeds, meets, or falls below the desired level of knowledge for each attribute. The chart shown in Fig. 1 summarizes the steps developed by the CMC.

Fig. 1 Direct assessments of attributes.

2.1 Curriculum Mapping

Course-based curriculum mapping have been completed for all Engineering and non-Engineering courses. The resulting maps allowed us to connect the content of each course to attributes and expected competency levels. This curriculum mapping was undertaken through the participation of all academics, during which many workshops, organized by both the Faculty and the Departments, presented relevant information associated with the attributes, outcomes and curriculum mapping. As a result each of the courses taught to Engineering students now has an attribute sheet assigned to it (see sample attribute sheet shown in Fig. 2). At the present time, the expected competency levels are based on Bloom's Taxonomy of Knowledge [1] to [4]. The attribute sheets allow determination of the extent to which each student is exposed to an attribute during the course of her/his degree. Figure 3 shows a typical chart that shows the number of courses in which attributes are

introduced at all levels in a program. This information has been extremely helpful in facilitating the choice of the individual courses that need to be more closely evaluated as part of the Continuous Improvement Process.

Learning Outcome	Attribute			
	A 1	A 2	A 3	A4
Explain relationship between composition, structure, properties of biological materials	Comprehension			..
Use mathematical relationships to analyze the relationships between parameters		Analysis		..
Analyze and interpret data in relation to properties of materials			Evaluation	..
..	..	..	..	..

Fig. 2 Typical attribute mapping the learning outcome to Bloom's competency levels.

Fig. 3 Typical chart showing number of courses per attribute addressed each year.

2.2 Establishing the Indicators for Assessments

For each attribute, associated focus areas and corresponding example learning indicators are defined [5]. As many indicators as possible are defined, allowing each instructor to decide which indicator(s) to use for evaluation of attributes to which the students are exposed in the course. Appropriate rubrics to allow quantitative evaluation of the indicator are essential and are being developed as we move on.

2.3 Measure Competency Levels and Develop Expectations

The commonly used two-cycle six-year plan to complete reviews and evaluation of all attributes has been implemented. Each year four attributes are assessed for seven courses that span all levels: one 1st year course and two 2nd, 3rd, and 4th year courses per program. The Program Curriculum Committee, working with the course instructors, will also determine the competency target for each indicator, and may suggest appropriate indicators and assessment tools, while revising the course mapping of learning outcomes to attributes [5].

Direct assessment of the graduate attributes has proven to be more challenging than indirect assessment. For example, in the Biosystems Engineering program the plan is to focus on the collection of evidence of student performance through the use of detailed grading rubrics developed for targeted assignments in selected courses. Each grading rubric is to clearly differentiate expectations related to indicators for each graduate attribute. Since the expected levels of competency for each indicator has not been established yet, it was not feasible to ask individual instructors to prepare detailed grading rubrics at this time.

As a preliminary step, however, an alternative strategy has been employed to collect direct evidence of student performance. Instructors have been asked to decompose their assigned course grades into individual assessments points that are correlated with the graduate attributes (see Table 1). This approach allows class performance to be reported on all attributes assessed in each course. It is anticipated that this process might detect discrepancies between what is stated in the learning outcomes for the course and what is actually being assessed in the course. This approach will yield a wealth of direct evidence of student performance correlated with the graduate attributes with minimal burden on the instructor.

On the subject of establishing acceptable competencies, the Department of Mechanical Engineering has been working toward the use of surveys that have been developed based on the structured indicator list previously developed by the Faculty. Four parallel surveys have been developed for: a) students at the time of graduation; b) instructors; c) administrators; and d) industry stakeholders. Two surveys have been administered thus far; one for students and one for instructors. Preliminary analysis of the results has indicated some areas of improvement, as well as some inherent difficulties with developing and administering meaningful surveys.

Table 1: Example spreadsheet showing graduate attributes assigned to each assessment point in a course.

	Assignment 1	Assignment 2	Design Project	Final Exam	Final Exam
	Attribute 2	Attribute 3	Attribute 4	Attribute 1	Attribute 2
Student 1					
.....					
Total	10	15	35	20	20
Class Average	7.8	12.5	27	18	14
Percentage	78	83	77	90	70

3. INDIRECT ASSESSMENT OF ATTRIBUTES

Indirect assessment of attributes refers to all assessment processes that do not originate from courses. Assessment methods include student surveys, industry/alumni surveys, and co-op surveys. Indirect assessment is completed in parallel with, and complements direct assessment; the frequency of the indirect assessments is process-specific dependent. Figure 4 shows the structure of the groups.

3.1 Industry-Oriented Assessment (Stakeholders Experience)

Co-op Survey - The employee of each student who completes a co-op work term or internship receives a survey to provide feedback about the student's performance. The questionnaire has been designed to represent the aspects of performance described by the twelve Graduate Attributes. This evaluation reveals how our co-op students score on questions regarding attributes.

Industry/Alumni Group Forum - In collaboration with the IEEE Chapter of Education, Management, and Communication, the Faculty of Engineering, University of Manitoba, introduced a new initiative, called *Industry/Alumni Group (IAG) Forum*, aimed at bringing industry and academia together on common ground in a *forum* environment to discuss what industry values and expects from new engineering graduates who work within it. The Industry Forum is a feedback approach to the assessment of new engineering graduates, and it is believed to be the first of its kind in Canada. The objective is to provide a central and impartial venue for industry stakeholders to convey their opinions in regards to what they believe are the strengths and weaknesses of

new engineering graduates at the time they enter the work force. The Industry Forum gives industry the opportunity to also express their opinions and to exercise their fiduciary responsibilities, as they are the primary beneficiaries of the programs in Faculty of Engineering. Their input is intended to help set the course for the future development of engineering graduates, their future employees. Furthermore, it will give industry the opportunity to give back, and to lend their experience to developing better understanding of our industry and what it values and expects from those who work within it. Two forums have been held so far. The forums have produced strengths and weaknesses of new graduates, and placed these in the context of the CEAB attributes.

Fig. 4 Indirect assessments of attributes.

Future IAG Forums will be held one or two times per year, as required. An industry representative will be appointed to become a leader for his/her discipline – an industry discipline specific focus sub-group (INSPEC focus group). The leader will manage and coordinate the IFG members and arrange for possibly discipline specific

meetings to gather and coordinate common ideas, so that their discipline can be better organized for upcoming IAG Forums. Furthermore, the Leader could be the liaison between the Faculty and the IAG. As the liaison, the leader would also follow up with faculty members to inspect the Faculty's plans and response to industry's concerns regarding the strengths and weaknesses of new graduates.

3.2 Student-Oriented Assessment (University Experience)

Exit Interview - The exit survey was developed using the list of learning objectives. For each of the example skills and abilities boxes were added so that survey respondents could select one of the three options: (i) skill/ability was not developed; (ii) skill/ability was developed but not sufficient enough to be mastered; (iii) skill/ability was covered in sufficient depth that it could be mastered. At the end of the survey, respondents are also asked to identify the three strongest and three weakest attribute areas in their Engineering program.

Student Evaluation of Course Attributes - The majority of students complete Students' Evaluation of Educational Quality (SEEQ) evaluations at the conclusion of each course. Thus, this evaluation can be viewed as a vehicle to obtain additional information regarding student perception of performance related to the specific learning outcomes that were prepared for each Engineering course by the instructors. Supplemental SEEQ questions were added to the standard SEEQ evaluation provided by the university administration. These supplemental questions include stated learning outcomes for the course in question, with students asked to indicate the competency level (from Bloom's Taxonomy) that they feel they have achieved from the course. Each instructor had been previously asked to indicate the expected level of competency for each of the learning outcomes in the course as summarized on the course attribute sheet. The information generated allows instructors to determine whether they have chosen the correct expected competency for each of the learning outcomes for their course. This approach was piloted by the Department of Biosystems Engineering in the Fall 2011 term for eight courses. It is now being adopted by all other programs.

Student-Run Curriculum Forum - A *Student-Run Curriculum (SRC) Forum* was established in 2010 to (i) expose our students to the graduate attributes and (ii) to provide a forum to influence the curriculum development through direct input from the students. The SRC Forum aims at engaging the students in the curriculum formation directly. While means of collecting data based on student performance, course evaluations, and professor assessments are established, the student forum provides a better gauging of the collective effect of changes on students' education before they complete their program

and graduate. The SRC forum also serves to educate students about the new graduate attributes and outcomes. This forum has been running for over two years in the Department of Electrical and Computer Engineering and is now being adopted in other programs as well.

4. EVALUATION OF SUCCESS AND IMPROVEMENT PROCESS

The evaluation of the success of our programs and subsequent improvements is the responsibility of the newly-established Curriculum Management Committee (CMC). The manner in which the CMC functions is shown in Figure 6.

Fig. 5 Continuous Curriculum Improvement Process.

The role of the CMC is to evaluate all the available information and then identify and prioritize areas that are in need of improvement. Recommendations to modify and re-shape the curriculum are forwarded to the appropriate committees. Communications between the CMC and the committees and all follow-ups are overseen by the newly appointed *Curriculum Improvement Coordinator (CIC)*. It is clear that while the CMC operates at the Faculty level, curriculum changes are implemented at the program level.

The Curriculum Management Committee is chaired by the Associate Dean, Undergraduate Programs. The members of the Committee are: five chairs of the Engineering program curriculum committees, Director of the University Teaching Services, Chair of the Faculty of Engineering Academic Regulation and Curriculum Committee, an expert from the Faculty of Education with knowledge in assessment and evaluation of educational outcomes and quantitative methods, and the CIC. The coordinator communicates with all committees, collects information from direct and indirect assessments, conducts analyses to correlate results and summarizes the findings to be presented to the CMC. In addition, the coordinator communicates the recommendations to the corresponding Department Heads, assures that follow-up action items are implemented, and reports back to the committee on outcomes. The recommendations on any improvement are developed collectively and in consultation with the programs involved through their representatives on the committee (chairs of the corresponding program's curriculum committees).

5. MOVING FORWARD

One significance of the proposed process is that the curriculum changes are intended to be done by simultaneously considering the direct attribute assessment in conjunction with other evaluation methods, including but not limited to indirect assessments methods as outlined earlier. For example, as a result of the co-op survey, it has become evident that our students could benefit by being exposed more to technical communication skills. As a result, an advisory board has been established to oversee the creation of a textbook on Engineering communication for students in their final-year capstone design projects. This text will be applicable across Engineering Departments and will enable students to bridge the gap between being a student and a professional engineer more effectively.

We have also begun to include other methods to the existing list of indirect methods of attribute assessments such as outcome of student participation in extra-curricular activities, participation in national/standard/international tests/competitions,

graduate school entries, job placement statistics, and completion time. Another initiative that is being considered, is the development of an online system that allows students to visually track the mapping of course and program contents to attributes, expected competency levels, and their progress throughout the entire program. This initiative is under way in collaboration with the University Teaching Services (UTS). With the recent implementation of an enterprise LMS, UTS now has the capability to take this to the next level; namely, real-time student progress-to-competency mapping. This will provide student and faculty with the ability to monitor progress and enhance formative feedback for learning.

In 2010, another major initiative started at the University of Manitoba: experiential learning through hands-on design, implementation, verification and testing of a complex project [6]. The project involved the design and development of a triple pico-satellite ($10 \times 10 \times 34$ cm in size, and below 4 kg in mass) by over 100 undergraduate and graduate students from 16 Engineering and non-Engineering Departments and five Faculties, supported by over 50 advisors from aerospace industries, business, military, government, and other organizations. The project is now in the second phase. Such complex projects provide students with unprecedented experience not only in the hard Engineering skills, but also in soft skills.

Focus is also placed on revising mapping of learning outcomes to attributes, selection of assessment tools, and reflection on assessments. More specifically, a study is currently being carried out, investigating how attributes manifest in the engineering curriculum, reflecting on how they are measured and, exploring the extent to which the measurable attributes result in course content proficiency.

The success of the continuous improvement process depends on the inclusive approach and involvement of the entire Faculty, including technical and support staff. For this reason, we have set up the process in such a manner that close to 50% of our faculty are involved, one way or another, in the process each year.

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