Supporting teaching practice, program improvement, and accreditation efforts in an engineering program

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ABSTRACT

This paper emphasizes the essential role of a support person for faculty teaching and assessing the Canadian Engineering Accreditation Board (CEAB) graduate attributes as part of an ongoing accreditation cycle. It details the continuous program improvement process adopted by the Department of Biosystems Engineering at the University of Manitoba, and the role of engineering stakeholders. It recounts a study that details the supportive efforts of a Research Associate who helped to validate and implement rubrics with individual professors as outcomes-based tools for teaching and assessing the 12 CEAB graduate attributes, which resulted in the creation of 14 rubrics for 12 courses. Findings included new pedagogical understandings, the appreciation of individual support from the Research Associate, and the continued use of rubrics; the work led most professors to think deeply and in new ways about teaching and assessment. There was evidence that six professors engaged in 'reverse design', developing rubrics with targeted learning outcomes and course materials in mind. The work led to critical improvement in teaching practices and evidence of continual program improvement. Despite overall engagement and success, some professors continued to struggle with the concept and use of rubrics. In sum, this experience emphasizes the benefit of a dedicated person to support professors to implement rubrics, and in creating and sustaining an outcomes-based assessment culture in the department.

RÉSUMÉ

Cet article souligne le rôle essentiel d'une personne de soutien pour les professeurs qui enseignent et évaluent les attributs des diplômés du Bureau canadien d'accréditation des programmes d'ingénierie (BCAPI) dans le cadre d'un cycle d'accréditation continu. Il détaille le processus d'amélioration continue des programmes adopté par le Département de génie des biosystèmes de l'Université du Manitoba, ainsi que le rôle des parties prenantes en génie. Il relate une étude qui décrit les efforts de soutien d'un associé de recherche qui a aidé à valider et à mettre en œuvre des rubriques avec des professeurs individuels. Ces travaux sur des outils axés sur les résultats pour l'enseignement et l'évaluation des 12 attributs des diplômés du BCAPI ont abouti à la création de 14 rubriques pour 12 cours. Les résultats comprennent de nouvelles connaissances pédagogiques, la reconnaissance du soutien individuel de l'associé de recherche et l'utilisation continue des rubriques. Ce travail a amené la plupart des professeurs à réfléchir en profondeur et à de nouvelles méthodes d'enseignement et d'évaluation. Il a été observé que six professeurs se sont engagés dans un processus de « conception inversée », en développant des rubriques visant des résultats d'apprentissage et du matériel de cours ciblés. Ce travail a conduit à une amélioration critique des pratiques d'enseignement et a démontré une amélioration continue du programme. Malgré l'engagement et le succès général, certains professeurs ont continué à éprouver des difficultés avec le concept et l'utilisation des rubriques. En somme, cette expérience souligne le bienfait lié à la présence dans le département d'une personne de soutien dévouée pour aider les professeurs à mettre en œuvre les rubriques, et pour créer et maintenir une culture d'évaluation fondée sur les résultats.

KEYWORDS

Rubrics, outcomes-based assessment, CEAB graduate attributes, accreditation, program improvement, validity, teaching support

MOTS CLÉS

Rubriques, évaluation fondée sur les résultats, attributs des diplômés du BCAPI, accréditation, amélioration des programmes, validité, soutien à l'enseignement
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INTRODUCTION

Maintaining accreditation of an engineering program is essential to the viability of an engineering department and faculty (Davis et al. 2002). Although the accreditation system in Canada functions on a six-year cycle (assuming the best-case scenario), it would be foolish to neglect proper preparation. Given the latest requirements of the Canadian Engineering Accreditation Board (CEAB) to assess student competency for 12 graduate attributes and ensure continual program improvement informed by graduate attribute assessment collection, the task is complex (e.g., Driscoll and Wood 2007; Miller and Linn 2000; McGourty et al. 1998; Prados et al. 2005). Processes for gathering and interpreting graduate attribute data must be in place – and functioning continuously (e.g., Felder and Brent 2003; Frank et al., 2011; Frank and Fostaty Young 2011; McCahan et al. 2011; Rogers 2000; Soundarajin 2002; Wolf and Stiver 2011).

The CEAB has not mandated specifications for collecting graduate attribute data or for an effective continual improvement process. Each engineering department or faculty requesting accreditation has the flexibility to develop its own process to suit the unique characteristics or context of that institution. This paper will give an overview of the continual improvement process that has been implemented by the Department of Biosystems Engineering at the University of Manitoba. Specifically, we will emphasize one lesson learned that enabled us to be prepared for an accreditation visit: the essential role of a Graduate Attribute (GA) Support person for one-on-one interaction with instructional faculty working to teach and assess the CEAB graduate attributes. This led to a critical improvement in teaching practices, and evidence of continual program improvement. Other institutions may find parts of what is covered here useful to inform changes in their own programs.

THE CONTINUAL IMPROVEMENT PROCESS

Formal Structure of Continual Improvement Process

The faculty Curriculum Management Committee created a flow diagram (Fig. 1) to depict the continuous improvement process that is in place within the Price Faculty of Engineering at the University of Manitoba. The Department of Biosystems Engineering has adopted the process represented in this diagram to ensure that program improvement is central to our decision-making.

Figure 1 depicts an overall circular process that involves the sharing of information at various levels. Faculty members represent the front-line workers in this continual improvement process as they are the individuals responsible for teaching and assessing the 12 CEAB graduate attributes at the course level. From the *instructional level*, graduate attribute data flows to the *departmental level* where analysis and interpretation of the graduate attribute data is completed largely through the mechanism of the existing department Curriculum Committee. The department Curriculum Committee is the conduit to the faculty-wide curriculum committee and oversees all course or program changes and reviews. The enhanced curriculum is then available to the individual faculty members back at the *instructional level*. There are two additional individuals identified in Fig. 1 – a GA (graduate attribute) Support person at the *instructional level* and a Program Lead at the *departmental level*. In this model, the GA Support person is envisioned to work with

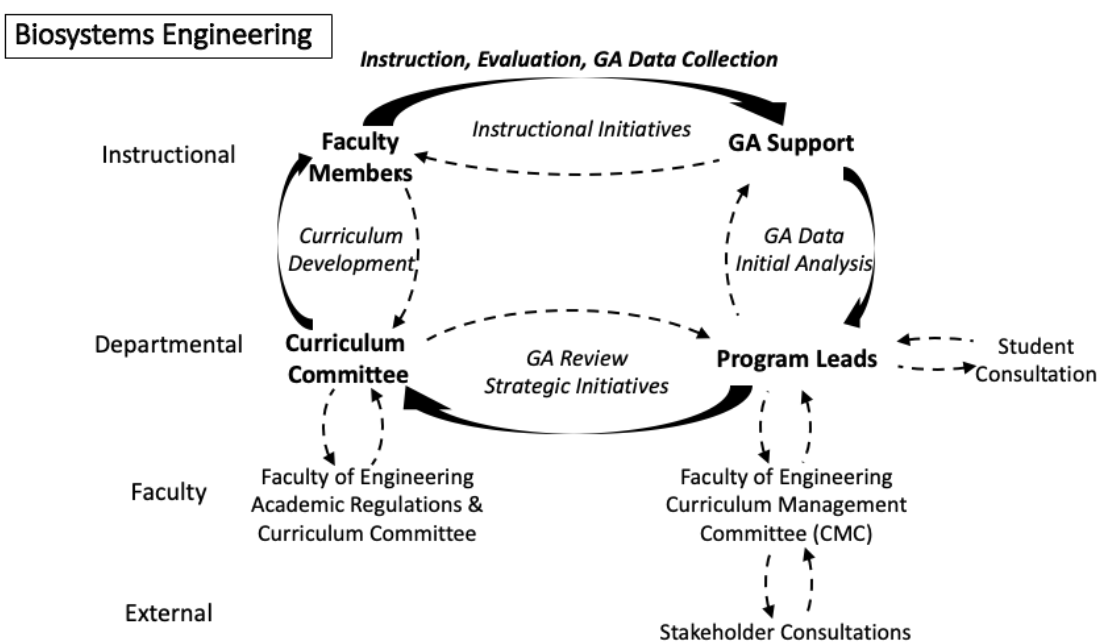

Fig. 1. Continual improvement process adopted by the Department of Biosystems Engineering.

individual faculty members to ensure appropriate graduate attribute data are being collected. The Program Lead serves several functions. The Program Lead is i) a conduit for student consultation, ii) a member of the faculty-wide Curriculum Management Committee (which subsequently manages external stakeholder consultations), and iii) responsible for sharing strategic initiatives with the department's Curriculum Committee.

Stakeholder Engagement

As Fig. 1 depicts, there are several distinct stakeholders involved in the decision-making for program improvement. The members of the Biosystems Curriculum Committee ultimately make decisions regarding course and program improvement, but the decisions are informed by input from the instructional staff, undergraduate students within the Biosystems Engineering program, and several stakeholders from outside the University of Manitoba (i.e., employers of Co-op students, industry stakeholders, alumni of the program). The consultation process differs depending upon the stakeholder; specific details are provided below.

Instructional Staff Although there is no formal mechanism in place for seeking input from instructional staff, there are opportunities throughout the academic year for staff members to discuss teaching issues. As part of the annual performance review process, all academic members of the Department of Biosystems Engineering prepare an 'annual activity report' that includes a section on teaching and meet with the Department Head to discuss. This process often yields insights into teaching initiatives that were tried over the previous year and, in some instances, suggestions for course or program changes. Because the Department Head is a member of the Biosystems Curriculum Committee, relevant information gleaned from instructional staff via the annual activity reporting cycle can flow to the Curriculum Committee to contribute to decision-making. Additionally, teaching and assessing concerns or initiatives can be brought forward at monthly department council meetings.

Undergraduate Students There are several formal mechanisms that have been established to enable undergraduate students to contribute to decision-making for program improvement. There is an informal event known as 'Biosystems Lunch'n Learn' that is organized once each academic term by the University of Manitoba Engineering Society (UMES) (see Sepehri et al. 2013). Biosystems Engineering students are provided with a venue to express concerns directly to the Department Head and Associate Head. Although the Lunch'N Learn event often yields insightful feedback regarding the program (or specific courses), the turnout is frequently low, and therefore, not representative of the entire student population in the Biosystems Engineering program. This may be due to students not feeling comfortable with expressing concerns directly to faculty in positions of power. For this reason, another formal mechanism has been implemented. Biosystems Engineering students are required to complete an exit survey as part of a fourth-year course and responses are anonymous; this provides an opportunity for students to reflect on the coverage of the graduate attributes across the entire program (see Seniuk Cicek et al. 2013). The exit survey gives students an opportunity to indicate the level of instruction received and the level of competence attained for each graduate attribute. It is a subjective self-assessment but provides useful feedback from students' perceptions. For example, via the exit survey (as well as other data), it became apparent that more emphasis was needed on the impact of engineering on society and the environment (graduate attribute #9). Subsequently, a second-year core course on engineering impact was added to the program.

Employers of Co-op Students There is a co-operative education program available to all engineering students at the University of Manitoba (see Peto & Geddert 2014). To assess the effectiveness of the Co-op program, a survey was developed by Co-op staff that is completed by employers at the end of the Co-op work term. The Co-op survey enables us to gather feedback on a subset of our student population (i.e., those who decide to apply to the Co-op program and who are successful in securing a placement) from an external stakeholder who can assess the capabilities of the student in an engineering work environment. Results of this survey are made available to each department via the faculty Curriculum Management Committee (see Sepehri et al. 2013).

Industry Stakeholders There were seven industry forums hosted by the Price Faculty of Engineering and the Friends of Engineering between 2011 and 2017 (see Ferens et al. 2014). (*Note:* The Friends of Engineering is 'a group of engineering industry leaders who share the Price Faculty of Engineering's commitment to excellence in engineering education' (Price Faculty of Engineering 2020).) These forums were intended to bring industry and academia together to discuss industry expectations of engineering graduates. Perceived strengths and weaknesses of graduates are discussed within the context of the CEAB graduate attributes (e.g., Ferens and Kinsner 2011).

Engineering Alumni As discussed, feedback via the exit survey is obtained from students as they approach completion of their engineering program (Seniuk Cicek et al. 2013). Although the exit survey is intended to provide an overview of students' perceptions of the entire program, it is administered at a time when these students have not yet entered the workplace. Considering that students' perceptions of learning may change from when they were about to graduate to afterward, when they become engaged in the practice of engineering, an alumni survey was created. It is administered through Engineers Geoscientists Manitoba. Survey participants are asked questions related to three of the 12 graduate attributes, selected randomly, and to indicate the level they feel they have attained for these three graduate attributes at the time of their graduation. The survey was developed by the Lead and Coordinator of the Price Faculty of Engineering Curriculum Management Committee (CMC) and is based on the Price Faculty of Engineering Graduate Attribute Rubrics (see *The Role of Rubrics in the Continual Improvement Process* below). Results are made available to each department via the faculty CMC.

Reflecting on the Continual Improvement Process

When the Department of Biosystems Engineering first began to consider how graduate attribute data would be gathered (dating back to the beginning of the 2010's), the formal model depicted in Fig. 1 had not yet been envisioned. Nevertheless, in looking back, this model does a reasonable job of describing the actions that were being undertaken and the flow of information.

There is one critical observation, however, that warrants further discussion. In terms of function, the Department Head was essentially filling the roles of both GA Support person and Program Lead as depicted in the model. There were numerous discussions about graduate attributes and how they should be assessed at the course level. These discussions sometimes took place at department retreats, at workshops focused specifically on graduate attributes, or at formal department council meetings. However, discussions were always organized in a group setting and were always led by the Department Head. During these early days, it was a struggle to fully engage the front-line workers at the *instructional level* (i.e., the faculty members). Some were annoyed that CEAB would be asking for the collection of graduate attribute data. Some were willing to embark on this new challenge but were unsure how to achieve the goal. Some were willing to fill out forms if told exactly what information was required. Some genuinely tried to think philosophically about graduate attributes – and it often led to more questions than answers. The Department Head had only marginally better knowledge of how to assess these graduate attribute outcomes. We were at the bottom of the learning curve – with a lot of work ahead of us.

At that stage, funding was received from the University of Manitoba's Teaching and Learning Enhancement Fund for a project to implement and validate graduate attribute rubrics in the Biosystems Engineering curriculum. One of the authors of this paper, at the time a PhD student with expertise in educational pedagogy, was employed as a Research Associate to assist professors with the task of developing evaluation rubrics to assess student performance with respect to specific graduate attributes in their core engineering courses. Although it was originally planned that the Research Associate would work with teams of professors, we quickly observed that professors preferred one-on-one assistance from the pedagogy expert. Referring to our continual improvement model depicted in Fig. 1, this Research Associate was filling the role of GA Support person. She brought expertise to the position that the Department Head did not possess. The remainder of the paper is dedicated to describing the lessons that were learned through this study and how the efforts of our Research Associate guided our preparations for the eventual accreditation submission and visit. This work was first reported in Seniuk Cicek, Mann et al. (2017).

THE ROLE OF RUBRICS IN THE CONTINUAL IMPROVEMENT PROCESS

A rubric is a qualitative (Jonsson and Svingby 2007), criterion-based tool (Biggs 2013), designed to describe a student's level of performance. It can be used by students as a guide to clarify expected learning outcomes, and by instructors to assess targeted learning outcomes in an efficient and fair manner (Allen and Knight 2009; Almarshoud 2011). With the global advent of engineering competencies in the 21st century (e.g., the ABET learning outcomes in the U.S., the International Engineering Alliance graduate attributes and professional competencies (IEA 2013), and the 12 CEAB graduate attributes in Canada) and accreditation demands for outcomes-based assessment, rubrics became a mechanism to define competencies, develop measurable indicators, and set expected performance levels that can be assessed more objectively. Specifically, discussion and development of outcomes-based assessment tools to measure engineering competencies were prolific in the U.S. (e.g., Hanson and Williams 2008; Jiusto and Di Biasio 2006; Jonassen et al. 2009; Olds et al. 2005; Roselli and Brophy 2006; Shuman et al. 2005; Siri Johnson 2006; Spurlin et al. 2008; Yavac et al. 2007; Zafft et al. 2009). The evolution of engineering accreditation requirements expanded the focus of teaching and learning from an inputs-based system to one of inputs and outcomes, which focus on the knowledge, skills, values, attitudes, and behaviours (Rogers 2000) students must demonstrate.

Constructive alignment, a term coined by John Biggs, is a student-centred approach that signifies that what the student is intended to learn (the *learning outcome*) and how that learning will take place to be identified and communicated *before* teaching occurs (Biggs 2013). A good way to do this is by identifying an action (defined by a verb), and then designing a learning activity that requires this action. Rubrics support constructive alignment as they describe the action required, and both the teacher and learner are cognizant of what is required to demonstrate the competency before the teaching and learning begins.

Between 2013 – 2014, members of the Price Faculty of Engineering developed a set of rubrics for the 12 CEAB graduate attributes (see Seniuk Cicek et al. 2014). They were based on the VALUE rubrics of the Association of American Colleges and Universities (AAC&U 2007) and supported by feedback from three stakeholder groups: i) between 20-30 Manitoba Industry members via online surveys and three in-person engineering Industry forums (see Ferens et al. 2014), ii) the Director of the Centre of the Advancement of Teaching and Learning, and iii) a professor from the Faculty of Education at the University of Manitoba. They were intended as a pedagogical assessment tool for both course and program levels and enabled the division of the graduate attributes into teachable and measurable learning foci and indicators; the definition of graduate attribute competency levels; and the development of a common language for engineering stakeholders (e.g., faculty, students, and industry) (Seniuk Cicek et al. 2014).

The Price Faculty of Engineering rubric committee validated the rubrics in several ways. First, we developed a list of indicators and respective performance levels for each attribute following the steps recommended by Gliner et al. (2009):

1. Define the concept that the investigator (instructor) is attempting to measure.
2. Conduct a literature review to see how this concept is represented in the literature.
3. Generate items that might measure this concept.
4. Reduce the list of items to form the test of measure.

Then, we determined content-related evidence by consulting a variety of faculty experts to determine whether the content of the rubric accurately described/demonstrated the intended concept being measured (Gliner et al. 2009). Consequently, the rubrics underwent multiple iterations to ensure that the content within each rubric was demonstrative of the intended concept to be measured, which is a measure of content-related validity.

The next step was to validate and implement the rubrics in our engineering programs. As such, the authors of this paper designed a study to validate and implement the rubrics in the Biosystems Engineering program.

METHODOLOGY

This study, devised to validate and implement the graduate attribute rubrics in the Biosystems Engineering curriculum, was originally designed using a team format and Delphi process (Allen & Knight 2009). However, it quickly became apparent that having the professors work individually with the Research Associate was more feasible, as well as more effective in achieving our study goals. Each professor had specific assessment needs for their individual courses that required the design of individualized rubrics, a process that lent itself to working one-on-one with the Research Associate. We obtained University of Manitoba ethics board approval. Ten professors in the department agreed to participate in the study to determine an acceptable level of content-related validity for one rubric, and to implement this rubric into their individual courses (see Seniuk Cicek, Mann et al. 2017). Faculty also completed pre and post surveys exploring their understanding of graduate attributes and rubrics.

We determined that an acceptable level of content-related validity (Gliner et al. 2009) would be reached when the professor and Research Associate agreed that the indicators chosen represented the specific graduate attribute(s) and the learning outcomes targeted in the course. The Research Associate and professor determined whether, for the specific course in question, these indicators effectively defined or 'unpacked' the graduate attribute. We discussed whether the verb prompts being used in the rubric indicators were representative of what students were doing when they demonstrated the outcome and reviewed/recalled students' performance assessments to reach consensus. Using Moskal and Leydens' (2000) questions to evaluate the content-related evidence, we asked:

1. Do the evaluation criteria address any extraneous content?
2. Do the evaluation criteria of the scoring rubric address all aspects of the intended content?
3. Is there any content addressed in the task that should be evaluated through the rubric, but is not?

Interactions between each professor and the Research Associate occurred in a preliminary meeting (1-1.5 h in duration), with iterations and the finalized rubric design confirmed via email.

RESULTS

In the end, 10 professors participated in this study, 14 individual rubrics were developed for 12 courses in the Biosystems Engineering program, and at least one rubric was developed for each of the 12 CEAB graduate attributes (see Appendix for an example of the rubrics developed for one biosystems course). Professors used indicators from more than one graduate attribute, designing rubrics to meet their individual assessment needs for their courses. Overall, six of the professors involved in the study appeared to gain new understandings and appreciation for the use of rubrics in the design and execution of program curricula, and ideally these new understandings will be applied in the future development and execution of program curricula. Eight professors used the newly designed rubrics in their courses in some capacity during the year of the study; only two professors did not confirm whether the rubrics were used. Eight professors stated that they would continue to use the rubrics the following year, either as developed, or re-designed, or in some cases, for the first time. In all cases, the use of the rubrics ranged from supporting learning outcomes, to marking students' work, to developing course curriculum.

Positive Outcomes

There were several positive outcomes that emerged from this study described through Bigg's (2013) 'constructive alignment' framework, and characterized as: *New Pedagogical Understandings, Appreciation of Individual Support*, and *Continued Use of Rubrics*.

(*1) New Pedagogical Understandings:* There was evidence of six professors coming to new pedagogical understandings, which can ultimately lead to improvements and best practices in teaching and assessing:

➢ *I am beginning to understand the necessity of preplanning a course using specific objectives in mind to achieve the demonstrable desired outcomes in the students' skillset.*

This comment was reflective of several comments made in the post survey that exemplified critical evidence of emerging understandings of best practice in assessment: specifically, the concept of designing course content, including teaching and assessment materials, with the learning outcomes in mind. This comment speaks to the importance of professors understanding the concept of reverse design in curriculum development to effectively teach and assess targeted competencies in students (Zmuda et al. 2007).

Additionally, there was evidence of professors making pedagogical improvements, such as how assignments were structured; how assignments were communicated to students; and the reevaluation of intended learning outcomes, course materials, teaching strategies, and assessment tools and processes to achieve the constructive alignment in their curriculum (Biggs 2013):

- *…the work associated with developing rubrics makes you think deeply about the purpose of the assignment. Thinking back on my teaching, I now recognize there are situations when I prepared a project or assignment without considering how it would be evaluated and exactly what I would be looking for in the assignment/project. When you develop a rubric, you must think about the evaluation up front. I believe the use of rubrics allows more consistency from year to year in terms of evaluating the desired course objectives.*

Six professors made statements reflective of the development of new pedagogical understandings, underscoring the importance of this study in the development of assessment tools facilitated by one-on-one interaction.

(*2) Appreciation of Individual Support:* There was evidence that professors appreciated the individual support in customizing and using the rubrics in their courses.

- *Yes, it was helpful in modify[ing] existing assignments to better meet course outcomes and CEAB indicators.* [The Research Associate] *gave specific examples of how to change my questions to match the indicators, which helped me see how to make the connection and where the link was missing.*

Ninety percent of the professors stated that time was an impediment to developing and using new assessment practices (such as rubrics) and expressed a desire for continued one-on-one support from a pedagogy expert.

(3) Continued Use of Rubrics: Some professors committed to the continued use of rubrics in their courses. This commitment appears to be divided between professors who were intrinsically motivated and confident that the use of rubrics supports best practice in assessment, and professors who appeared extrinsically motivated by other factors, such as accreditation demands and processes.

Challenges

There was evidence that although the rubrics were designed for their individual courses, not all the professors implemented the rubrics. There was indication that some professors struggled with the concept of rubrics and with using rubrics in their courses. These challenges were found in the amount of time perceived by professors as needed to create and use rubrics in their courses; the perception of inflated student marks; and in the structure of the rubric itself. Finally, there was no indication that professors were discussing assessment or the use of rubrics with other professors in the department outside of the work that was conducted between the researcher and individual professors.

DISCUSSION

Having the Research Associate work individually with professors to design rubrics for their specific assessment needs was very constructive because in addition to designing 14 individual rubrics for 12 courses, these discussions led many of the professors to think more deeply about teaching and assessing, and in many cases, to think about assessment in new ways. There was evidence that six of the professors engaged in a 'reverse design' approach, where the rubrics were developed with the targeted learning outcomes and course materials in mind, and course materials were revised to align with the learning outcomes and the rubrics. Although this seems like a logical way to approach designing assessment tools, several professors who engaged in reverse design during the study expressed surprise and satisfaction by the logic and ease of this process. The Research Associate's experience that this process requires a shift in the way educators think about assessment, was supported by previous findings (Seniuk Cicek, Friesen et al. 2017). Once the shift happens, developing curricular tools becomes easier, and the developed tools embody sound assessment practices that support student learning and lead to curricular alignment. In the end, the shift in perception is perhaps more important than the physical work with the rubrics; but it was through the Research Associate's facilitation of individual rubric design that this understanding was achieved. This change can be flagged as a critical improvement in teaching practices, and evidence of continual improvement in support of accreditation efforts.

There were also other findings that lended themselves to program improvement. One area that was flagged for improvement was the further development and use of rubrics for the CEAB graduate attribute, *Individual and Teamwork*. While all the 12 CEAB graduate attributes were targeted in Biosystems courses during this study, *Individual and Teamwork* was not as broadly represented. Only one indicator was assessed in one course using the rubrics during the 2015-2016 academic year, with plans for one other indicator being assessed in two courses during the 2016-2017 academic year. In both cases, the indicators were housed within rubrics that emphasized other graduate attributes. *Individual and Teamwork* is an attribute that has received much attention in engineering education research: working in teams is considered one of the most important competencies for new engineers as they enter the field (Hurst et al. 2016; Passow 2012). Although the skills and knowledge necessary to competently demonstrate this attribute are wholly required of students in the Biosystems curriculum, the attribute needs to be directly assessed more comprehensively.

Although rubrics were designed for individual courses, not all professors implemented them. Some professors continued to struggle with the concept and structure of rubrics and using them in their courses, despite the individual support. They perceived rubrics required excessive time in both creating and using them, and that rubrics inflated student marks. This emphasizes the need for a dedicated GA Support person to support professors in customizing, implementing, and using rubrics as over the longer term, creating and using a rubric can save time. Rubrics (1) help plan more efficient instruction, (2) help design more relevant assessments, and (3) can reduce time spent responding to concerns/appeals. One suggestion would be to train teaching assistants to use rubrics in professors' courses.

Finally, there was no indication that professors were discussing assessment or the use of the rubrics with other professors in the department while this study was being conducted. Perhaps this shouldn't be surprising, as changing assessment practices is not an easy feat: it requires dedication and a change in culture, and change takes time and determination. As Biggs (2013) writes:

> CA [constructive alignment] provides a framework for adjusting teaching and assessment to address the attainment of those outcomes and the standards reached. Research indicates that CA is effective in this but it initially requires time and effort in designing teaching and assessment and, as a systems approach, it is important that supporting institutional policies and procedures are in place. (p. 5)

Institutional support is essential in facilitating the change and fostering the climate needed for the adoption and sustainability of outcomes-based pedagogical practices. Culture is manifested and demonstrated through communications. Creating a culture that supports pedagogical discussions demonstrates to all stakeholders that best pedagogical practices are valued.

CONCLUSIONS

Through this study to develop individualized rubrics for meaningful collection of direct evidence of student performance with respect to the CEAB graduate attributes, we learned useful information about supporting teaching faculty. Providing one-on-one pedagogical support was crucial to evincing a shift in the way educators think about assessment. It led to a critical improvement in teaching practices, and evidence of continual improvement to support program accreditation. It cannot be assumed that all engineering educators are aware or have experience with outcomes-based teaching and assessing. Overall, continued support for individual professors in outcomes-based pedagogical practices ensured by institutional policy and procedures will be valuable in facilitating and sustaining the cultural change in assessment beliefs and practices required to effectively support engineering program continual improvement and accreditation.

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REFERENCES

ABET. 2021. Criteria for Accrediting Engineering programs 2019-20. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/#GC3 (2021/01/02).

Allen, S. and J. Knight. 2009. A Method for collaboratively developing and validating a rubric. *International Journal for the Scholarship of Teaching and Learning* 3(2): 1-17. https://doi.org/10.20429/ijsotl.2009.030210

Almarshoud, A. 2011. Developing a rubric-based framework for measuring the ABET outcomes achieved by students of electric machinery courses. *International Journal of Engineering Education* 27(4): 1-8.

AAC&U (Association of American Colleges & Universities). 2007. VALUE Rubric Development Project. http://www.aacu.org/value/rubrics/index_p.cfm?CFID=41030298&CFTOKEN=68905942 (2021/01/02).

Biggs, J. 2013. Constructive alignment in university teaching. *HERDSA Review of Higher Education* 1: 5-22. https://www.tru.ca/__shared/assets/Constructive_Alignment36087.pdf (2017/04/24).

Davis, D.C., K. L. Gentili, M.S. Trevisan and D.E. Calkins. 2002. Engineering design assessment processes and scoring scales for program improvement and accountability. *Journal of Engineering Education* 91(2): 211-221. https://doi.org/10.1002/j.2168-9830.2002.tb00694.x

Driscoll, A. and S. Wood. 2007. Developing Outcomes-based Assessment for Learning-centered Education: A Faculty Introduction. Sterling, VA: Stylus.

Felder, R.M. and R. Brent. 2003. Designing and teaching courses to satisfy the ABET engineering criteria. *Journal of Engineering Education* 92(1): 7-25. https://doi.org/10.1002/j.2168-9830.2003.tb00734.x

Ferens, K., and W. Kinsner. 2011. Industry Focus Group Forum Approach for Assessing Undergraduate Engineering Program Outcomes. In Proceedings of the 2nd annual CEEA Conference, 6 pp. St. John's, Newfoundland: Memorial University. June 6-8. https://doi.org/10.24908/pceea.v0i0.3653

Ferens, K., J. Seniuk Cicek, N. Sepehri, W. Kinsner, J.P. Burak, A. Parker, D. McNeill, D. Ruth, I. Jeffrey, N. Godavari, S. Ingram. 2014. Industry focus group forum approach for assessing undergraduate engineering program outcomes. In Proceedings of the 5th annual CEEA Conference, 6 pp. Canmore, AB: University of Calgary. June 8-11.

https://doi.org/10.24908/pceea.v0i0.5950

Frank, B. and S. Fostaty Young. 2011. What can our students do: Year 2 of graduate attribute assessment at Queen's University. In Proceedings of the 2nd annual CEEA Conference, 6 pp. St. John's, Newfoundland: Memorial University. June 6-8. https://doi.org/10.24908/pceea.v0i0.3587

Frank, B., S. McCahan, C. K. Watts, S. Fostaty Young, P. Ostafichuck, P. Wolf and N. Saleh. 2011. Engineering graduate attribute development (EGAD) project. In Proceedings of the 2nd annual CEEA Conference, 6 pp. St. John's, Newfoundland: Memorial University. June 6-8. https://doi.org/10.24908/pceea.v0i0.3566

Gliner, J.A., G.A. Morgan and N. L. Leech. 2009. Research in Applied Settings, 2nd ed. New York, NY: Routledge Taylor and Francis Group.

Moskal, B.M. and J.A. Leydens. 2000. Scoring rubric development: Validity and reliability. *Practical Assessment, Research & Evaluation* 7(10): 1-6.

Hanson J.H. and J.M. Williams. 2008. Using writing assignments to improve self-assessment and communication skills in an engineering statics course. *Journal of Engineering Education* 97(4): 515-529. https://doi.org/10.1002/j.2168-9830.2008.tb00997.x

Hurst, A., E. Jobidon, A. Prier, T. Khaniyev, C. Rennick, R. Al-Hammoud, C. Hulls, J. Grove, S. Mohamed, S. Johnson, and S. Bedi. 2016. Towards a multidisciplinary teamwork training series for undergraduate engineering students: Development and assessment of two first-year workshops. In Proceedings of the American Association of Engineering Education (ASEE), 18pp. New Orleans, LA. June 26-29.

IEA 2013. Graduate Attributes and Professional Competencies (v. 3). https://www.ieagreements.org/assets/Uploads/Documents/Policy/Graduate-Attributes-and-Professional-Competencies.pdf

Jiusto, S. and D. Di Biasio. 2006. Experiential learning environments: Do they prepare our students to be self-directed, lifelong learners? *Journal of Engineering Education* 95(3): 195-204. https://doi.org/10.1002/j.2168-9830.2006.tb00892.x

Jonassen, D. H., D. Shen, R.M. Marra, Y.H. Cho, J.L. Lo and V.K. Lohani. 2009. Engaging and supporting problem solving in engineering ethics. *Journal of Engineering Education* 98(3): 235-254. https://doi.org/10.1002/j.2168-9830.2009.tb01022.x

Jonsson, A. and G. Svingby. 2007. The use of scoring rubrics: Reliability, validity and educational consequences. *Educational Research Review* 2:130-144. https://doi.org/10.1016/j.edurev.2007.05.002

McCahan, S., L. Romkey and G. Allen. 2011. Development of the graduate attribute quality assurance process at the University of Toronto. In Proceedings of the 2nd annual CEEA Conference, 6 pp. St. John's, Newfoundland: Memorial University. June 6-8. https://doi.org/10.24908/pceea.v0i0.3590

McGourty, J., C. Sebastian and W. Swart. 1998. Developing a comprehensive assessment program for engineering education. *Journal of Engineering Education* 87(4): 355-361. https://doi.org/10.1002/j.2168-9830.1998.tb00365.x

Miller, D.M. and R.L. Linn. 2000. Valid performance-based assessments. *Applied Psychological Measurement* 24: 367. https://doi.org/10.1177/01466210022031813

Moskal, B. M. and J. A. Leydens. 2000. Scoring rubric development: Validity and reliability. *Practical Assessment, Research & Evaluation* 7(10): 1-6.

Olds, B., B. Moskal and R. Miller. 2005. Assessment in engineering education: Evolution, approaches and future collaborations. *Journal of Engineering Education* 94(1): 13-25. https://doi.org/10.1002/j.2168-9830.2005.tb00826.x

Passow, H. 2012. Which ABET competencies do engineering graduates find most important in their work? *Journal of Engineering Education* 101(1): 95-118. https://doi.org/10.1002/j.2168-9830.2012.tb00043.x

Peto, L. and C. Geddert. 2014. Using career education to help students build and articulate employability skills. In Proceedings of the 5th annual CEEA Conference, 7 pp. Canmore, AB: University of Calgary. June 8-11. https://doi.org/10.24908/pceea.v0i0.5857

Prados, J.W., G.D. Peterson and L.R. Lattuca. 2005. Quality assurance of engineering education through accreditation: The impact of engineering criteria 2000 and its global influence. *Journal of Engineering Education* 94(1): 165-184. https://doi.org/10.1002/j.2168-9830.2005.tb00836.x

Price Faculty of Engineering, University of Manitoba. 2020. Friends of Engineering. https://umanitoba.ca/faculties/engineering/alumni_community/alumcomm_friends.html

Rogers, G. 2000. EC2000 and measurement: How much precision is enough? *Journal of Engineering Education* 89(2): 161-166. https://doi.org/10.1002/j.2168-9830.2000.tb00510.x

Roselli, R.J. and S.P. Brophy. 2006. Effectiveness of challenge-based instruction in biomechanics. *Journal of Engineering Education* 95(4): 311-324. https://doi.org/10.1002/j.2168-9830.2006.tb00906.x

Seniuk Cicek, J., M. Friesen, S. Ingram and D. Ruth. 2017. Action research: A methodology for transformative learning for a professor and his students in an engineering classroom. *European Journal of Engineering Education* 44(1-2): 49-70. https://doi.org/10.1080/03043797.2017.1405242

Seniuk Cicek, J., S. Ingram, N. Sepehri, J.P. Burak, P. Labossiere, D. Mann, D. Ruth, A. Parker, K. Ferens, N. Godavari, J. Oleszkiewicz and A. Topping. 2014. Rubrics as a vehicle to define the twelve CEAB graduate attributes, determine graduate competencies, and develop a common language for engineering stakeholders. In Proceedings of the 5th annual CEEA Conference, 6 pp. Canmore, AB: University of Calgary. June 8-11. https://doi.org/10.24908/pceea.v0i0.5876

Seniuk Cicek, J., P. Labossiere and D. Mann. 2013. Surveying fourth year engineering student perceptions of graduate attribute competencies. In Proceedings of the 4th annual CEEA Conference, 7 pp. Montréal, QB, École Polytechnique. June 17-20. https://doi.org/10.24908/pceea.v0i0.4857

Seniuk Cicek, J., D. Mann and S. Ingram. 2017. Validating and implementing engineering graduate attribute rubrics in a biosystems engineering curriculum. In Proceedings 2017 IEEE Frontiers in Education Conference (FIE), 6 pp. Indianapolis, IN. October 18-21. https://doi.org/10.1109/FIE.2017.8190632

Sepehri, N., W. Kinsner, J-P. Burak, C. Shafai, U. Annakkage, D. Mann, D. Kuhn, A. Shalaby, M. Alfaro, J. Morrison, K. Ferens, M Birouk, P. Labossiere, M. Torchia and J. Beddoes. 2013. The process of continual improvement of engineering programs at the University of Manitoba: Now and next. In Proceedings of the 4th annual CEEA Conference, 6 pp. Montréal, QB, École Polytechnique. June 17-20. https://doi.org/10.24908/pceea.v0i0.4901

Shuman, L. J., M. Besterfield-Sacre and J. McGourty. 2005. The ABET "professional skills" - Can they be taught? Can they be assessed? *Journal of Engineering Education* 94(1): 41-55. https://doi.org/10.1002/j.2168-9830.2005.tb00828.x

Johnson, C.S. 2006. The analytic assessment of online portfolios in undergraduate technical communication: A model. *Journal of Engineering Education* 95(4): 279-287. https://doi.org/10.1002/j.2168-9830.2006. tb00903.x

Soundarajan, N. 2002. Preparing for accreditation under EC2000: An experience report. *Journal of Engineering Education* 91(1): 117-123. https://doi.org/10.1002/j.2168-9830.2002.tb00680.x

Spurlin, J.E., S.A. Rajala and J.P. Lavelle. 2008. Assessing student learning. In Designing Better Engineering Education Through Assessment, eds. J. E. Spurlin, S. A. Rajala and J. P. Lavelle, 23-58. Sterling, VA: Stylus.

Wolf, P. and W. Stiver. 2011. Graduate attributes: Intentional mapping and assessment portfolios. In Proceedings of the 2nd annual CEEA Conference, 4 pp. St. John's, Newfoundland: Memorial University. June 6-8. https://doi.org/10.24908/pceea.v0i0.3572

Yalvac, B., H.D. Smith, J.B. Troy and P.L. Hirsch. 2007. Promoting advanced writing skills in an upper-level engineering class. *Journal of Engineering Education* 96(2): 117-128. https://doi.org/10.1002/j.2168-9830.2007.tb00922.x

Zafft, C.R., S.G. Adams and G.S. Matkin. 2009. Measuring leadership in self-managed teams using the competing values framework. *Journal of Engineering Education* 98(3): 273-282. https://doi.org/10.1002/j.2168-9830.2009.tb01024.x

Zmuda, A., J. McTighe, G.P. Wiggins and J.L. Brown. 2007. Schooling by Design. Alexandria, VA: Association for Supervision & Curriculum Development.

APPENDIX

Appendix: Sample rubrics for Biosystems 3320: Engineering Properties of Biological Materials
(Next page)

Appendix: Sample rubrics for Biosystems 3320: Engineering Properties of Biological Materials.

1. Focus Area: A Knowledge Base for Engineering: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.				
INDICATORS	**Level 4**	**Level 3**	**Level 2**	**Level 1**
	Strong	***Competent***	***Developing***	***Needs Work***
Mathematical and Scientific Terms: *Ability to interpret (understand and apply) mathematical and scientific terms.*	Demonstrates a skillful ability to interpret mathematical and scientific terms correctly.	Demonstrates an ability to interpret most mathematical and scientific terms correctly.	Demonstrates some ability to interpret mathematical and scientific terms correctly.	Demonstrates minimal or no ability to interpret mathematical and scientific terms correctly.
Theory in Engineering Problems: *Ability to understand and apply theory in engineering problems.*	Demonstrates a comprehensive understanding of underlying theory and application to the problem.	Demonstrates an ability to understand the application of theory to the problem.	Demonstrates some ability to understand the application of theory to the problem.	Demonstrates minimal or no ability to understand the application of theory to the problem.
Mathematical Models: *Ability to choose the mathematical model that most closely represents the mechanical model.*	Chooses an optimal mathematical model that applies to the mechancial model.	Chooses a mathematical model that applies to the mechanical model.	Chooses a mathematical model that applies to the mechanical model with assistance.	Demonstrates minimal or no understanding of the connection between the mathematical model and the mechanical model.
Assumptions and Limitations: *Ability to make and evaluate important assumptions and see limitations.*	Evaluates assumptions /limitations with complete and compelling rationale for their appropriateness. Awareness that conclusions may be limited by their accuracy.	Describes assumptions/limitations and provides rationale for why they are appropriate.	Describes assumptions/limitations, and provides some rationale for why they are appropriate.	Attempts to describe assumptions/limitations, but minimal or no rationale given.
Calculations: *Ability to carry out calculations.*	Demonstrates skillful ability to carry out calculations. Calculations are relevant, correct and comprehensive, and are presented elegantly (clearly, concisely).	Demonstrates ability to carry out calculations. Calculations are relevant and correct.	Demonstrates some ability to carry out calculations. Only a portion of the relevent calculations are done, and may contain errors.	Demonstrates minimal or no ability to carry out calculations. Calculations attempted are wrong or irrelevant.
Statistical Analysis: *Ability to use statistical concepts to analyze data.*	Demonstrates a skillful ability to analyze data using statistical concepts.	Demonstrates an ability to analyze data using statistical concepts.	Demonstrates some ability to analyze data using statistical concepts. Some errors in analysis.	Demonstrates minimal or no ability to analyze data using statistical concepts. Major errors in analysis.
Interpretation of Data: *Ability to explain information presented in graphical and/or mathematical forms (equations, graphs, diagrams, drawings, schematics).*	Demonstrates a skillful ability to provide rational explanations and can make appropriate inferences based on that information.	Demonstrates an ability to provide rational explanations of information presented.	Demonstrates some ability to provide explanations of information presented, and occasionally makes minor errors.	Demonstrates minimal or no ability to provide explanation of information presented. Frequently misinterprets the information presented.

5. Focus Area: Use of Engineering Tools: An ability to select, apply, adapt, extend and create appropriate tools (resources, software, techniques, hardware, equipment) to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.				
INDICATORS	**Level 4**	**Level 3**	**Level 2**	**Level 1**
	Strong	***Competent***	***Developing***	***Needs Work***
Understand Tools: *Ability to describe and explain the principles behind and applicability of engineering tools and/or mathematical relationships.*	Demonstrates skillful ability to describe and explain the principles behind and applicability of engineering tools and/or mathematical relationships.	Demonstrates ability to describe and explain the principles behind and applicability of engineering tools and/or mathematical relationships.	Demonstrates some ability to describe and/or explain the principles behind and applicability of engineering tools and/or mathematical relationships.	Demonstrates minimal or no ability to describe and/or explain the principles behind and applicability of engineering tools and/or mathematical relationships.
Evaluate Tools: *Ability to understand the limitations in the use of engineering tools, and their underlying assumptions.*	Demonstrates skillful ability to understand the limitations of tools and discusses the assumptions.	Demonstrates the ability to understand the limitations of tools and understands the assumptions.	Demonstrates some ability to understand the limitations of tools and some understanding of the assumptions.	Demonstrates minimal or no ability to understand the limitations of tools & understand assumptions.

6. Focus Area: Individual and Teamwork: An ability to work effectively as a member and leader in teams, including in multidisciplinary settings				
INDICATORS	**Level 4**	**Level 3**	**Level 2**	**Level 1**
	Strong	***Competent***	***Developing***	***Needs Work***
Individual Work Contributions: *Ability to carry out individual responsibilities.*	Completes all assigned tasks by deadline; work accomplished is thorough and comprehensive.	Completes assigned tasks by deadline; work accomplished meets all requirements.	Completes most assigned tasks by deadline; most work meets requirements.	Completes some assigned tasks by deadline; and some work meets requirements.

8. Focus Area: 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				
INDICATORS	**Level 4**	**Level 3**	**Level 2**	**Level 1**
	Strong	***Competent***	***Developing***	***Needs Work***
Behaviour and Responsibility: *Ability to exhibit appropriate behaviour and to take responsibility for own actions.*	Demonstrates exemplary professional behavior. Work is exceptionally neat and detailed. Attendance is always regular and punctual	Demonstrates appropriate professional behavior. Work is neat and detailed. Attendance is mostly regular and punctual.	Demonstrates mostly appropriate professional behavior. Work is fairly neat and detailed. Attendance is fairly regular and punctual.	Demonstrates inappropriate professional behavior. Work is often messy neat and lacks detail. Attendance is unregular and noticeably unpunctual.

Rubrics adapted from The University of Manitoba Faculty of Engineering Graduate Attribute Rubrics © 2014. Informed by: Assessing Outcomes and Improving Achievement: Tips and tools for Using Rubrics, edited by Terrel L. Rhodes, © 2010 by the Association of American Colleges and Universities; and University of Delaware College of Engineering Civil & Environmental Engineering ABET Scoring Rubrics for Program Outcomes.