APPROACHES TO GRADUATE ATTRIBUTES AND CONTINUAL IMPROVEMENT PROCESSES IN FACULTIES OF ENGINEERING ACROSS CANADA: A NARRATIVE REVIEW OF THE LITERATURE

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Abstract –The CEAB accreditation requirement of graduate attributes and continual improvement processes (GACIP) has been a pervasive topic in the annual CEEA conference proceedings since 2010. The proceedings are a rich primary source of work being done in Canadian tertiary institutions. This narrative review of the literature consolidates and discusses the relevant CEEA papers for 2010-2017 in a manner that is useful to leadership and decision-makers at accredited faculties of Engineering nationwide.

Four guiding research questions were asked of this literature: (1) What general frameworks are being implemented as accredited faculties of Engineering across Canada approach GACIP?; (2) What are the specific activities and methods of one or more of the GACIP steps?; (3) What are the roles and responsibilities of people involved?; and (4) What perspectives are taken in response to the CEAB accreditation criteria, including concerns, issues, and benefits? A qualitative content analysis was conducted on 106 papers meeting selection criteria. Emergent topics were used to form the discussion.

Keywords: CEAB, graduate attributes, continual improvement, continuous improvement, outcomes based education.

1. INTRODUCTION

For more than two decades, there has been a global shift in engineering education and accreditation from inputs (what is taught) to outcomes (what is learned). This has been, in part, a response to the nature of engineering work crossing geographical borders and necessitating professional skills, such as communication, teamwork, problem solving, and lifelong learning [1, 2].

Outcomes-based education in engineering has its roots in mutual recognition agreements between countries, such as the Washington Accord (first signed in 1989) [2, 3], and standards, such as EC2000 (adopted by the

Accreditation Board for Engineering and Technology in 1996) [4]. As a practicing profession, professional skills are now considered equally or more important for young engineers to develop than the finite scientific and technical content knowledge of traditional input education models [1]. Engineers Canada was one of six original signatories of the Washington Accord, which now includes a commitment to integrating graduate attributes, such as Communication and Lifelong learning, into outcomes-based accreditation criteria [2].

In 2009, the Canadian Engineering Accreditation Board (CEAB) introduced graduate attributes and continual improvement processes (GACIP) to its accreditation criteria [5]. Ever since, faculties of Engineering across Canada have been re-evaluating and reshaping their traditional approaches to curriculum design and assessment to integrate all twelve graduate attributes into their programs. The goal is to have effective processes that help identify and implement meaningful program improvements, and to maintain good standing with the CEAB.

Concurrent to this past decade of pedagogical reform in engineering education, literature on the topic has been increasing, as has discussion around outcomes-based education in the annual Canadian Engineering Education Association (CEEA) conference proceedings for 2010 to 2017 [6]. In these proceedings, authors have discussed activities at their respective institutions, sharing best practices and lessons learned with colleagues and other stakeholders. These conference papers, therefore, are a rich and valuable primary source of the GACIP groundwork being done at course, program, department, faculty, and institutional levels nationwide.

While the CEEA proceedings provide an extensive body of first-hand accounts with GACIP implementation, what is missing is a comprehensive summary of this information, a purposeful organization of the authors' insight, including approaches, methods, people involved, and perspectives. Such a reference would be beneficial for Engineering faculty leadership and decision-makers at

accredited institutions nationwide. Hence, the purpose of this narrative review of the literature is to explore the implementation of GACIP at accredited faculties of Engineering in Canada by surveying CEEA proceedings for 2010 to 2017 on this topic, encapsulating a previously uncharted approach to engineering education and accreditation in Canada.

2. METHODOLOGY

The steps for this narrative review were: (1) identifying research questions, (2) determining inclusion criteria, (3) finding and organizing sources, and (4) conducting a qualitative content analysis [7, 8].

2.1. Research Questions

The following four research questions informed inclusion criteria and enabled a thorough exploration of the literature, thus providing a useful summary of work in this area of engineering education.

1. What general frameworks are being implemented as accredited faculties of Engineering across Canada approach GACIP?
2. What are the specific activities and methods of one or more of the GACIP steps?
3. What are the roles and responsibilities of people involved?
4. What perspectives are taken in response to the CEAB accreditation criteria, including concerns, issues, and benefits?

2.2. Inclusion Criteria

Articles considered in this review have met three inclusion criteria:

- Published online at the CEEA conference proceedings website between 2010 to 2017 [6];
- Contain one or more of the following key terms and phrases in the title or abstract: attribute(s), graduate attribute(s), outcomes based education, outcomes based learning, continuous improvement, continual improvement, and CEAB;
- Explicitly focus on an institutional response to the CEAB mandate, discussing one or more components of GACIP.

2.3. Finding and Organizing Sources

Articles were located by scanning the tables of contents of the CEEA conference proceedings website, searching titles and abstracts for the key terms and phrases. Hand-selected papers were organized using RefWorks (a searchable web-based reference

management tool) and within Google Drive folders shared amongst the researchers.

2.4. Qualitative Content Analysis

Qualitative methodology is well suited for exploring and developing an understanding of a central phenomenon, in this case, GACIP [8]. The steps for a qualitative content analysis are to collect, read, and code the data. These steps are simultaneous and iterative in nature [8].

Upon a first read through all the articles, each was categorized for its strongest alignment with one of the four research questions. The Findings section shows the breakdown of number of articles relating to each research question. When more than one research question was touched upon, these were noted as secondary foci and considered in the Discussion section.

Through subsequent readings, relevant text blocks were extracted and organized into emergent topics. A matrix was created with papers (row headings) and the four research questions and their topics (column headings); see Appendix A. The text blocks were studied and integrated, and topics were used to shape the Discussion section.

Because of the qualitative nature of this review, the findings, discussion, and conclusions are not factual, but rather constructions shaped by the values of the researchers [9]. Efforts toward trustworthiness (quality) [9] of the review were made throughout the data collection, organization, and reporting phases by means such as: care in searching and selecting articles best fitting the research questions and inclusion criteria; revisiting the data time and time again to ensure accurate representation; and co-authorship for combined expertise and maximal accountability.

3. FINDINGS

Since the CEEA proceedings represent discussions within the engineering education community, the following findings give an idea of the breadth and depth of the dialogue. From a total of 878 papers in the proceedings spanning 2010 to 2017, 106 papers (12%) were deemed to focus primarily on the CEAB mandated GACIP accreditation criteria at Canadian tertiary institutions. These papers were selected for their alignment with one or more of the research questions of this review.

Research question 1: Sixteen of the 106 papers reviewed (15%) spoke of general frameworks and approaches to GACIP. More than half of these (10 papers) summarized a model of steps, strategies, and best practices toward meeting CEAB criteria. Some (6 papers) compared CEAB criteria with an existing framework of

graduate attributes, such as the CDIO (Conceive, Design, Implement, Operate) Syllabus [10] and Ontario's UDLEs (Undergraduate Degree Level Expectations) [11].

Research question 2: Eighty-two of the papers reviewed (77%) detailed specific activities and methods for one or more of the GACIP components. The following topics emerged: construction of indicators and mapping them to the curriculum (12 papers); assessment of graduate attributes (52 papers) with sub-topics of direct and indirect assessment examples, challenges associated with assessing the soft (professional) attributes, and the creation of rubrics; continual improvement processes (3 papers); and the development and use of software tools (15 papers).

Research question 3: While only two of the papers (2%) focused primarily on the roles and responsibilities of people involved in GACIP, topics of collaborations and specialized positions were integrated into most papers as secondary foci.

Research question 4: Similarly, only six of the papers (6%) aligned most strongly to topics of concerns, issues, and benefits, yet perspectives were integrated throughout the literature.

Table 1: Breakdown of GACIP articles relating to research question

Research Question	Number of Articles
1. General frameworks and approaches	16
2. Specific activities and methods	82
3. Roles and responsibilities	2
4. Perspectives	6

4. DISCUSSION

4.1. General Frameworks of GACIP

4.1.1. New Frameworks

In the CEEA literature, many authors either referred directly to, or implied, the EGAD (Engineering Graduate Attribute Development) Project guidelines as a general framework and approach to meeting the CEAB mandate [12-18]. The EGAD multi-step process includes: defining and mapping indicators to the curriculum; collecting, analyzing, and interpreting data; and continual improvement of programs [19].

The second EGAD National Snapshot Survey revealed that faculty-led approaches had increased, replacing what was once primarily delegated to the department level [20]. In many cases with a single approach for an entire institution, departments were still able to make adjustments for their circumstances. A centralized

approach at McGill University had uniform processes across engineering programs, including common indicators, indirect assessments, data analysis and interpretation, and continual improvement [21]. Here, while the lack of departmental tailoring might be seen as a downfall, benefits included improved efficiency, collaboration, reduced workload for instructors, and leveraging of personnel and resources.

A unique framework in place at Concordia University, COGAF (Common Graduate Attributes management Framework), was based on models from business and military [22]. It organized GACIP into four components: governance (leadership and direction), people (all stakeholders), processes (operational activities), and technology (supportive tools). The authors described each component in detail so as to share a turnkey solution for other institutions integrating graduate attributes into their programs.

4.1.2. Comparing CEAB Criteria with Existing Frameworks

Particularly in the early years of the CEAB mandate, the new graduate attribute requirements were compared with frameworks already in place. Two papers examined alignment of the CDIO Syllabus with CEAB graduate attributes [23, 24]. One questioned if a program was meeting CDIO standards, would it automatically be satisfying CEAB requirements? [24] The authors found that this indeed would be the case, since CDIO standards could be matched with each graduate attribute, as well as with continual improvement. The relationship between the two structures was described not as equivalent, but rather CDIO being a resource that could be utilized to meet CEAB requirements [23].

Three papers cross-referenced Ontario's UDLEs (Undergraduate Degree Level Expectations) with CEAB graduate attributes, since both were learning outcome structures with expected compliance [25, 26, 27]. Authors found considerable, but not complete, overlap, and therefore encouraged simultaneous consideration of each structure by engineering schools. The CEAB graduate attributes were described as a more complete list, but two absences in the CEAB architecture noted were UDLE 1: Depth and breadth of knowledge (specifically (b) understanding of the major fields in a discipline from an interdisciplinary perspective and (f) apply learning outside of the discipline), and UDLE 5: Awareness of limits of knowledge [25, 27]. Two CEAB graduate attributes not linked to any UDLEs were 3.1.9 Impact of engineering on society and the environment and 3.1.11 Economics and project management [25].

One paper linked the CEAB graduate attributes with Employability Skills 2000+, a framework created by the Conference Board of Canada that described essential

employee competencies for 21st century workplaces [28]. Employability Skills 2000+ had categories of academic/fundamental, personal management, and teamwork, for which the language and concepts were similar to that of the CEAB attributes. The authors were able to map all twelve CEAB attributes to the Employability Skills 2000+ categories. The authors argued that through the lens of employability skills and potential for career success, student understanding and perceived value of the graduate attributes would increase.

4.2. Specific Activities and Methods

The reviewed CEEA literature was extensively dedicated to specific activities and methods for GACIP in effort to satisfy the CEAB accreditation criteria.

4.2.1. Creation of Indicators

At the University of Toronto, expert subcommittees found that creating a small set of sub-attributes (referred to as *global objectives*) helped bridge the general language of the attributes to the specific, measurable indicators [29]. Similarly, at the University of Alberta, sub-attributes (short phrases referred to as *aspects*) captured the essential components of each graduate attribute. One or more indicators were composed for each aspect [30].

Faculty at the British Columbia Institute of Technology (BCIT) questioned if their existing learning outcomes were synonymous with indicators of graduate attributes, and they found that this was not the case [31]. The authors compared their learning outcomes to indicators and found a 1:1 relationship in some cases, but a 1:many in other cases. They explained that while both described competencies, and there was some overlap, learning outcomes were specific to course content. Indicators, however, were broader and served as a bridge between learning outcomes and graduate attributes.

Faculty-level development of indicators (having common indicators for use by all programs) was the case in a paper comparing seven institutional GACIP approaches (Concordia University, Dalhousie University, Queen's University, University of British Columbia, University of Calgary, University of Manitoba, and University of Toronto) [15]. At Concordia University and University of Toronto, the faculty-wide indicators were malleable at the program level; otherwise, at the remaining institutions, programs selected the indicators most applicable to their content but did not adapt them. Ryerson University [14] and University of Alberta [30] also reported the top-down approach of creating faculty-wide indicators. By comparison, a bottom-up approach was taken at Memorial University of Newfoundland with instructors tasked with creating learning outcomes for their courses, which was intended to help preserve academic freedom [32]. These course-based learning

outcomes were then mapped to graduate attributes for measurement.

At the University of Waterloo, teams from six different departments collaborated using a structured brainstorming process to create common indicators for the seven professional (soft) attributes [33]. They kept Bloom's taxonomy in mind when selecting nouns and verbs for the statements. Although arriving at a consensus for the statements, the authors noted that, due to the dynamic nature of indicators (needing reassessment in a few years), the brainstorming process itself would require periodic repetition.

Authors from Carleton University also referred to Bloom's taxonomy when selecting verbs for indicators (what they called *competencies*) [25]. They created two expectation levels for each competency: *threshold* (minimum level of student performance) and *target* (higher level that a certain amount of students will reach).

4.2.2. Curriculum Mapping

In the paper comparing seven institutional approaches, curriculum mapping was either in progress or complete for all attributes across all programs [15]. A variety of approaches and tools were used, such as instructor surveys, departmental workshops, and use of the customized mapping software.

At the University of Manitoba, a three-year study (2011-2014) had instructors using a self-administered checklist to map the teaching and measurement of attributes in their courses [34, 35, 36, 37]. Each year of the study, four attributes were chosen (two representing hard (traditional) attributes and two representing the soft (professional) attributes), thus addressing all twelve attributes over the three years.

Faculty contribution was also required at Ryerson University to create a curriculum mapping matrix [13]. The matrix was composed of programs and courses (row headings) relating to the twelve graduate attributes (column headings). Some attributes required more than one column, as they consisted of more than one dimension. For example, the Communication attribute had oral and written dimensions. A scale of 0 to 3 was used at the University of Alberta to indicate the degree an attribute was developed in a given course [30]. Similarly, McGill University incorporated the CEAB conventions of I (introduced), D (developed), and A (applied) into their curriculum maps [18].

4.2.3. Assessment

The assessment conversation in the CEEA literature can be broadly organized into three topics: (1) challenges and solutions for assessing the professional (soft) graduate attributes; (2) authentic assessment and efforts at tool development, namely rubrics, and (3) indirect

measures to supplement direct measures and provide a comprehensive data set.

Assessment of Soft Graduate Attributes—There was acknowledgement of the amorphous and subjective nature of the professional (soft) graduate attributes, which are represented by the latter seven of the twelve CEAB graduate attributes: Individual and team work; Communication skills; Professionalism; Impact on society and the environment; Ethics and equity; Economics and project management; and Lifelong learning. Authors pointed out the difficulty of the teaching and assessment of these attributes and discussed a variety of strategies and solutions.

Capstone courses lend themselves to evaluating the soft attributes [38], as do co-op experiences [39, 40]. One paper advocated for communication education to be integrated throughout a program for a more formative student experience [41]. Another pointed out that not all students participated in co-op courses, and thus described an on-campus curricular solution that had students developing an awareness of lifelong learning in the profession [42]. The development of a course called The Engineering Profession at Memorial University focused student learning on six of the soft attributes [43]. Activities included one-on-one interviews and small group work. Several other papers concentrated specifically on the Lifelong learning attribute. One described a laboratory experience with unstructured pre- and post-lab components than had students evaluating their own learning [44]. Another told of a third-year course in which students set goals for their learning in the upcoming week and reflected on their learning achievements over the previous week [45].

Authentic Assessment and Development of Tools—Authors brought forth two points in regard to assessment challenges. First, the complexity of assessing graduate attributes, particularly the soft skills, called for authentic measures (open-ended tasks that typify the professional setting), versus traditional measures (such as exams and assignments that emphasize information recall, which are more suited to the hard attributes) [46, 47]. Second, authentic assessment required good tools, particularly rubrics. Authors reported on rubric creation activities at their institutions.

Authentic assessments have students working and thinking like engineers, encountering ill-defined problems and drawing upon their knowledge, skills, and attitudes [46, 47, 48]. As compared to typical assignments, authentic tasks, such as projects, give students autonomy and choice as they identify and research problems with more than one reasonable answer [48]. A program at Conestoga College reported having two or three such projects each term [48].

Some institutions had portfolio or dossier systems in place, which, in addition to being collections of student work, incorporated self-reflections [49, 50, 51]. Portfolio items were mapped to graduate attributes, and the self-reflection component was a means for self-assessment, as well as building a personal story and professional identity [49, 50].

While not specifically mentioning rubrics, CEAB criteria includes having documented assessment tools that are suited to the attribute and used to obtain data on student learning [4]. For instructors, marking authentic assessments requires substantial time and effort, which necessitates the development of high quality assessment tools, in most cases, rubrics [51, 52]. Rubrics are well suited to authentic assessment, because they distinguish levels of proficiency and provide more valuable feedback to students as compared to marks alone [46]. There is an optimal level of descriptiveness within rubrics—enough so that different evaluators can provide similar evaluations, but not so detailed as to be overwhelming [53].

At the University of Toronto rubrics were created for five CEAB graduate attributes (Design, Communication, Teamwork, Problem analysis, and Investigation) and then tested for validity [52]. This was part of a larger provincial initiative. Focus groups with students and instructors helped ensure clarity in rubric terminology, develop proficiency levels, and advise on missing criteria. It was intended that instructors would tailor the rubrics to their individual course needs.

At the University of Guelph, four rubrics were created at the faculty level for use in capstone design courses of the institution's seven accredited engineering programs [54]. The intention was to provide grading consistency and improved student feedback. While continuing to be refined, the rubrics were positively received by faculty and students.

At the University of Manitoba, rubrics were to be developed faculty-wide for all twelve CEAB graduate attributes [55]. These rubrics would be based on an initiative from the Association of American Colleges and Universities (AAC&U). They would be rooted in research and consultation with the faculty's curriculum committee, the University's Centre for the Advancement of Teaching and Learning, as well as industry. In addition to rubrics being tools for assessment, they provided direction for course development and creation of other tools, such as surveys.

Indirect Measurements of Graduate Attributes—While direct measures (such as exams, reports, and presentations) provide information about student learning of graduate attributes within a course, indirect measures are a means for obtaining information about the

effectiveness of a program [56]. Indirect measures (such as surveys, interviews, focus groups, and forums) are complementary. They incorporate stakeholders' perspectives, and thus can provide a comprehensive data set for accreditation, as well as continuous improvement [34, 56].

Authors shared their efforts at indirect assessment of graduate attributes, capturing student, alumni, faculty, industry, and co-op employer perspectives. Student surveys, asking students about their perceptions of graduate attribute development in their courses and program, were prevalent [13, 56, 57, 58, 59, 60, 61]. Student surveys at the University of Calgary focused specifically on the Individual and team work attribute and resulted in twelve evidence-based curricular recommendations [61]. One paper described the planning and implementation of a focus group event with industry stakeholders [62]. The focus group format enabled industry representatives to discuss ideas and bring forth cumulative experiences, which surpassed the confines of individual perspectives surveys.

4.2.4. Continual Improvement

While continual improvement was acknowledged throughout the CEEA literature, authors mostly spoke of it resulting from graduate attribute assessment, and of it being part of accreditation processes. However, little was offered in the way of details or examples. For example, a summary of the continual improvement approach, namely the committees involved, at the University of Manitoba was as follows: a faculty-level committee evaluated information, identified and prioritized areas needing revision, then passed recommendations along to department-level committees to implement the program changes [56]. The committee involvement at McGill University had an opposite flow: necessary changes were determined by department-level committees, then submitted in an annual report to a faculty-level committee, at which point they were put to a vote [21].

Authors from the University of Alberta described in detail one element of their continual improvement process—their post-course assessment system (PCAS), which was a tool that prompted curricular changes [63]. With PCAS, instructors reflected and reported on their successes and challenges at the end of a term. The tool included six sections (student preparation, learning outcomes, course content, learning strategies, graduate attributes, and other). For questions within each section, instructor responses of 2 or higher (using a 1-5 scale) automatically triggered an investigation to determine necessary changes. The importance of instructor input was stressed, due to their frontline position and understanding of issues, concerns, inconsistencies, and best practices.

In the report on the first EGAD survey, institutions overall lacked continual improvement processes or means of closing the loop for graduate attributes assessment [64]. In the second survey administration (two years later), institutions were now examining data collected, using it to inform curricular improvements, and closing the loop with cyclic, sustainable practices [20].

Authors from Queen's University mentioned several important facets of continual improvement processes: clear goals and planning, good leadership, sustainability (not labour intensive), supportive software, and the generation of useful information [64]. Also, they mentioned that the continual improvement process itself requires periodic evaluation.

4.2.5. Software Tools

The CEAB mandate has been described as a data science problem because of its potential to generate overwhelming amounts of data and necessitate streamlined workflows for users [66]. The process involves many users [67] and massive amounts of data to be collected, visualized, analyzed, interpreted, discussed, and implemented into program improvement [68, 69, 70]. Mathematically, the number of attributes, sub-attributes, programs, courses, and students could result in more than one million data entries each year at a single institution [30].

Software applications and platforms should be comprehensive and easy to use for instructors to report grades and develop course outlines aligned with graduate attributes [22]. Institutions and outside vendors have been developing software tools and systems to meet the accreditation requirements. For example, CurricKit mapping software was developed at the University of Guelph to meet the internal need for systematic data collection connecting program-level outcomes with course activities [49].

For three consecutive years beginning in 2013, authors compared and contrasted sixteen different software tools that supported outcomes-based assessment [70, 71, 72]. They discussed the strengths and weaknesses of each tool and derived five categories of classification: AP (Assessment Platform); AS (Analytics System); CMT (Curriculum Mapping Tool); LMS (Learning Management System); and L/CMS (Learning Content Management System). For each of the three papers, the researchers presented the evaluations as a matrix with a star-rating system for criteria, such as the ability to generate and customize rubrics, the ability to provide learning analytics reports, and cost. While some tools had a licensing fee, others were open source and free of charge.

In the absence of any comprehensive, turnkey solution, institutions have been developing their own in-house tools

that combine existing applications [66]—for example: the Integrated Course Design Tool (ICDT) at the University of Calgary [68]; the Graduate Attribute Information Analysis (GAIA) system at the University of Ottawa [69]; and the Outcome-Based Analytics and Continuous Improvement System (OBACIS) at the University of Regina [67]. The efficiency and sustainability of these ad hoc processes is questionable [66]. Also, free, collaborative cloud-based environments of Mendeley and the Google suite are advantageous, yet still have their shortcomings [73].

Three papers reviewed the Desire2Learn software [65, 72, 74]. It was praised for its comprehensiveness as a learning content management system, yet concern was expressed over its reporting and analytics capacities. Nevertheless, Desire2Learn was described as a willing partner with improved analytics as a high priority [65].

The University of Alberta developed a customized accreditation management system, the standardized Engineering Accreditation Systems (SEAS) [75]. Structural requirements for the SEAS included having a centralized database for consistency across the faculty, a web-based interface with varying privileges depending on user roles, and an ability to generate reports with correct content and format for CEAB.

4.3. Roles & Responsibilities

4.3.1. Collaborative Approaches

Throughout the CEEA literature, authors noted that GACIP required input, effort, and expertise from many people, for which faculties of Engineering had responded by creating committees (also referred to as councils, teams, and working groups) and delegating responsibilities for instructors through to deans.

The norm among the most institutions was to establish faculty-level committees with departmental representation [15]. A large group that met regularly at Carleton University reportedly helped develop faculty buy-in and support for GACIP [25]. At the University of Toronto, having processes developed by a faculty-level committee enabled representatives to then take on a coaching role within their respective departments [29].

Some authors spoke of collaboration with colleagues outside engineering, namely faculties of Education and campus-wide pedagogical support services, for advice and assistance developing outcomes-based education procedures and resources [12, 18, 76].

4.3.2. Specialized Roles

According to the second EGAD survey, there was a noted increase in the creation of job positions dedicated to the GACIP component of accreditation [20]. This included part- and full-time administrative positions,

teaching relief for instructors, and faculty positions that blended teaching with accreditation responsibilities. This was said to be due to the time-intensive nature of the process, and human resources needed to ensure sustainability. The establishment of GAPNet (graduate attribute professional network), a community of people who meet regularly through teleconferencing, is further evidence of the growing number of people and responsibilities involved [77]. In 2017, GAPNet had 33 members from 17 institutions across eight provinces. A survey of GAPNet members revealed that they were mostly academics with expertise in engineering and/or education, and the nature of their work included all aspects of GACIP from data collection to managing change. It was predicted that since the CEAB mandate was ongoing, GAPNet would continue to provide support for graduate attribute professionals as their roles continued to grow and evolve.

4.4. Perspectives

4.4.1. Concerns and Issues

Concerns and issues indicated in the CEEA literature targeted the impacts on faculty (for instance, perceived loss of academic freedom and increased workload) and critiqued components of the CEAB mandate itself.

Impact on Faculty—It was suggested that faculty resistance to adopting graduate attributes might stem from the imposition by an outside agency, namely the CEAB [26]. Such would result in skepticism and disinterest in the process of curricular evaluation and change [78]. Resistance to change was attributed to a culture of autonomy that exists at academic institutions, and onus was placed on those in leadership positions to acknowledge and consider this phenomenon with patience and perseverance [78]. One paper explained that the culture of autonomy and academic freedom has a positive effect on student learning and should be supported during development of an outcomes-based curriculum [79].

Interviews with faculty at Simon Fraser University revealed concerns over the discrepancy between the traditional instructor role as providers of information versus the role as facilitators within the outcomes-based education model [80]. It was thought that the latter, in the context of enduring student expectations to be passive recipients of information, could negatively impact teaching evaluations by students.

The redevelopment of curricula imposes additional responsibilities on faculty, who are already busy with research, teaching, and administration priorities [23, 73]. Efforts to measure graduate attributes at the University of Manitoba were limited by the willingness of instructors, since the research required input over and above regular teaching [37]. At the University of Alberta, it was estimated that the accreditation process for nine programs

required 16,000 hours of personnel time at a cost of over \$1,000,000 [75]. Successful GACIP requires contributions from all faculty, who should be credited accordingly [23].

Critique of the CEAB Mandate—Some authors took issue with the language and content of the CEAB mandate itself. One paper stated that the Design attribute could not stand alone, since the eleven other attributes were inseparably wound into the engineering design process [81]. These authors also suggested two attributes were missing, namely information literacy and gathering and creativity. Another paper argued that it would be impossible for graduates to possess the Investigation attribute without a mandatory course solely dedicated to teaching the myriad of issues accompanying complex problems [82]. To support this point, the author described fifteen characteristics of complex problems faced by engineers, which students could not learn in the existing curricular structure.

Also noted as a major issue was the changing requirements on the CEAB accreditation questionnaire, specifically: adding a definition for complex engineering requirements; instituting the I-D-A (introduced, developed, or applied) mapping convention; and subdividing the Knowledge Base attribute to essentially increase the number attributes from twelve to fifteen [18].

4.4.2. Benefits

Benefits of GACIP and outcomes-based education in general that were presented by authors of the reviewed CEEA literature pointed to perceived advantages for teaching and learning, as well as to the engineering profession.

For faculty, authors felt that collaborative discussions and reflections around curriculum content and assessment practices resulted in improved teaching and instructor development [17, 18, 32, 37, 29, 49]. The CEAB mandate kept program quality front of mind [31].

For students, one author expressed that an awareness of expectations enabled them to be active participants in their own learning, which could result in higher engagement and accountability [79].

For the profession, it was reported that CEAB criteria may be transformational not just to the curriculum, but to all stakeholders [79]. New graduates may now be able to present adequate skills to their employers and would be better prepared for the challenges of their global occupation [47].

5. CONCLUSION

The EGAD multi-step process was found to be the general framework of GACIP used by most faculties of Engineering across Canada. The CEAB mandate, a result

of Canada's participation in the Washington Accord, was cross-referenced and, for the most part, aligned with existing frameworks, such as CDIO and Ontario's UDLEs. There has been a trend to centralize processes at the faculty level, such as the development of indicators, rubrics, and indirect assessments, with some institutions permitting departmental-level tailoring.

Specific activities and methods for GACIP extensively discussed in the CEEA literature were: the creation of indicators for each graduate attribute; mapping of attributes and indicators to learning activities within a program; using direct and indirect measures to assess student levels of proficiency with graduate attributes, as well as the development of rubrics; and the demonstration of specific, identifiable continual program improvements rooted in the assessment data collected. Also, institutions have been creating or purchasing software solutions tailored to their needs.

GACIP requires a significant amount time and expertise from the people involved. The norm at all institutions reviewed in the literature was to take a collaborative approach by having faculty-level committees with departmental representation. Assistance from faculties of Education and campus-wide pedagogical support services was often sought. Also reported was teaching relief for instructors, as well as the creation of specialized administrative positions and faculty positions with a blended accreditation component.

Concerns and issues raised by faculty around GACIP included the imposition of an increased workload, perceived loss of academic freedom, and potentially negative impacts on the student learning experience and faculty teaching evaluations. The CEAB mandate itself was critiqued for its content and language used, as well as the feasibility of its implementation. Benefits of GACIP highlighted were the positive impact of faculty collaboration and discussion on teaching quality and the student experience, increased student engagement and accountability, and the end result of having highly skilled young engineers entering the profession.

While the CEAB mandate is succinct in its composition—to provide evidence of twelve attributes of graduates and the continual improvement of programs—content in this eight-year span of CEEA proceedings (2010-2017) is complex and dynamic, which potentially hinders its navigation and usefulness. The purpose of this narrative review of the literature has been to explore GACIP across Canada by means of surveying pertinent CEEA proceedings, presenting findings and encapsulating topics in a manner that is advantageous to those with a vested interest, particularly Engineering faculty leadership and decision-makers seeking insight and guidance for GACIP implementation at their own institutions.

Acknowledgements

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References*

*References [1] through to [82] are cited throughout this paper. References [83] to [118] were selected and included in the qualitative content analysis, and thus contributed to the Findings and Discussion sections; however, they were not cited directly in the body of this paper.

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APPENDIX A: MATRIX OF CEEA PROCEEDINGS INCLUDED IN THIS REVIEW

The articles are sorted first by publication year, then alphabetically by lead author.

RESEARCH QUESTION:	1: General Frameworks (16 papers)		2: Specific Activities & Methods (82 papers)				3: Roles & Responsibilities (2 Papers)	4: Perspectives (6 Papers)	
TOPIC:	Model (steps) followed	Framework comparison	Creation of indicators, curriculum mapping	Assessment	Continual improvement	Software tools	Collaborative approaches, specialized roles	Concerns, issues	Benefits
Cloutier et al. 2010		✓							
Remenda 2010		✓							
Stiver et al. 2010								✓	
Strong & Young 2010								✓	
Cloutier et al. 2011				✓					
Dew & Lavoie 2011						✓			
Easa & Lachemi 2011	✓								
Ferens & Kinsner 2011				✓					
Frank et al. 2011									✓
Frank & Young 2011				✓					
Harris et al. 2011		✓							
Kozanitis & Cloutier 2011				✓					
McCahan et al. 2011			✓						
Parker et al. 2011				✓					
Platanitis & Pop-Iliev 2011		✓							
Romkey & McCahan 2011							✓		
Stiver 2011		✓							
Wolf & Stiver 2011			✓						
Acheson et al. 2012					✓				
Ambidge et al. 2012				✓					
Chong & Romkey 2012				✓					
Easa 2012	✓								
Easa et al. 2012				✓					
Hodgson & Van der Loos 2012				✓					

Appendix A, continued.

RESEARCH QUESTION:	1: General Frameworks		2: Specific Activities & Methods				3: Roles & Responsibilities	4: Perspectives	
TOPIC:	Model (steps) followed	Framework comparison	Creation of indicators, curriculum mapping	Assessment	Continual improvement	Software tools	Collaborative approaches, specialized roles	Concerns, issues	Benefits
Ingram et al. 2012			✓						
Kaupp et al. 2012	✓								
Lye 2012								✓	
MacIsaac et al. 2012				✓					
Mann & Morrison 2012				✓					
McCahan & Romkey 2012	✓								
Spracklin-Reid & Fisher 2012			✓						
Ahmed et al. 2013				✓					
Akhmadeeva et al. 2013								✓	
Bégin 2013						✓			
Bégin & Charland 2013	✓								
Cicek, Ingram & Sepehri. 2013			✓						
Cicek, Labossiere & Mann 2013				✓					
Dupuis & St-Pierre 2013				✓					
Gopakumar et al. 2013								✓	
Kaupp et al. 2013						✓			
Moazzen et al. 2013				✓					
Parker & Topping 2013				✓					
Sepehri et al. 2013				✓					
Spracklin-Reid & Fisher 2013				✓					
Wright et al. 2013				✓					
Beach & McCahan 2014			✓						
Brennan et al. 2014				✓					
Cicek, Ingram & Sepehri 2014			✓						
Cicek, Labossiere & Ingram 2014				✓					
Cicek, Ingram, Sepehri et al. 2014				✓					

Appendix A, continued.

RESEARCH QUESTION:	1: General Frameworks		2: Specific Activities & Methods				3. Roles & Responsibilities	4: Perspectives	
TOPIC:	Model (steps) followed	Framework comparison	Creation of indicators, curriculum mapping	Assessment	Continual improvement	Software tools	Collaborative approaches, specialized roles	Concerns, issues	Benefits
Dew et al. 2014			✓						
Donald et al. 2014						✓			
Frank et al. 2014						✓			
Hertrich & Chassé 2014				✓					
Kaupp & Frank 2014 (Approaching the loop)					✓				
Kaupp & Frank 2014 (Evaluation of software tools)						✓			
Kennedy et al. 2014			✓						
Kishawy et al. 2014	✓								
Mackie & Mann 2014				✓					
Nelson 2014				✓					
Parker et al. 2014				✓					
Spracklin-Reid 2014				✓					
Spracklin-Reid & Fisher 2014						✓			
Stagner & Johrendt 2014				✓					
Cicek, Ingram & Sepehri 2015			✓						
Cicek, Laboissiere & Ingram 2015				✓					
Gwyn & Gupta 2015				✓					
Hamou-Lhadj et al. 2015	✓								
Kaupp & Frank 2015						✓			
Nizami et al. 2015				✓					
Oakes et al. 2015				✓					

Appendix A, continued.

RESEARCH QUESTION:	1: General Frameworks		2: Specific Activities & Methods				3: Roles & Responsibilities	4: Perspectives	
TOPIC:	Model (steps) followed	Framework comparison	Creation of indicators, curriculum mapping	Assessment	Continual improvement	Software tools	Collaborative approaches, specialized roles	Concerns, issues	Benefits
Petkau 2015 (Industry perceptions of graduate attribute requirements)				✓					
Petkau 2015 (Industry perceptions of graduate attribute competencies)				✓					
Saunders & Mydlarski 2015	✓								
Spracklin-Reid et al. 2015				✓					
Wagner et al. 2015				✓					
Zytner et al. 2015				✓					
Bouslimani et al. 2016				✓					
Brennan et al. 2016						✓			
Cicek et al. 2016		✓							
George et al. 2016						✓			
Gwyn 2016				✓					
Ismail 2016						✓			
Jamieson & Shaw 2016				✓					
Kaupp 2016						✓			
Kaupp & Frank 2016	✓								
Kocheksaraai & Osgood 2016				✓					
Lanziner & Strong 2016				✓					
Lesmond et al. 2016				✓					
Milne et al. 2016				✓					
Parker et al. 2016				✓					

Appendix A, continued

RESEARCH QUESTION:	1: General Frameworks		2: Specific Activities & Methods				3. Roles & Responsibilities	4: Perspectives	
TOPIC:	Model (steps) followed	Framework comparison	Creation of indicators, curriculum mapping	Assessment	Continual improvement	Software tools	Collaborative approaches, specialized roles	Concerns, issues	Benefits
Patterson et al. 2016				✓					
Ahmed 2017				✓					
Al-Hammoud et al. 2017			✓						
Anderson et al. 2017						✓			
Cicek et al. 2017				✓					
George & Peyton 2017			✓						
Gwyn 2017							✓		
Hoffart et al. 2017				✓					
Ismail 2017, OBACIS Phase II						✓			
Ismail 2017, OBACIS Phase III						✓			
Ivey et al. 2017					✓				
Kocheksaraii & Osgood 2017				✓					
Memarian & McCahan 2017				✓					
Milne et al. 2017				✓					
Razavinia & Mydlarski 2017	✓								