A SYSTEMATIC APPROACH FOR TOOL-SUPPORTED PERFORMANCE MANAGEMENT OF ENGINEERING EDUCATION

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Abstract

Performance management of engineering education emerges from the need to assure proper training of future engineers in order to meet the constantly evolving expectations and challenges for the engineering profession. The process of accreditation ensures that engineering graduates are adequately prepared for their professional careers and responsibilities by ensuring that they possess an expected set of mandatory graduate attributes. Engineering programs are required by accreditation bodies to have systematic performance management of their programs that informs a continuous improvement process. Unfortunately, the vast diversity of engineering disciplines, varieties of information systems, and the large number of actors involved in the process makes this task challenging and complex.

We performed a systematic literature review of jurisdictions around the world who are doing accreditation and examined how universities across Canada, US and other countries, have addressed tool support for performance management of engineering education. Our initial systematic approach for tool supported performance management evolved from this, and then we refined it through an iterative process of combined action research and design science research. We developed a prototype, Graduate Attribute Information Analysis (GAIA) in collaboration with the School of Electrical Engineering and Computer Science at the University of Ottawa, to support a systematic approach for accreditation of three engineering programs.

This thesis contributes to research on the problem by developing a systematic approach, a tool that supports it, a set of related data transformations, and a tool-assessment checklist. Our systematic approach for tool-supported performance management addresses system architecture, a common continuous improvement process, a common set of key performance indicators, and identifies the performance management forms and reports needed to analyze graduate attribute data. The data transformation and analysis techniques we demonstrate ensure the accurate analysis of statistical and historical trends.

Acknowledgments

I would like to express my sincere gratitude to Claude D'Amours, Voicu Groza, Stéphane Sommé, Emad Gad, Derek McNamara and all professors from the School of Electrical Engineering and Computer Science who used GAIA – those who joined recently and those, who stood by me since the very challenging and full of surprises Fall of 2015. Miguel Garzon, Christopher Sibbald, David Knox, Hussein Al Osman, Fadi Malek, Gilbert Arbez, Tet Yeap, Daniel Amyot and Emil Petriu - your input, trust and devotion made this project a success!

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List of Acronyms

Acronym	Definition
ABET	Accreditation Board for Engineering and Technology
ACTS	ABET Compliance Tracking System
AMM	Accreditation Management Model
AMS	Accreditation Management System
AP	Assessment Platform
API	Application Programming Interface
AR	Action Research
AS	Analytics System
BINT	Behavioral Intention
CCIP	Common Continuous Improvement Process
CDEF	Course Data Entry Form
CEAB	Canadian Engineering Accreditation Board
CETA	Comprehensive Economic and Trade Agreement
CIP	Continuous Improvement Process
CIPS	Canadian Information Processing Society
CKPI	Common Key Performance Indicators
CMT	Curriculum Mapping Tool
COOPR/C	COOP Progress Report per cohort
CPR/C	Course Progress Report per Cohort

CPRF	Common Program Report Form
CRF	Course Report Form
DTAT	Data Transformation and Analysis Technique
DSR	Design Science Research
EC	Engineers Canada
EC2000	Engineering Change 2000
EEF	Employer Evaluation Form
FTE	Full Time Equivalent
GAA	Graduate Attribute Assessment
GAIA	Graduate Attribute Information Analysis (System)
GAR/C	Graduate Attribute Report per Cohort
IQAP	Institutional Quality Assurance Process
L/CMS	Learning Content Management System
LMS	Learning Management System
LO	Learning Outcome
LTC	Level of Tool Complexity
LTI	Learning Tools Integration (standard)
PBC	Perceived Behavioral Control
PRF	Program Report Form
PRF-C	Cohort Program Report Form
PEOU	Perceived Ease of Use
PI	Performance Indicator
PU	Perceived Usefulness

SaaS	Software as a Service
SUS	System Usability Scale
TAI	Technology Adoption Issues
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
UA	User Attitude
UCTEP	User-Centered Tool Evaluation Process
UI	User Interface
UTAUT	United Theory of Acceptance and Use of Technology
WA	Washington Accord

Chapter 1. Introduction

1.1 The Problem

In general, performance management of engineering education emerges from the need to prepare engineering programs for accreditation and the need to assure that the proper training of future engineers meets the constantly evolving expectations and challenges of the engineering profession. Performance management of engineering education is complex, since it requires data collection across a large number of actors (professors, students, employers), over a large period of time (4+ years), across a diverse and sophisticated set of activities (engineering education involving many disciplines). Matters are further complicated by the fact that engineering education cuts across many departments (including ones outside the faculty of engineering) and many information systems. A systems approach to performance management of engineering education is needed to ensure consistency, completeness, integration, sustainability, adoption, and adaption within the context of the ongoing evolution and continuous improvement of engineering program themselves as they continue to meet the needs of society around the world.

The traditional approach to performance management of engineering education in Canada, via accreditation, has been input-based, focused on metrics mainly related to course content and curriculum coverage (Kennedy et al, 2014). Previous accreditation standards targeted successful development of mathematical, scientific and technical knowledge and listed particular requirements for program faculty and facilities (Volkwein, Lattuca, Terenzini, Strauss, &

Sukhbaatar, 2004). The need for advanced benchmarking set by the EC2000 project (Lattuca, Terenzini, & Volkwein, Engineering Change: A Study of the Impact of EC2000, 2006), and mobility of engineering professionals due to globalization has led to a shift to outcome-based assessment (EC, 2014), (Dixon, 2013), (PPF, 2009), (Greenwood, 2011), (Grear, 2006), (SA, 2014). Developing professional skills, such as solving unstructured problems, communicating effectively, and working in teams are important for today's engineers (Barrie, 2006), (IEA, 2016), (CEAB, 2015).

Performance management of engineering education, though, is not simply a Canadian issue. The era of globalization and mobility we live in has allowed for the exchange of skills, knowledge and ideas beyond any geographic or political borders. Educational institutions around the world are expected to graduate engineering professionals who can perform and succeed in a consistent manner in any international location. To assure the successful completion of that task, engineering accreditation boards' focus begins to evolve from quality of engineering curriculums and their implementation to performance management of engineering education.

The history of engineering education is wrapped around the constant request to meet employers' needs and improve professional performance. The first engineering professional organization to deal with accreditation, regulation, and professional development of engineering programs was established in 1934 in New York under the name Engineers' Council for Professional Development (ECPD). In 1980 it adopts a new name Accreditation Board for Engineering and Technology (ABET) to more accurately describe its emphasis on accreditation (ABET, Accreditation Board of Engineering and Technology. History., n.d.). In 1997, it launched a revolutionary program EC 2000 that focuses on outcomes-based learning. It also established procedures and requirements for engineering programs to provide graduates with the technical and professional skills employers demand. The conceptual framework of EC 2000 as presented in *A study of the impact of EC* 2000 (Lattuca, Terenzini, & Volkwein, 2006) is shown in Figure 1.

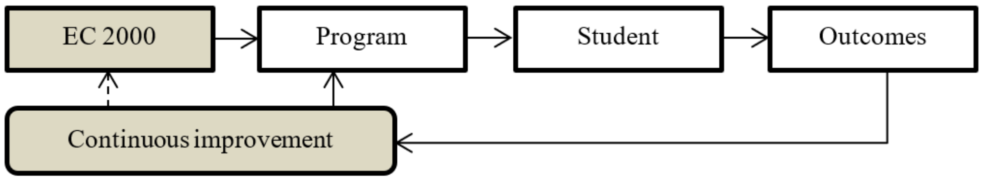


Figure 1. Conceptual framework of EC 2000 Change Study

Two of the four elements of the Canadian Accreditation Improvement Program (AIP) are related to selecting and implementing a data management system and introducing a process for continual improvement (EC, Accreditation Improvement Program, 2018). There is a long history of how this may or should be done. The experiences lead to (1) identifying the need for performance management, and (2) identifying the difficulty of the process. A common conclusion is that for the performance management to be comprehensive, consistent and repeatable we need a systematic data-intense approach; in order to minimize its complexity, we heed a tool support. Several ways to analyze and interpret assessment information in engineering (Stassen, Doherty, & Poe, 2001), the role of an engineering faculty network in the accreditation (Klassen, 2018), and issues like data aggregated approach (Pieper, Fulcher, D. L. Sundre, & Erwin, 2008), data reliability within the process (Weber, 2009), and how methods of data investigation affect the use of assessment data for continuous improvement (Heritage, May 2005) are being addressed. A detailed approach on how to address Engineering Criteria 2000 and ABET accreditation requirements is presented by the Ohio State University (Soundarajan, September 2010).

A summary and comparison of the outcome-based criteria for international accreditation bodies and the statements of graduate attributes and professional competency profiles is outlined in the *Graduate Attributes and Professional Competences* document issued by International Engineering Alliance (IEA) (IEA, 2013). The document is of particular interest for this thesis because it presents the background of the developments, as well as their purpose and methodology.

Most of the literature from the 1960s, 1970s and 1980s on quality assessment of engineering programs focused on the curriculum in terms of the subject matter taught and hours spent in lectures and labs. Since 1997, there has been a major change in the approach. The focus is on outcome-based assessment with an emphasis on what is learned rather than on what is taught. In Canada, the transition to outcome-based assessment is outlined in a publication from CEAB (EC, Manual of Accreditation Precedures, Updated January 2015, 2015), approved by Engineering Canada (EC) and published in 2008. It has been updated each year ever since. Engineering programs undergoing review in 2014 - 2015 were the first in Canada required to collect and use outcome-based data for graduate attribute (GA) assessment within a process of ongoing continuous improvement.

Without processes, tools and systems in place, the task has proven challenging (Chanock, 2013) (Radloff, de la Harpe, Dalton, Thomas, & Lawson, 2008). The need for collecting and processing data from different sources (courses, coop, employers, and alumni) and in different forms (quantitative and qualitative reports, surveys, exams, evaluation forms etc.) created many issues for instructors and program managers. Thus, the whole process of data selection, collection, analysis and application of results needed to be planned, executed, analyzed and reviewed on a continuous basis. Alongside the process arises the need for a systematic approach to engineering education performance management. The aim of this research is to identify the gaps in engineering education performance management that prevent successful program improvement and to address those gaps by introducing a technology-supported systematic approach for engineering education performance management.

1.2 Motivation

In this work, we explore accreditation experiences from engineering schools in Canada, US, Australia, Ireland and the UK. Furthermore, we iterate through a series of theoretical analysis and practical experiences deploying a prototype tool to support performance management of engineering education for three programs in the School of Electrical Engineering and Computer Science at the University of Ottawa.

We have taken a system engineering approach that focusses on identifying the roles, the actors, the user interfaces and the reports. The approach is focused on data, but also on user interfaces. Both are critical to address data collection, real-time reporting, analysis, historic data trends, and cohort data in the context of continuous program improvement for engineering education.

1.3 Research Methodology

In defining our research methodology, we use the classic “research onion” model shown in Figure 2 below (Saunders, Lewis, & Thronhill, 2012).

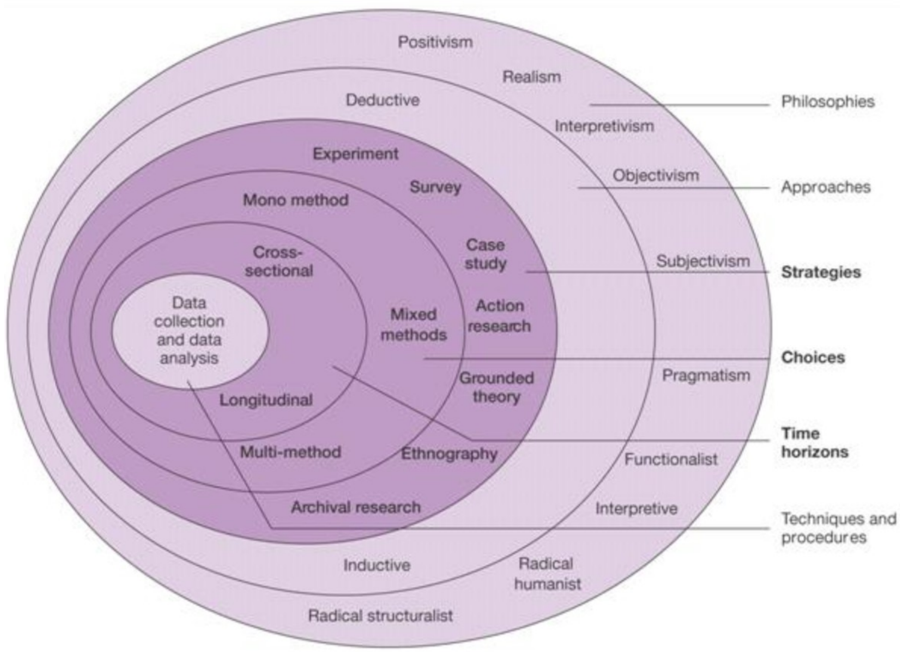


Figure 2. Research Onion. Original Source (Saunders, Lewis, & Thronhill, 2012).

The complexity of our choice comes from the fact that the systematic approach for tool-supported performance management we propose is in continuous dynamic state of ongoing development. We are working in collaboration with the School of Electrical Engineering and Computer Science at the University of Ottawa, motivated to address the particular challenges they are facing. At the same time, we are very much aware that others around the world are also motivated to address similar challenges as mandated by the global approach to accreditation of the engineering profession. This means that although the aim of our research remains constant (reflecting its long-term outcomes), its objectives or short-term targets are far from being perpetual. De facto they are in parabolic relation to two constantly moving targets: 1) an ongoing continuous improvement process within the faculty and 2) maintaining and exceeding standards achieved by other domains/educational institutions. Following Shaw's argument that the aims and objectives of a research are determined by how much is already known about the object of that research (Shaw, 1999), we are obliged to explore current developments across engineering institutions and programs in Canada and internationally. We seek improvement by ensuring the needs of our faculty are met, and also by comparing our own approach to other approaches. These tasks define our research as exploratory. Furthermore, an exploratory type of research approach is also used in developing the tool evaluation criteria as described in Section 2.1.4. In the research process, we apply empirical observations supported by logical deductive statistical analysis of quantitative data using positivism as our research philosophy (John & Johnson, 2010).

We use an iterative deductive research approach to derive a hypothesis, test it against selected criteria, evaluate the outcomes and implement respective modifications. Within each iteration (case study) though we use data collection (observations) followed by analysis. They respectively lead to a hypothesis through which we develop an improved version of the theory. This defines an internal set of elements of induction (building hypothesis).

Our research strategy is based on case studies as a combination of action research and design science research methodology. The goal is to generate an artefact by iteratively solving a problem targeting specific characteristics of the real-life cases.

We apply mixed research model as well - the design science research process model (DSR) in combination with elements of action research (AR) for management of change. We follow the elements of DSR model as described by (Vaishnavi & Kuechler, 2004). The original model is shown in Figure 3.

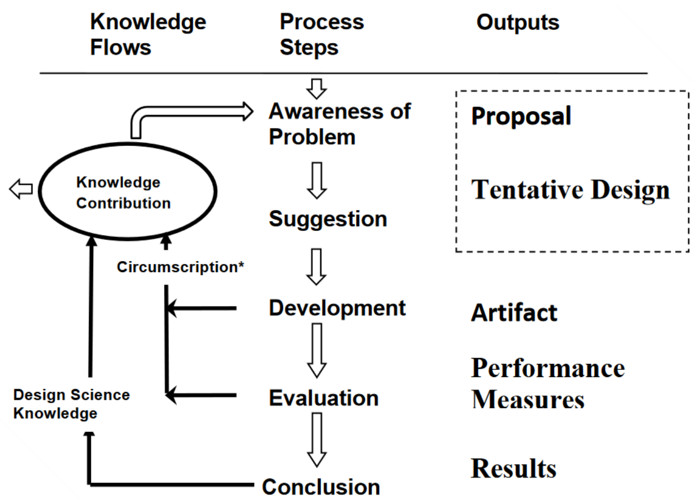


Figure 3. Design Science Research Model.

Source (Vaishnavi & Kuechler, 2004).

Related scholar publications along the process of implementing, evaluating and communicating the change brought our research model closer to the DSR process model sequence defined by Peffers et al. (Peffers, et al., 2006) as shown in Figure 4.

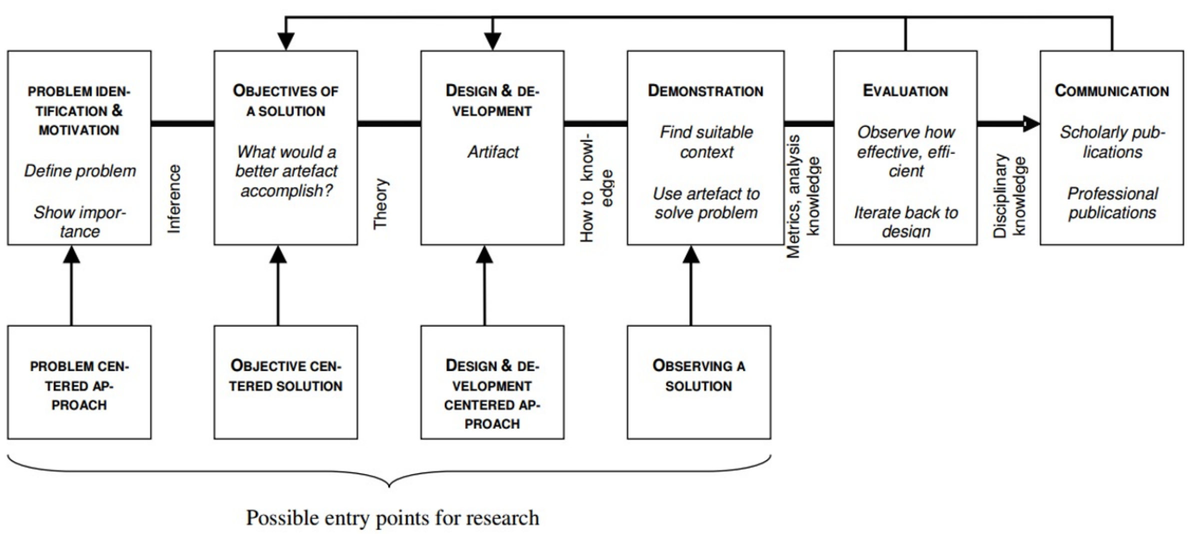


Figure 4. DSR Process Model Sequence.

Original Source (Peffers, et al., 2006).

In each of the six steps we analyze the results and identify the gaps we address in the next phase of the tool. Results and analysis are recorded after each iteration as shown in Figure 5.

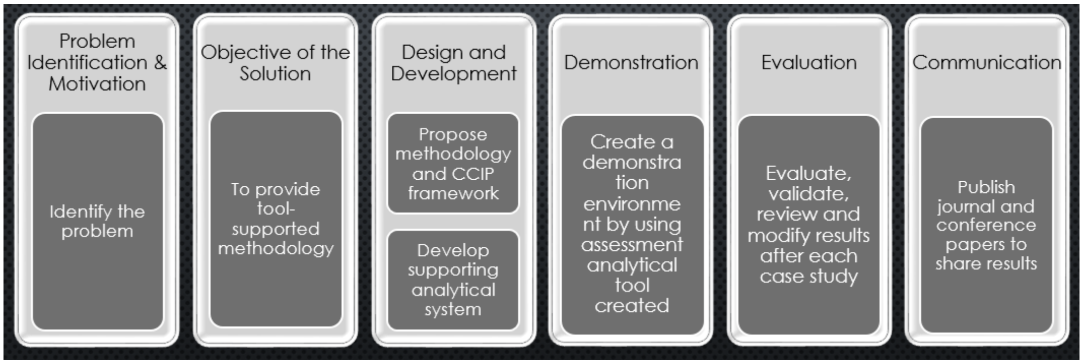


Figure 5. 6-Step DSR Components

A graphical presentation of our complete research model is presented in Figure 6. The grey column on the far right indicates the phase of our research that corresponded to each of the case studies that are described in Chapter 4 of this thesis. The first stage of our research was inductive. We did a systematic literature review to infer a systematic approach for tool-supported performance management. This stage was supported by a case study to evaluate how well the theory we had developed was able to explain the gaps in current practice. In the subsequent phases of the research we pursued a deductive DSR approach. At each stage, we built prototypes based on a modified theory to address the gaps. Evaluation included meeting the expectations for our local collaborator in the case study, as well as comparison to related works in the literature. There is a publication related to each phase of the research.

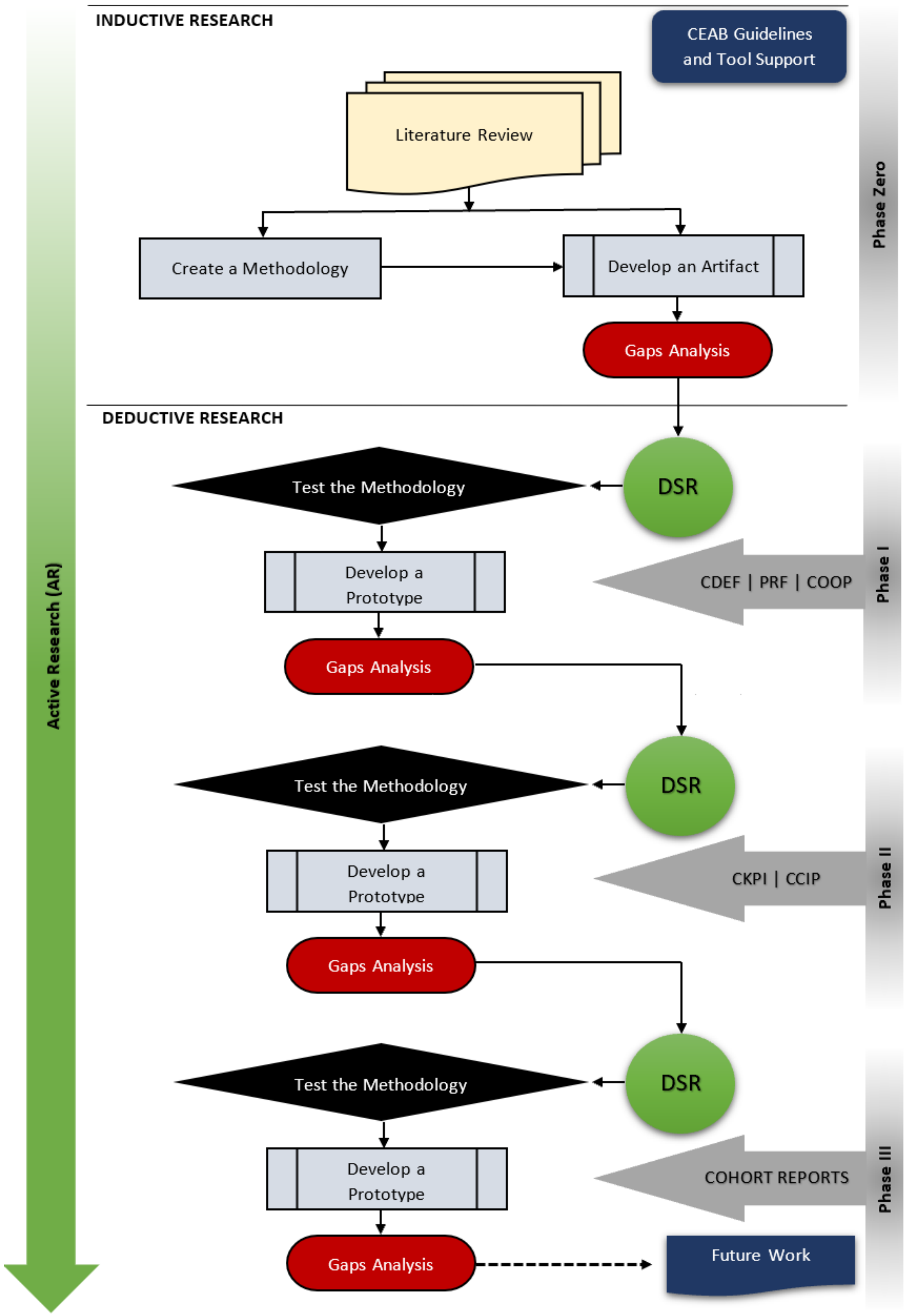


Figure 6. GAIA Research Model

In addition to the application and combination of several research methods in our study we have implemented the four types of triangulation – methods triangulation (different types of data), triangulation of sources, analysis triangulation and theoretical perspective triangulation (Patton, 2002), (Denzin, 2006):

- Evaluation of the tool is performed by specifically developed TAM–based method;
- We use checklist to evaluate the methodology;
- For graduate attribute assessment (GAA) we use quantitative data from academic users, qualitative data from non-academic users (employers, stakeholders) as well as data provided through different LMSs already in place.

1.4 Thesis Contributions

Our thesis work has resulted in the following contributions:

A) A systematic approach for tool-supported performance management of engineering education that is designed to guide anyone responsible for engineering programs at an educational institution on the steps to follow in creating a system for assessing engineering programs with appropriate tool support to ensure adoption, efficiency and effectiveness. The steps include:

- Establishing a system architecture for engineering education performance management that defines actors and system components; their inputs, outputs and responsibilities; and the relationships and interactions between them.

- Establishing a common continuous improvement process (CCIP) that defines how performance management takes place in a manner that ensures continuing evolution and improvement of engineering programs as technology and society change.
- Establishing a set of common key performance indicators (CKPI) to standardize how programs are measured and enable comparisons between programs.
- Establishing tool-support with a set of performance management forms for collecting and processing data to visualize the state of an engineering program and guide decision making in the continuous improvement process.

B) A prototype system for supporting engineering education performance management based on our methodology, called the Graduate Attribute Information Analysis (GAIA) system that has been prototyped and improved on an ongoing basis in collaboration with the School of Electrical Engineering and Computer Science at the University of Ottawa since 2015.

C) A set of data transformation and analysis techniques, used by performance management forms, to generate reports for visualization of engineering education performance.

D) A tool-assessment checklist that is designed to guide anyone responsible for engineering programs at an educational institution on how to evaluate the quality of any tool or tools used to support a systematic approach to performance management of engineering education.

The following papers have been published related to the thesis:

1. **A. George**, V. Groza, "Information Analytics System Database for Uniform Approach to Continuous Engineering Program Improvement", 15th International Conference on Engineering of Modern Electric Systems (ICEMES 2019), June 13-14, 2019, Oradea, Romania
2. **A. George**, L. Peyton, "Cohort Analysis and Reporting for Graduate Attribute Assessment", Canadian Engineering Education Association Conference (CEEA 2018), Vancouver, BC, June 3-6, 2018
3. **A. George**, L. Peyton, V. Groza, "Systematic Tool Support of Engineering Education Performance Management", Advances in Science, Technology and Engineering Systems Journal Vol. 3, No. 1, 418-425 (2018), Special issue on Advancement in Engineering Technology, ISSN:2415-6698, DOI 10.25046/aj030151
4. **A. George**, V. Groza, L. Peyton, "Graduate Attribute Assessment in Computer Engineering Program at University of Ottawa - Use of Assessment Analytics for Engineering Accreditation", 17^{th} IEEE International Conference on Advanced Learning Technologies – ICALT2017, Timisoara, Romania, July 3-7, 2017, DOI 10.1109/ICALT.2017.99
5. **A. George**, L. Peyton, "Faculty Level Support of Graduate Attribute Assessment and Continuous Improvement Process", Canadian Engineering Association Conference, CEEA'17, Toronto, ON, June 4-7, 2017, DOI 10.24908/pceea.v0i0.1076
6. **A. George**, L. Peyton, V. Groza, "Graduate Attribute Information Analysis System (GAIA) – From Assessment Analytics to Continuous Program Improvement - Use of Student Assessment Data in Curriculum Development and Program Improvement", IEEE CAS/CS 14th International Conference on Engineering of Modern Electric

Systems ICEMES 2017, Oradea, Romania, June 1-2, 2017, DOI 10.1109/EMES.2017.7980398

7. **A. George**, L. Peyton, “Work-Term Experience and Graduate Attribute Assessment in Software Engineering Co-op Program at University of Ottawa”, Canadian Engineering Education Association Conference, CEEA’16, Halifax, NS, June 19-22, 2016, DOI 10.24908/pceea.v0i0.6485
8. **A. George**, T. Lethbridge, L. Peyton, “Graduate Attribute Assessment in Software Engineering program at University of Ottawa – Continual Improvement Process”, Canadian Engineering Education Association Conference, CEEA’16, Halifax, NS, June 19-22, 2016, DOI: https://doi.org/10.24908/pceea.v0i0.6484

1.5 Thesis Organization

In Chapter 2, we explore the evolution of assessment methodologies in engineering education and its relation to accreditation of engineering programs. In the process, we identify the need for tool support for performance management in engineering education and identify related works. We address the related works again in Chapter 7 for comparison as part of the GAIA tool assessment. Furthermore, using TAM as background for our analysis, we discuss adoption issues for tool support of graduate attributes assessment.

In Chapter 3, we present our systematic approach for tool-supported performance management of engineering education. We introduce a standardized performance management model to support common continuous improvement process, standardized performance indicators and generated reports.

Chapter 4 follows the development stages in the evolution of our prototype system GAIA that supports the proposed systematic approach by introducing four GAIA case studies: Phase 0, GAIA Phase I, GAIA Phase II, and GAIA Phase III. All case studies are subsequent to the need to meet CEAB accreditation requirements and assure common CIP across three engineering programs.

The data transformation and analysis techniques we developed for performance management reporting of engineering education are presented in Chapter 5.

In chapter 6 we design a tool-assessment checklist for performance management of engineering education. Evaluation of tools against 13 variables including usefulness, usability, good attitude toward usage and interoperability is proposed. The evaluation criteria focus on major TAM variables, UTAUT models used in academia and custom created variables which serve our particular interest.

In Chapter 7, we evaluate the thesis contributions. We perform statistical analysis of the GAIA User Survey we administered on campus among different categories of GAIA users, provide comparison to related work, and discuss assumptions, limitations and threats to validity.

Finally, in Chapter 8 we present our conclusions and discuss possible future work.

Chapter 2. Background and Related Work

"We think we have knowledge of a thing only when we have grasped its cause."

Aristotle (SEP, 2015)

In this chapter, we provide background information relevant to the thesis, identify related work and perform gap analyses in terms of information system models, tool support specifications and tool adoption.

To highlight the specifics of the problem as well as innovative aspect of proposed solutions we survey achievements reported by engineering schools across Australia, Ireland, New Zealand, UK and US, all co-signatories alongside Canada, of the Washington Accord (WA), Dublin Accord (DA) and Sydney Accord (SA) (IEA, 2015)..

2.1 History of Engineering Accreditation

"[Herbert] Hoover[1] used to tell of meeting a woman on a ship while traveling. After several conversations over a week or so, the woman asked what his occupation was. Hoover told her he was an engineer, a mining engineer. And the woman replied: An engineer? I thought you were a gentleman."

(MachineDesign, 2009)

[1] Herbert Hoover (1874 – 1964), mining engineer, civil engineer, businessman, humanitarian, 31st president of the United States.

General directions for the evolution of engineering education in Canada were first established by the Canadian Academy of Engineers. In a report published in 1998, the academy outlines five recommendations meant to broaden the engineering undergraduate curriculum and expand the relevant technology – (1) learning beyond the technical aspects of a specific engineering discipline, (2) developing learning skills, (3) vision, values and behavior of faculty members, (4) quality of research, (5) efficiency of engineering faculties in improving technological literacy of the general public (Heidebrecht, 1999).

1989 is the year that marks a milestone in engineering education, accreditation and mobility. Australia, Canada, Ireland, New Zealand, UK and US identified substantial similarities in their set of criteria, policies and processes for engineering accreditation that allowed for a common formative approach toward engineering legislation and licensing (IEA, 2016). Thus in 1989, they become the founding signatories of The Washington Accord (WA), a multi-lateral international agreement between bodies responsible for accrediting engineering programs. The basis for WA model is a three-stage process (IEA, 2014) outlined as follows:

1. Stage I (education) – completion of externally accredited engineering program of 4-5 years duration at the post-secondary level.
2. Stage II (supervised training and experience) – meeting standards for professional competency by gaining experience in engineering practice under the supervision of a licensed professional engineer.
3. Stage III (practice) - observe a code of conduct and maintain competency at workplace.

This was the very first international engineering agreement to establish the goal of a globally connected workplace with a mutual understanding about the quality of engineers. The WA was a major force for introducing the concept of graduate attributes in 2001. The increase of engineering mobility and the need to accommodate developments from non-signatory countries initiated in 2008 development of rules for trans-national accreditation and WA recognition (IEA, 2014).

The WA mutual recognition agreement was the result of a decades-long effort from each signatory country to establish professional engineering organization committed to the development and application of good practice in engineering education and at professional level. Figure 7 below illustrates the history pyramid of developing engineering into restricted profession. Figure 7a illustrates the time-line from creating a professional engineering organization to the first accreditation of engineering programs (indicated in brackets). Figure 7b tracks the time when different accreditation bodies started implementing outcomes-based criteria and measuring graduate attributes for accreditation of engineering programs.

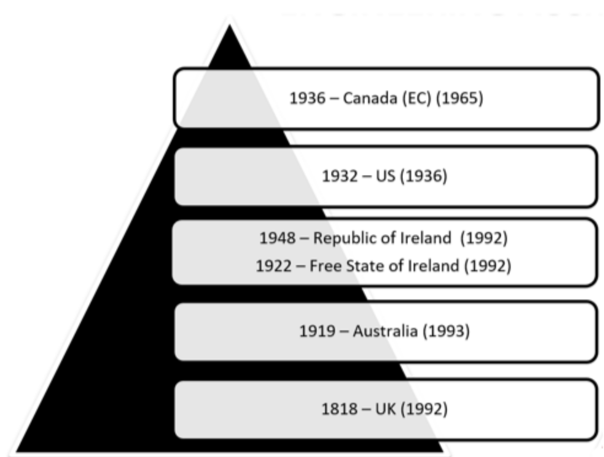


Figure 7a. Creation of Professional Engineering Organization

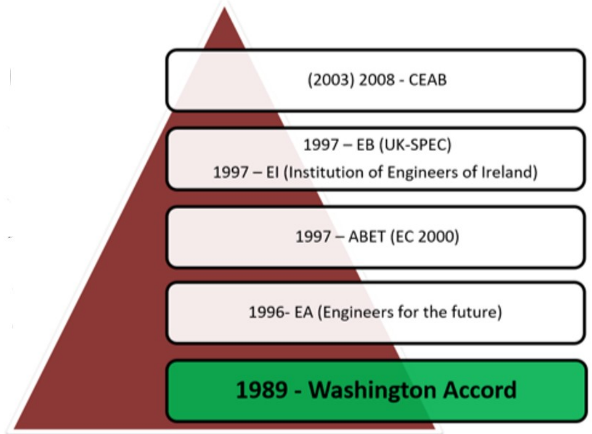


Figure 7b. Involving Outcomes-Based Criteria

By definition, a professional degree is designed to provide professional knowledge for application in professional practice; as opposed to an academic degree which emphasizes the theory rather than professional practice. It is estimated that the path from academic engineering degree to professional engineering degree is about 4 years given that the academic degree is achieved at an accredited engineering institution. Statistics Canada reports that only 47.7% from the 12,994 engineering graduates in 2013 expanded their engineering degree from academic to professional (Canada, 2017). According to 2018 National Membership Information at Engineers Ontario as of December 31, 2017, there are 295,926 engineering graduates who have professional engineering degree (P. Eng.) (Engineers, 2018).

2.2 Performance Management of Engineering Education

In this section, we review and discuss approaches, processes, systems and tools used by different engineering schools across Canada and countries who are signatories to the Washington Accord. We explore the need for technology support in engineering education management (2.2.1) and establishing related processes (2.2.2). In section 2.2.3 we explore different models and analytical tools used for graduate attribute assessment (GAA). Developing criteria for assessment tool evaluation is explored in section 2.2.4. We discuss technology adoption issues and their corresponding proposed solutions in section 2.2.5. We discuss a theory-based approach to evaluation of graduate attributes assessment tool support in section 2.2.6. Finally, we discuss the concept of continuous improvement that is supported by performance management in section 2.2.7.

2.2.1 The Need for Tool-Supported Management of Engineering Education

The Canadian Engineering Accreditation Board (CEAB) identifies 12 graduate attributes (GA) to measure engineering undergraduate students' achievement required for the successful acquisition of academic and practical skills they must possess at graduation in order to be licensed as professional engineers in Canada. They are also obliged to provide evidence of using the data for continuous program improvement (CEAB, 2014). Although reporting GA achievement is required, a way to measure them or a defined process of data management is not specified by the accreditation board. Instead, engineering schools are given the opportunity to adapt, adopt or develop their own systems and processes. Thus, establishing a proper tool-supported system for data collection, analysis and reporting becomes essential for accreditation and program development. We started with exploring experiences and successes of engineering schools in Europe, Americas, Australia and New Zealand. We only looked at accreditation tools and methodologies that incorporate outcomes-based assessment criteria.

Radloff, de la Harpe, Dalton, Thomas and Lawson report that for over a decade the academic staff at several Australian universities charged with accreditation, finds assessing GA challenging (Radloff A. , de la Harpe, Dalton, Thomas, & Lawson, 2008). They see the solution as deeper engagement of the staff into a shared understanding of how to teach and assess GA integrated into their subject.

Different statistical approaches to analyzing and interpreting assessment data are presented by the Office of Academic Planning and Assessment (OAPA) at the University of Massachusetts (Stassen, Doherty, & Poe, 2001).

Integrating data by cohort using analytical methods and correlations is the subject of collaborative research between Northern Arizona University, Christopher Newport University and James Madison University (Pieper, Fulcher, D. L. Sundre, & Erwin, 2008).

Weber addresses the major concern in data analysis – reliability of the results (Weber, 2009). The study compares different treatments of assessment data using T-test, ANOVA and ANCOVA. By dividing the data set into distinct components, it illustrates the use of different methods to analyze data variance for reliability.

Approaches by Canadian universities involve adopting suitable vendor products, adapting tools and processes in place and evolving them into their own learning management system that suits the institutional needs. Queen's University, University of Calgary, University of Toronto, Concordia University, University of British Columbia, University of Manitoba and Dalhousie University outlined and compared their institutional approaches to accreditation requirements in a joint publication (Kaupp J. , et al., 2012). In that joint research, Concordia University is identified as one of the first Canadian engineering schools to develop their own Learning Management System able to collect data and allow for sharing between users.

Chong and Romkey explore the challenges of using common rubric development to simultaneously serve two purposes - measure learning objectives of a course and provide reliable data for students' GAA (Chong & Romkey, 2012a). They evaluate the process of mapping performance indicators (PI) to existing rubrics through collecting feedback from students and supervisors. The authors identify the need for adding a criterion to the rubric that recognizes engineering and science-based knowledge, which is not only learned, but also applied by students. The paper concludes that changes in global learning outcomes and key performance indicators, associated with graduate attributes, over time, lead to ongoing match of course-based assessment tools and rubric elements to accreditation related outcomes. In a relevant paper, Chong and Romkey also identify the need of involving multiple parties in the assessment, in order to maintain usability, reliability and validity of the rubric (Chong & Romkey, 2012b).

In order to develop data transformation and analysis techniques for generating the reports, we explored the different ways for administering assessment data presented by Carleton University (Harris, Russell, & Steele, 2011), University of Alberta (Csorba, Chelen, Yousefi, Andrews, & More, 2013) and University of Calgary (UC, 2017).

2.2.2 Processes for Evaluating Performance Management of Engineering Education

In his famous paper on graduate attributes published back in 2006, Barrie defines assessing GA as "assessing students' qualities" (Barrie, 2006). As a set of "features and characteristics of a product or service that bears its ability to satisfy stated or implied needs" (ISO 9000, 2015). Quality can be measured in different ways especially in academia. Since EC2000, quantifying engineering qualities shifted from measuring what is taught to measuring what is learned (Lattuca, Terenzini, & Volkwein, Engineering Change: A Study of the Impact of EC2000, 2006).

In 2004, Maxim describes an assessment plan for student performance in three undergraduate engineering programs - computer science, information systems, and software engineering at University of Michigan at Dearborn (Maxim, 2004). It lists course learning outcomes (LO), measurement instruments used to assess them, student achievement on each particular outcome, and the average score. The assessment plan is in fact a process involving the use a gradebook tool for evaluation. The approach gained popularity because of its ability to serve simultaneously as a grade book and LO evaluation tool (Maxim, 2004).

In 2009, Engineers Australia proposed a set of common performance indicators per criteria and advised that a "unified analysis either for all programs or groups of programs, will be appropriate because of a common operating environment" (EA, 2009). Reports on the Australian national project to create, identify, develop and implement "indicators and metrics across the Australian university sector" are provided by Chalmers (Chalmers, 2008).

In Canada, Carleton University and the University of Alberta merged the twelve CEAB graduate attributes with their respective indicators, measures and rubrics. The University of Alberta adds an additional step to the process by involving sub-categories associated with learning objectives. They developed a set of sub-attributes per each of the twelve CEAB graduate attributes. Most of these sub-attributes are common across all engineering programs and are measured using assigned performance indicators (UA, 2013). The Queen's university EGAD Project, proposed a GA Assessment Summary (EGAD, 2011). Similar procedures to measure indicators of graduate attributes is proposed by McMaster University (Lightstone, 2015). The Graduate Attribute Committee at University of Toronto developed their own faculty level outcomes and indicators (Norval, 2012) while allowing the modification of performance indicators at the departmental level (Kaupp J. , et al., 2012). In 2014, Guelph presented their own faculty process (Donald & Gordon, 2014) defining indicators for each GA. McGill University in preparation for their 2016 accreditation for 10 of 11 engineering programs determined the graduate attribute indicators for each component within a graded assessment tool (McGill, 2015a), (McGill, 2015b).

2.2.3 Models and Analytical Tools Used for Graduate Attribute Assessment

There have been several attempts by different universities to create their own tool that will inform student learning, serve accreditation, and inform program development as well.

University of West Georgia, US, created a custom-designed software tool intending to collect, analyze and report assessment data for program requirements and for accreditation purposes. The tool called COMPASS supports an existing open-source classroom management system by adding the ability to map course LO (Abunawass, Lloyd, & Rudolph, 2004). It allows for further review and analysis of collected assessment data, but lacks a direct reporting feature. The data needs to be retrieved and formatted in order to produce a course assessment report. The study concludes that such approach complicates the process of data analysis and its implementation for informing program improvement (Abunawass, Lloyd, & Rudolph, 2004).

Curtin University of Technology in Perth, Australia expands the very same approach by developing the Outcomes Database web-based tool in 2005. It maps course LO, unit LO, generic graduate attributes and assessment rubrics. The reports it automatically generates help with the difficult transition from existing program to using outcomes focused assessment (Konsky, et al., 2006). Although the paper does not specify any method of tool evaluation, it does show that the Outcomes Database was successfully implemented across courses that share common units in Information Technology, Computer Science and Software engineering.

A method for evaluation of a centralized e-assessment Research Learning system (REAL) implemented in one US campus is described by McCann (McCann, 2010). The research measures the level of adoption of the tool by faculty, specifically outlining the reasons, and measures the impact the tool has on improving teaching and learning.

In 2015, the University of Notre Dame, Australia introduced an outcomes-based curriculum mapping system, Prudentia©. It allows for constructive alignment between different learning outcomes and informs assessment and instructional methodology (Steketee, 2015). The weak point of the tool as described by the author is its dependence on the quality of the curriculum framework itself.

A targeted search on accreditation supporting tools recommended or provided by an accreditation board have identified the cloud-based accreditation management software Creatrix (Creatrix, 2017) specifically developed to support engineering programs undergoing or preparing for ABET accreditation.

McGill University reports on challenges related to finding a suitable LMS to adapt for the purpose of Graduate Attribute Assessment (Saunders & Mydlarski, 2015). An Excel spreadsheet was specifically developed to automatically calculate the GA score. Reporting of the GAs achievement is based on the overall grade. The authors argue that despite that flaw, the tool was effectively used by instructors and did allow for quicker implementation of the reporting process.

Some of the educational institutions refer to ready products on the market, but their inability to comply with existing processes and systems leads to difficulties and eventually to their use being discontinued. Keeling reports that almost a 3 years search for compatible computer-based assessment tools found no tool able to meet particular program needs (Keeling, 2013). Thus, the College of Engineering, Architecture and Computer Science developed a prototype of a tool they called Course Management System (CMS) which, 2 years later evolved into a new more robust system called AssessTrack. Although the evaluation of the tool performed through students' survey indicates their high level of satisfaction (lowest 3.7, highest 4.63) on the Likert 5-point scale (5-strongly agree, 4-agree, 3-neither agree nor disagree, 2-disagree, 1-strongly disagree), the research provides no evidence of the program being able to use the LMS to inform CIP.

2.2.4 Criteria for Assessment Tool Evaluation

The evaluation of assessment tools for the purpose of program development and improvement gained popularity with the rise of outcomes-based assessment methodology. Outcomes-based assessment requires core changes to the assessment techniques that reflect the measurement of what is learned oppose to what is taught.

In exploring available criteria for assessment tool evaluation, we have looked at the experiences reported by engineering and non-engineering programs. The Ontario Adult Literacy Curriculum Framework (OALCF) delivers its goals through the Literacy and Basic Skills (LBS) program. Similar to an engineering program, OALCF satisfies the requirements of employers, trainers and community partners reflecting the need for Employment Ontario to build a highly skilled and educated workforce. They have created an Assessment Tool Evaluation Form (OALCF, 2011) used to measure the efficacy of their formal and informal assessment tools. They propose three evaluation criteria - separating assessment resources containing different assessment tools from individual tools; the ease of accessibility of the tool; and tool's usability (OMTCU, 2011).

Coryn gives a different insight on the role a tool support has in the evaluation practice (Coryn, 2006). He argues that a general misrepresentation of basic terminology creates confusion leading to wrong choice of supporting platform. In his research, the author addresses the difference between support, report and dissemination and points out the importance of being able to correctly identify their targeted aspect. To make support an integral part of the evaluation practice, Coryn sorts it into three categories - direct and indirect, technical and general, and ones that assist clients, stakeholders and users.

Harlen explores a different type of evaluation criteria. It measures advantages and disadvantages of assessment techniques and processes (Harlen, 2007). Its main components are validity, reliability, desired impact, and good use of resources that apply to summative and formative assessment. It allows for creating a reliable assessment database. The study concludes that the criteria are better met when there is greater use of teachers' judgment in assessment as opposed to external tests.

In 2005 Michael Scriven proposes a Key Evaluation Checklist (KEC) that consists of 21 criteria (Scriven, 2011). To each criterion, he assigns "stars, bars and steps". "Stars" are values (weights) that measure the distance between collected data to conclusions about the tool. Their importance is expressed qualitatively (major, medium, minor), quantitatively (by points), or relatively (in a scale in order of their importance). "Bars" are the absolute minimum standard for acceptability and have to be exceeded if the tool is to be accepted. To increase precision each bar and star may include holistic bars or stars. "Steps" are intervals of measured dimensions where the weight of a star changes but does not affect the overall evaluation. Most relevant to our proposed evaluation criteria for assessing GAA tools are cost(reduction), superiority to feasible alternatives (comparison) and generalizability (which covers sustainability, longevity, durability, resilience) alongside knowledge, skills and attitude change of users.

John Brooke created the System Usability Scale (SUS) in 1986 to measure usability of engineering electronic office systems (Brooke, 1996), including ease of administering; reliable results on small sample sizes; effective differentiation between usable and unusable systems. Evaluation results were obtained in a form of survey. Participants were asked to answer 10 questions on a 5-scale grading grid from "Strongly Agree" to "Strongly Disagree". The 10 questions evaluate the usability of an engineering software program that provides integrated email, word processing, and task and time management. In 2013 Brook re-evaluates the efficiency of the SUS model and concludes that it "proved to be an extremely simple and reliable tool for use when doing usability evaluations" (Brooke, 2013). He also demonstrates the potential of the tool when used to compare different systems.

In 1985 Fred Davis proposed the Technology Acceptance Model (TAM), which is described in his Ph.D. thesis (Davis F. , 1986). This is the first model that attempts to explain the reasons behind a system's acceptance or rejection. All previous models failed to provide explanation for the evaluation reason (Davis F. , 1989). In his 1985 model, illustrated in Figure 8, Davis introduces TAM that defines a system use as predictable by user motivation. According to Davis, the system's features and capabilities define user motivation. Figure 8 below shows the original TA conceptual model.

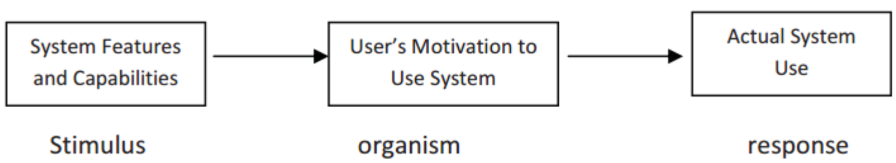


Figure 8. Technology acceptance concept model.

Adapted from: (Davis, 1986)

We also considered the types of constraints selected for the Technology Adoption Model (TAM) by Davis (Davis F. , 1989) and their implementation in measuring behavioral intention to use Learning Management Systems (LMS) (Alharbi & Drew, 2014). Davis initially used 10 closed type statements assessed on a 7-point scale (1= Strongly Agree, 2-6 = Neutral, 7 = Strongly Disagree) for measuring users' responses in regards to Perceived Ease of Use and Perceived Usefulness (Davis F. D., 1986, p.256). Statements were grouped into 3 sections addressing respectively 1) users demographics, 2) methodology and 3) system evaluation.

Developing the structure of our survey we considered the analytical advantages for calculating reliability coefficients such grouping possesses and recommendations for use of different criteria according to the targeted dimensions discussed in (Milner & Furnham, 2017). Further developing the scale, Davis adds Perceived Importance, Evaluation of Information Reports and Usefulness of Findings which increases the initial scale items from 10 to 14 (Davis F. , 1989). Furthermore, we referred to specific characteristics measured in evaluating an ABET related tool for Engineering programs accreditation (Essa, 2010). Being a direct application of the Computer System Usability Questionnaire (CSUQ), developed by IBM in the early 1990s, it consists of 19 questions to assess users' perceived satisfaction with the computer system evaluated on a 7-point scale (IBM-CSUQ, 1995). Several researches point out the advantages of a 5-point scale in terms of decreasing the guess and providing a better response quality (Vagias, 2006), (Bowling, 1997), (Paulhus, 1984). A higher reliability for five-point scales is also reported by several researchers (Harlen, 2007), (Lei, 1994), (Liu, Wu, & Zumbo, 2009).

2.2.5 Technology Adoption Issues

Today's technology provides a variety of LMS solutions, specifically developed to ease the process of data collection and analysis, and yet their implementation is well known to be a difficult process, usually combined with frustration and resistance. Proposing and adapting our new systematic approach for tool-supported performance management was not expected to be any different. In the quest to overcome the anticipated resistance we examined several publications focusing on the causes of this phenomenon. We aimed to identify potential problems and proposed solutions that will not ruin the existing equilibrium of clearly not as efficient as they used to be, but becoming very comfortable with time tools and processes we already have in place.

Predicting, explaining, analyzing and dealing with the difficulties accompanying accommodation of any difference in our human well-balanced domain of familiar features has been an object of long-standing interest (SEP, 2018). The philosophical view on change as union of matter, form, efficiency and purpose (SEP, 2015) is applied for the first time in 1949 by the German philosopher Heidegger in a complex analysis of technology as “human activity” that aims at getting things done (Heidegger M. , 1977). His view is being accepted by many and treated as controversial by many more (Waddington, 2013).

A detailed inside on the concept of “how and why” a new technology is adopted is given by Everett Rogers in his Diffusion of Innovation theory (Rogers, 2003). Based on findings from 5000 research studies Rogers analyzes the factors behind the success in adopting an innovation. He concludes that the attributes with highest influence on the success of the process (with 49-87% interference) are relative advantage, compatibility, trialability (ability to easily transform from empirical to practical solution), observability (user is able to see the results) and complexity.

Several researchers point to a number of reasons people resist change – feeling “overloaded and overwhelmed” (Schuler, 2003), having “obsolete” skills (Yilmaz & Kılıçoğlu, 2013), lacking the ability to handle the change, or even see the need for the change, they see the change as not consistent and potentially failing, or they lack trust towards the people responsible for the change (Hultman, 2003). In fact, recent research indicates that a majority of people who object to change are experienced workers having the ability to foresee the failure of a newly promoted plan which will question their ability to “do things right” (Ford & Ford, 2009).

A case study based on the implementation of a new management program (BATON) was used to develop a managing resistance framework (Kebapci & Erkal, 2009). The authors base their analysis on three differentiated levels of change – individual, team, and organizational level. The research concludes that such structure can be successfully applied to locate problems due to resistance and be used as guide to identify correct solutions. These include clear identification of the purpose for the change and its plan, clear description of expected performance, established decision-making procedures, and established trust and respect among members and teams.

Kezar and Eckel stress the importance of support, collaboration, flexibility, staff development and use of visible results as the most important administrative actions that support an easy adoption of a new approach or tool (Kezar & Eckel, 2002).

Research into adapting a new software package in a variety of European countries offers insides on the time-related aspect of the technology adoption process (Waarts, Everdingen, & Hillegersberg, 2002). The study concludes that the main reason behind an early implementation of the new model was a combination of internal (strategic plan) and external (competition) strategy. The late adoption though was mainly driven by the implementation (scalability) of the tool.

There has been work on TAM for LMS (Fathema, Shannon, & Ross, 2015), (Alharbi & Drew, 2014), (Sharma & Chandel, 2013) for students and course professors, which is relevant, but still leaves a variety of issues to deal with. Available Learning Management support tools (LMST) and Enterprise Solutions (ES) only target a few aspects of GAA process (Alharbi & Drew, 2014), (Kaupp & Frank, 2015), (Essa, 2010). This unnecessary complicates and sometime even prevents the use of technology by causing resistance from players involved (Fathema, Shannon, & Ross, 2015), (Jeffrey, 2015). To explore the dilemma, we will analyze a variety of research related to TAM models used in higher education.

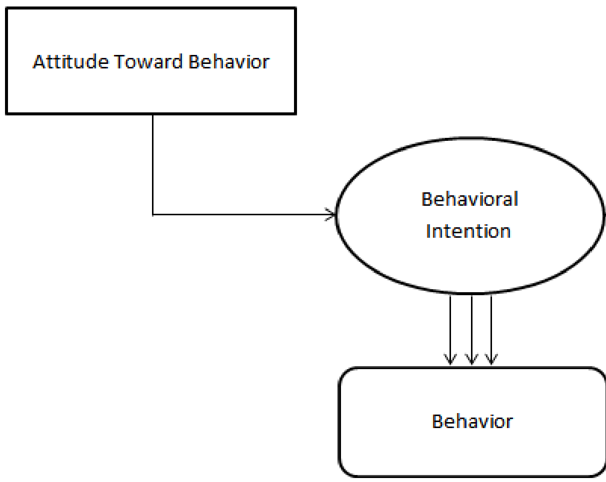


Figure 9. Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980)

Davis uses the Theory of Reasoned Action (TRA) shown on Figure 9 above. This theory is explicitly concerned with behavior (Fishbein & Ajzen, 1975), (Ajzen & Fishbein, 1980) to improve his model.

Situations in which users do not have behavioral control are better modeled by an improved variation of TRA, the Theory of Planned Behavior (TPB) (Ajzen, 1991). It involves an additional variable - perceived behavioral control (PBC) shown in a gray oval in Figure 10 below. It is important to notice, that while the term *attitude* maintains its meaning as one's opinion about whether a behavior is positive or negative, the concept behind the *subjective norm* has developed with time. The original (and most popular) definition of *subjective norm* is given by Ajzen, in 1991 as "the perceived social pressure to perform or not to perform the behavior" (Ajzen, 1991).

However, today's understanding of the term is associated with specific situations where the decision to perform or not perform expected behavior is based on one's "opinion about what important others believe the individual should do" (Finlay, Trafimow, & Moroi, 1999).

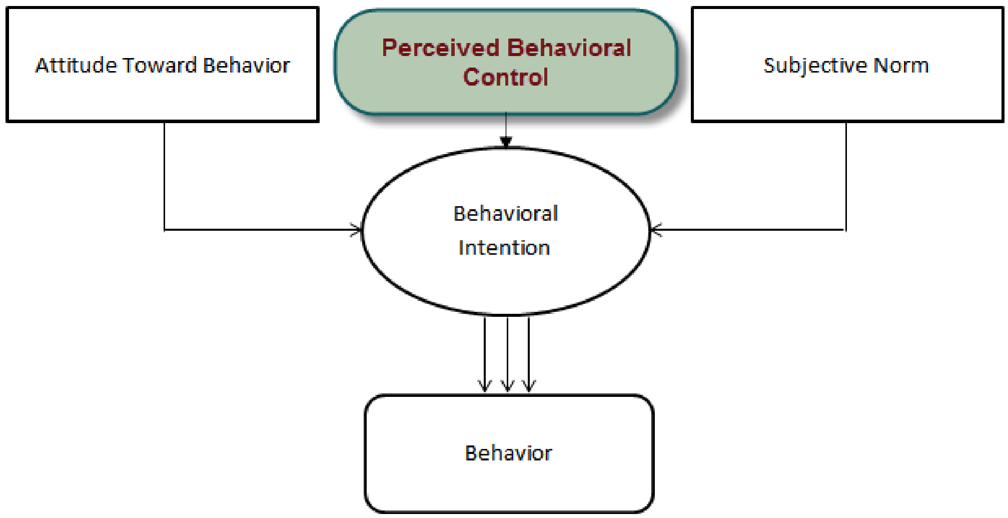


Figure 10. Theory of Planned Behavior (TPB)

Adapted from: (Ajzen, 1991)

Similar to the three major components of TRA – behavioral intention, attitudes and norms (or expectations of other people) shown in white ovals on Figure 9, Davis divides user motivation into three factors - perceived ease of use; perceived usefulness; and attitude toward using the system with latter being influenced by the two formers. They remain the three major components of each TAM and are used to justify user motivation. In 1986, he acknowledges the effect of external factors as well.

Figure 11 below shows the interaction between these components acknowledging the fact that system design characteristics affect directly both the perceived ease of use and the perceived usefulness.

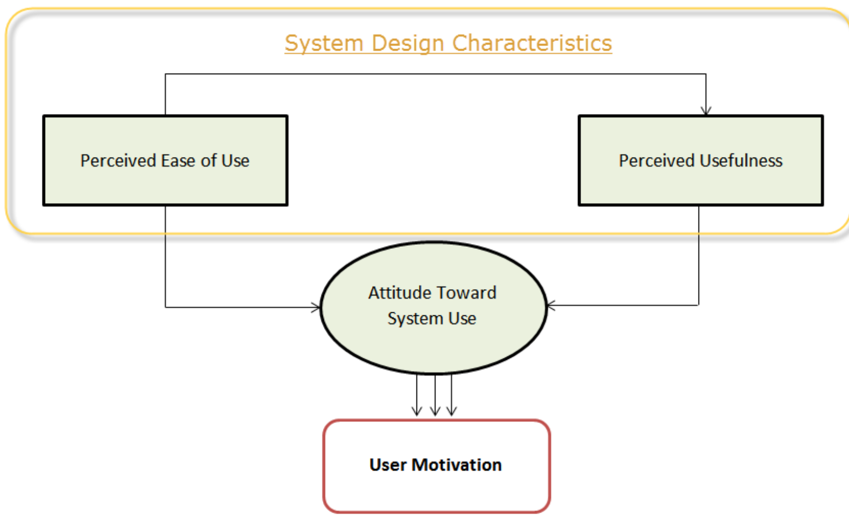


Figure 11. User Motivation Model.

Adapted from: (Davis, 1989)

The way that the User Motivation Model is nested within the TAM shown in Figure 12. X1, X2 and X3 represent design characteristics (variables) which directly influence PEOU and PU.

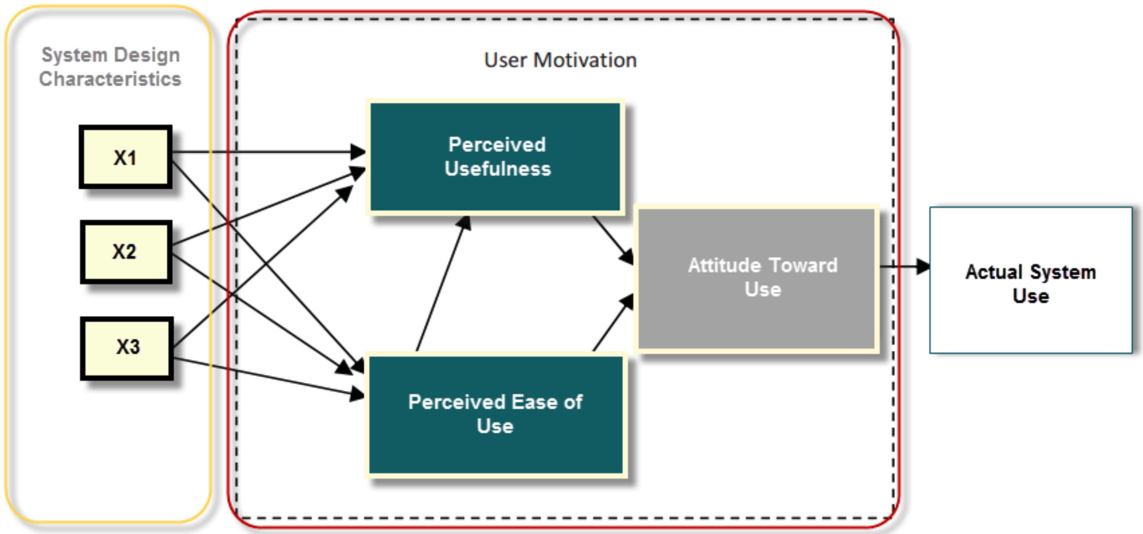


Figure 12. User Motivation Model within TAM

Adapted from: (Davis, 1986)

In 1989, Davis proposes and validates his initial 14 items scale for perceived usefulness and perceived ease of use (Davis, 1989). The scale items were tested for validity and reliability on four applications in two studies involving 152 users. To improve the model, Davis combines similar items into clusters thus avoiding destruction and increasing the accuracy of the model. His updated 6-items scale used ratings from 1 to 7 covering the "strongly agree" to "strongly disagree" evaluation range. The results for usefulness were better, as opposed to ease of use. It also established that usefulness has a greater correlation with self-reported current usage and self-predicted future usage compared to ease of use.

The easy application of the model, though, has brought about a misconception that its use is mainly to ease a research rather than to point to real problems of technology acceptance (Lee et al, 2003). Since 2003, TAM was applied on applications such as email, voicemail, fax, dial-up system, e-commerce related apps, word processor and spreadsheets, database programs, hospital IS and telecommunication. Among its users are undergraduate and graduate students, bank managers, program analysts, computer programmers and internet users (Lee, Kozar, & Larsen, 2003), (King & He, 2006), (Yousafzai, Foxall, & Pallister, 2007).

One weakness of TAM was its ability to address general items only, which complicated the process of identifying the reasons behind perceived ease of use or perceived usefulness of evaluated system. Furthermore, most participants were volunteers thus there were no consideration for mandatory settings (Chuttur, 2009). This problem was partially solved by an improved modification of TAM, TAM 2. It complements the original model by explaining perceived usefulness and usage intentions in terms of social influence (subjective norm), cognitive processes (like job relevance) and experience (Venkatesh & Davis, 2000). Figure 13 below shows a simple model of TAM 2 complementing the original TAM.

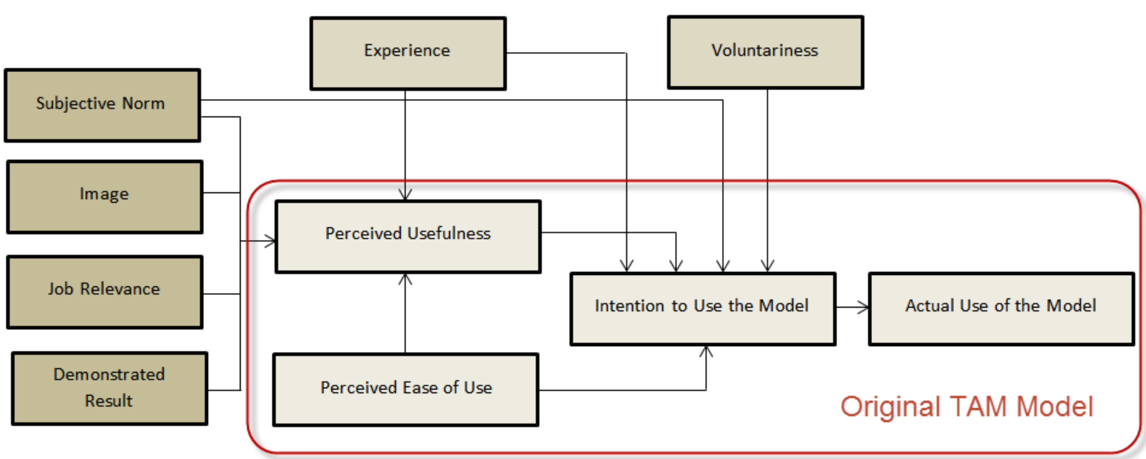


Figure 13. TAM 2 Structural Model as Complement to the Original TAM

Adapted from: (Venkatesh & Davis, 2000)

Although the test results demonstrated that TAM 2 was able to achieve about 60% of adoption in usefulness and about 50% in usage intentions, still several major concerns remained. They are related to using self-reported data to evaluate a system, rather than data being actually used; using attitude as variable; and the poor theoretical foundation of the model (Bagozzi, 2007). Still the flexibility of TAM and its ease of use create solid bases for improved variations and implications of the model.

In 2003, the United Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003) was introduced. It consists of four core variables for intention and usage, and up to four factors indirectly affecting key relationships shown in Figure 14 below.

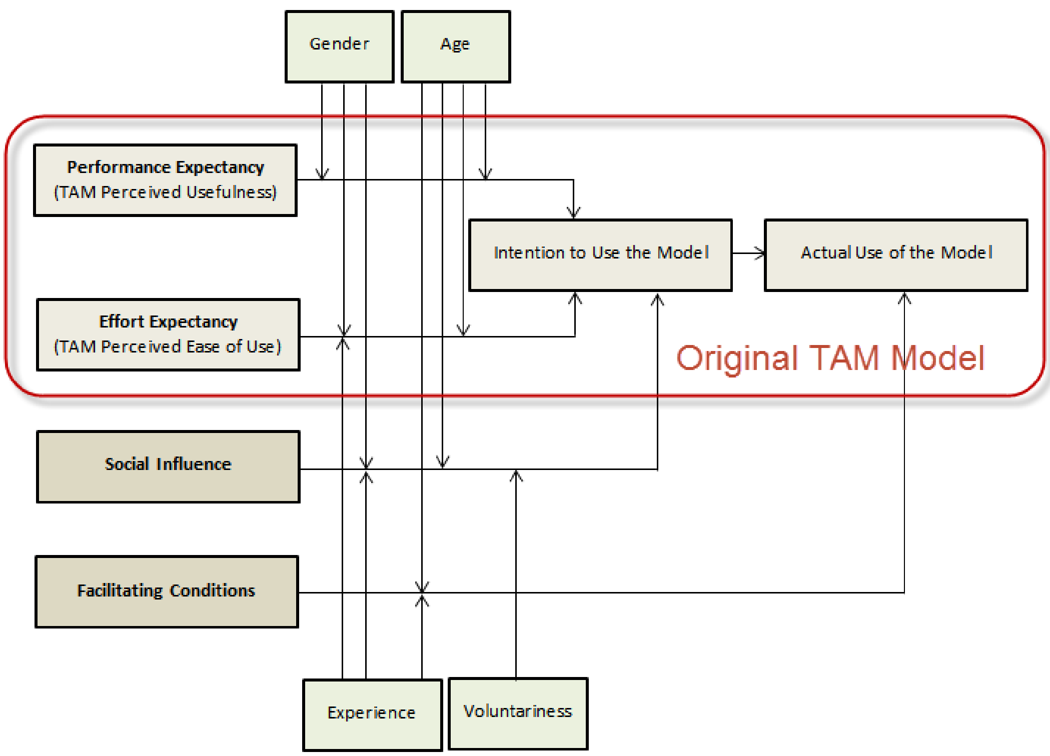


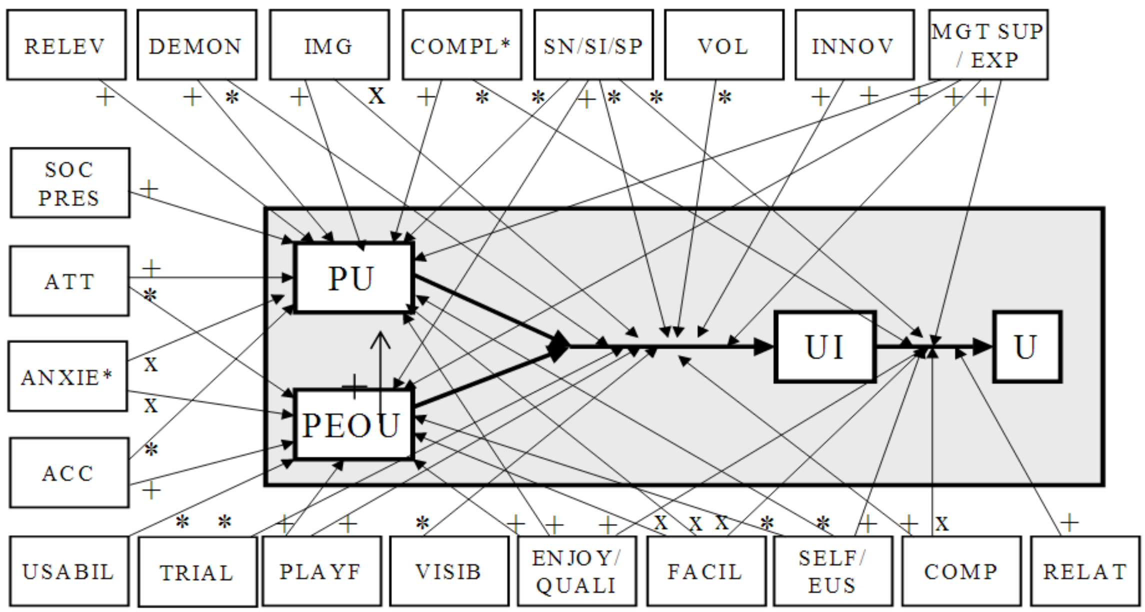
Figure 14. United Theory of Acceptance and Use of Technology (UTAUT)

Adapted from: (Venkatesh, Morris, Davis, & Davis, 2003)

This is a technology acceptance model, which was found to be most applicable in academia (AlQudah, 2014). Some of its characteristics and variables we refer to when proposing evaluation criteria in Chapter 7.1.

Different types of TAMs use a variety of variables, but all models share the four major ones. A research project exploring 101 studies identified the level of significance between the four major TAM variables shared by all TAMs - perceived usefulness (PU), perceived ease of use (PEOU), behavioral intention (BINT), and behavior (B) (Lee, Kozar, & Larsen, 2003). The variables are categorized as dependent or independent based on the relationship between them. A variable is "dependent" if it is affected by another one. A variable is "independent" if it affects another one. Thus, a variable can act in three different ways – as dependent, independent or both. For example, (PU) is predicted by (PEOU) (therefore PU is dependent). At the same time, it predicts (BINT) and (B) (therefore PU is also independent). Such relationships indicate that users easily accept the use of a system with poor behavior (functionality). Similarly, the relationship between (PEOU) and (PU) was not significant. This indicated that a user's belief that a system is easy to use is not always useful. A similar analogy applies to (PEOU) and (BINT) or (B) – a user –friendly system does not guarantee it has high functionality. Not at all that significant is the relation between (BINT) and (B) indicating that systems intended to be functional do not necessarily function up to expectations. (B) is identified as always, a dependent variable, measured by frequency of use, time spent using, real number of usages and varieties of usage.

Lee, Kozar and Larsen also discovered the effect that a number of external variables have on the four major ones (PU, PEOU, BINT or B). Figure 15 below is taken from the original research paper (Lee, Kozar, & Larsen, 2003) for the purposes of future use in our research.



Legend: * (mixed relationship), + (significant relationship), x (insignificant relationship)

ACC: Accessibility, ANX IE: Anxiety, ATT: Attitude, CO M P: Compatibility, COMPL: Complexity, DEMON: Result Demonstrability,
ENJOY: Perceived Enjoyment, EUS: End User Support, EXP: Experience, FAC IL: Facilitating Conditions, IMG: Image,
RELEV: Job Relevance, MGT SUP: Managerial Support, PLAYF: Playfulness, INNOV: Personal Innovativeness,
RELAT: Relative Advantage, SELF: Self-Efficacy, SI/SN/SP: Social Influence, Subjective Norms, and Social Pressure,
SOC PRES: Social Presence, TRIAL: Trialability, USABIL: Usability, VISIB: Visibility, VOL: Voluntariness

Figure 15. Relation between External and Major TAM Variables.

Source: *(Lee, Kozar, & Larsen, 2003) p. 760*

The technology adoption issues discussed above, blend components of the theory of reasoned action (TRA), theory of planned behavior (TPB), the original TAM model and the united theory of acceptance and use of technology (UTAUT). We have analyzed existing literature in order to explore available technology adoption issues especially in academia, and identified a model suitable for evaluating GAA tools. Researches, surveys and various publications related to TAM were analyzed in order to identify most compatible construct definitions, variables and scales that will allow for fair assessment of constructs. Part of the research executed was related to identifying relations between different variables. Data collected was used to define suitable constructs and use them as part of our modified version of TAM. We kept the major TAM constructs and complemented them with suitable external variables. We made the selection after evaluating the possible effect these variables may have on the perceived ease of use, perceived usefulness and attitude. We supported our choice with samples from the literature review. The results and proposed solutions are gradually implemented in GAIA's evolution phases described in Chapter 5.

2.2.6 Theory-based Approaches to Evaluation

Key concepts of theory-based approaches to evaluation are discussed in a document developed by the Centre of Excellence for Evaluation at the Treasury Board of Canada Secretariat (TBCS, 2012). Theory-based evaluation is presented as an analytical model rather than a method or technique. It undertakes analysis of results following evaluation of a tool or system.

Funnell argues that well defined success criteria that allows for comparison within a particular context will significantly empower one's program evaluation theory (Funnell, 2000).

A detailed look at different stages of program theory stressing on its use for monitoring and evaluation is explored by Funnell and Rogers. The authors conclude that it can only be successful if supported by suitable methods for research design, data collection and respective analysis. The difference between a theory of change and theory of action is reviewed. The authors recommend the use of logic models for better representation and understanding the relations between the outcomes ((Funnell & Rogers, 2011).

A general reverse engineering approach through designing a result framework is addressed by Roberts and Khattri (Roberts & Khattri, 2012). A step-by-step development process that links target values and project outcome indicators is described. The authors explore a logical flow from assumptions to achieving expected changes. The process is divided into three phases – beginning (assumptions), planned work (inputs and activities), and intended results (outputs, outcomes and impacts).

A criteria-based empirical model for measuring GAs is presented by the University of Alberta (Ipperciel & ElAtia, 2014). The study is supported by examples of GA scales derived from a theory-based abstract category.

The use of logical models has been identified as a key factor in standardized approaches towards evaluation (NHS, 2016). The authors deduce that the method is especially efficient in larger programs where the goal is achieving long-term outcomes within an environment of high level of uncertainty.

2.2.7 Continuous Improvement

Deming defines the principals for transformation based on his famous 14 points for Management (Deming, 2000). According to the author, who was awarded the US National Medal of Technology in 1987, a "long-term commitment to new learning and new philosophy is required of any management that seeks transformation... and the people that expect quick results, are doomed to disappointment" (Deming, 2000). His theory is first published in 1982 and credited for the philosophy behind the popular "kaizen" (good change), the Japanese practice for continuous improvement. Although it targets improving quality, productivity and the ability to compete in business, its principles relate to continuous improvement in many areas, including engineering education. In January 2017, state university presidents from top performing engineering programs in technical partnership with the Japan International Cooperation Agency visit Japan to learn the kaizen of Engineering Education Management.

The relationship between continuous process improvement and business process reengineering is a subject of a research presented by Chris White (White, 1996). The researcher argues that both methods differ only in focus. He explores an approach of looking at a process or a system as built from components. To assure quick improvement, each individual part becomes the object of improvement and the focus is on relations between them.

Experiences in continuous improvement of programs for undergraduate engineering education in several universities as part of ABET accreditation is explored by Jack McGourty (McGourty, 1998). A year later he summarized four strategies to integrate assessment into the engineering education for continuous improvement (McGourty J. , 1999). Based on the experience from engineering programs at Columbia University, Cooper Union, Drexel University, New Jersey Institute of Technology, Ohio State University, Polytechnic University, the University of Pittsburgh, and the University of South Carolina successful strategies have been identified as follow:

- Strategy 1 – Initiate a structured process: definition of educational objectives and LO, selecting assessment methods, developing a pilot testing the methods, expanding the assessment process by developing methods as part of an overall educational process including training and resources; applying results to inform program improvement.
- Strategy 2 – Educate staff, faculty and students on comprehensive assessment program from developing assessment methods to providing outcomes-based performance feedback.
- Strategy 3 – Create series of assessment tools to measure learning outcomes. His approach is towards identifying and reflecting on common needs across the institution. Using common sets of assessment methods flexible common assessment templates have been designed. They can be customized by instructors to better reflect their particular course or program.
- Strategy 4 – Align the assessment program with institutional practices. This includes the identification of existing policies, procedures and systems that can act as "barriers for assessment and continuous improvement" (McGourty J. , 1999)

The Discipline Agile Framework (DA) proposed by the Foundation for Business Agility identifies a CIP with one's ability to share improvement learnings in a systematic way (FBA, 2017). The proposed framework looks at the continuous improvement from three different aspects - identify, share, and capture improvements; support teams; organized committees of practice and centers of excellence; and govern improvement.

2.3 Related Work

There are several research papers we have identified as most relevant to our work. They provide description and evaluation of systems and tools for performance management of engineering education. We will evaluate our proposed systematic approach (and prototype tool) by comparison in Chapter 6.

2.3.1 ABET Related Experience

1. ACAT, ABET Course Assessment Tool (Essa, 2010)

The study was selected due to similarities in terms of architecture, performance management forms, handling assessment data and reporting ability.

Essa proposes a custom-developed ABET Course Assessment Tool (ACAT) which was developed and implemented at the University of Nevada Reno. The goal of ACAT is to streamline the course assessment process and standardize reporting. To validate the design and user interface of the tool, Computer Science and Engineering faculty members perform a usability study. The tool was tested, based on International Organization for Standards criteria (ISO13407, 1999) that measure effectiveness, efficiency and satisfaction in a specified context of use by specific users. The results showed that the ACAT tool is an improvement over the existing manual process used to assess graduate attributes. This study is one of the earliest we have identified that attempts to theoretically compare technology adoption issues between three different tools – COMPASS, Outcomes Database and ACAT.

2. ABET Compliance Tracking System, ACTS (Zahorian, Summerville, & Craver, 2012)

Web-hosted ABET Compliance Database Tracking System (ACTS) was created at the Binghamton University (Zahorian, Summerville, & Craver, 2012). The tool accommodates qualitative and quantitative data, allows for historic trend track and comparison and follows established process for data collection. Reminders are sent to instructors at the start of each semester, during the semester and at its end. Faculty committee meets at the end of semester to summarize each individual course evaluation and at the beginning of the next semester the undergraduate studies committee reviews the data to identify achievement, recommend curriculum/course changes and/or changes to performance criteria. The authors describe the success of the tool being based on its accessibility and convenient way of organizing the data. The system allows for comparison between student achievements on particular GA in different years. The data is being periodically backed up. An earlier version of the project was presented during the ASEE (American Society for Engineering Education) conference in Vancouver, 2011 as part of the ABET Accreditation, Assessment and Program Improvement in ECE (Zahorian S. , Summerville, Craver, & Elmore, 2011).

3. ABET Accreditation Manager (Shankar, Dickson, & Mazoleny, 2013)

A similar tool for ABET accreditation is described by Shankar, Dickson and Mazoleny (Shankar, Dickson, & Mazoleny, 2013). The tool called ABET Accreditation Manager considers variability in the information technology infrastructure at different universities and account for it by identifying appropriate stakeholders (ABET coordinator, faculty members and graduation coordinator). The tool has user friendly interface. The application automates the data collection process, performs analysis and generates reports compatible with ABET accreditation requirements. It completely eliminates the previous manual approach. The tool supports identifying gaps and reasons behind a particular criteria achievement per cohort. The application is cloud based and the database accepts meta-format of CVS files.

2.3.2 CEAB Related Experience

1. OBACIS (Ismail, 2016)

At home, University of Regina develops their own Outcomes-Based Analytics and Continuous Improvement System, OBACIS (Ismail, 2016). The system analyzed assessment data per category, learning outcomes and graduate attributes. It's an Excel-based platform that allows for outcomes-based analysis and data-informed continuous improvement. It consists of Excel-App for creating Auto Grading Sheets, Web-App for updating server databases, uploading related documents and conducting surveys, and Win-App for OBA data compilation, analysis and data informed continuous improvement. OBACIS generates reports on outcomes-based assessment analysis (OBA) through mapping some assessment tools or grade items to OBA indicators.

2. An Engineering AMS (Dew, Lavoie, & Snelgrove, 2011)

An Engineering Accreditation Management System (AMS) is a web-based system custom developed to assist the CEAB accreditation process at the University of Alberta (Dew, Lavoie, & Snelgrove, 2011). This is a centralized database tool offering course and instructor database management, offers data collection and tracking, and supports preparation of reports for accreditation. The authors recognize accreditation as an ongoing continuous activity but tend to target data presentation and analysis rather than informing a continuous improvement process. Major plus for the system is that it uses a centralized database within the university's own network. Distribution of user's responsibilities is done according to user's appropriate security level (ID, passwords, user privileges based on their respective roles). The system does not need an additional software installation. Built as web tool, the AMS requires Windows Server 2008 R2, MS SQL Server 2005, Apache Tomcat, IIS 7 and ASP.NET 3.5 software and estimated 1TB storage. As reported, an online help provided minimizes user frustration and increases productivity. It is identified by the authors as "very effective particularly given the growing complexity of accreditation with the introduction of Qualified AUs and graduate attributes". They report that the AMS was developed in response to approximately 16,000 preparation hours with estimated personal cost of over $1M.

3. GA Assessment and CPI at McGill University (Saunders & Mydlarski, 2015)

Faculty-wide process developed over 3 years and implemented at the University of McGill is described by Saunders and Mydlarski (Saunders & Mydlarski, 2015). Data collection and analysis are performed using existing tools (mainly Excel spreadsheets). Processes already in place are being reviewed and later on become faculty-wide implemented. In 2014-2015 a commercially purchased curriculum mapping and program outcomes software as part of the LMS already in place at the university was piloted. The five steps process is described as sequence of curriculum mapping, gathering student assessment data, data analysis and interpretation, validation of curriculum content and informing program improvement. The authors do not report on use of COOP data for accreditation. Evaluation of the pilot project is still to take place as well as analyzing of previous data for informing continuous program improvement process at faculty level.

2.3.3 Off-the-shelf Software Tools Supporting Outcomes-Based Continuous Improvement process

A long-term study (Kaupp & Frank, 2013), (Kaupp & Frank, 2014), (Kaupp & Frank, 2015) assesses and reviews the suitability of a wide variety of commercially available off-the-shelf software tools for the purposes of accreditation, GAA analytics and data collection, and managing a CIP in engineering education programs. Ten "of the shelf" vendor products (Chalk & Wire, Course Peer, Entrada, Attlas Curriculum Mapping, iSeek Supercruncher, Taskstream, Civital Learning, Vena, CBlue and R) are being measured against eight-component criteria built up of three direct and five latent constructs. System type, ability to integrate with other tools and pricing are measured directly. Three to six indicators are used to inform on use of rubrics, LOs, types of assessment data they are able to process, types of reports generated and analytics. The study concludes that none of the tools is able to manage the GA assessment data independently and they can only address a specific aspect of the GA process. Being distinct from the actual assessment process was identified as common general weakness for all vendor tools. Issues like duplication of grading, need for instructors to re-enter data, compatibility with existing tools or systems but most of all, the tools' inability to cope with the diverse nature of student assessment clearly characterizes them as a supplementary tool only.

2.4 Gap Analysis

In this section, we identify some critical gaps, highlighted in current research, that need to be addressed, which will be the focus of our thesis research. Exploring the experiences of six WA countries (Canada, US, UK, Ireland, Australia, and New Zealand) we differentiate the gap analyses into three categories: (1) information systems models, (2) supporting tools specifics to meet accreditation requirements and inform a continuous improvement process, and (3) technology adoption issues.

2.4.1 Information Systems Model

Analyses of the information systems from CEAB (Canada), Engineers Australia, ABET (United States), Engineers Ireland, Engineering Council UK, and IPENZ (New Zealand) are presented in this section. We also analyze how the performance management and continuous improvement processes that back accreditation need to be supported. Subject for exploration are: (1) the ways engineering schools lever the ongoing changes of accreditation policies and procedures, (2) how do they manage the changes, and (3) how selecting a compatible accreditation management model can eliminate the reasons for drawback and support the improvement process.

1. Accreditation Requirements

Following the shift to outcomes-based assessment and continuous program improvement marked by EC2000 (Lattuca, Terenzini, & Volkwein, 2006), which lead to mandatory changes in accreditation criteria, processes and procedures, information systems were developed and implemented across WA signatories. In its 2014-2015 accreditation manual, ABET divides accreditation criteria into three types – general criteria (for all programs), program criteria (program-specific requirements), and proposed new criteria and changes to criteria (to be published for typically a year of public discussion in "Proposed Criteria" section available in each respective ABET criteria document) (ABET, Accreditation Policy and Procedure Manual, II.D, 2014). But for engineering programs undergoing accreditation the process is not simple. Kam and Lightner argue that for faculty members although they care about education and innovation, accreditation remains a time-consuming administrative task (Kam, Lightner, Penfield, Heywood, & Burd, 2010). EC2000 did not set criteria for a new accreditation framework, it rather set criteria for an open-ended lane of changes mandated by a continuous improvement process.

Changes to accreditation procedures described by Engineers Ireland in 2013 board document take place the very next year (EI, 2014c), (Foley, 2016).

Changes like additional description for some programs and new definitions driven by economic, social or career perceptions are expected to "pose challenge to educators who seek to maintain and raise standards" (Owens, 2014).

Getting used to surprises, engineering schools begin to foresee the upcoming changes (Kennedy & Good, 2008). Challenges in keeping up with the new ways of assessing student achievement in response to constant developments and updated benchmarks are the subject of research by Kennedy and Good (Kennedy & Good, 2008). There's a discussion by Engineers Ireland about ways to support the rigorous engineering accreditation process where students are being assessed against individual model learning outcomes but also against program outcomes as described in the accreditation criteria (Marcus-Quinn, Bruen, Allen, Dundon, & Diggins, 2012). The specifics of the changes affecting graduates are described by Foley (Foley, 2016).

Some researches begin to question the credibility of ABET accreditation approach itself. Cheville gives accreditation the philosophical perspective of intention and reflection (evaluation). Applying the theory of Irish philosopher John Macmurray, he predicts that the current model of engineering reflection (evaluation) efficiently improves students' "engineering" ability oppose to having much less impact on their personal growth, thus encouraging a quest for alternative evaluation approach (Cheville, 2016).

The continuous search for solutions gives first positive results in early 2015 when the results of long-term studies become available. Surprisingly, the successes reported are related to processes and procedures not usually associated with measuring student achievement or even with education as a field. Problems associated with documenting achievements and processes and using rubrics to support standardization of student evaluation over time are subject of discussion as well (Byron, 2016). He describes a process supported by graphics and table-form reports that successfully presents collected assessment data and decisions for improvement. It has been used for 5 years to report on GA achievement in a capstone course.

A way to share data for the process of evaluating engineering programs provides a construct to explore the opportunity to re-design and re-engineer the whole approach to accreditation (Jerome, 2016). It's a call for ABET to review the content of the data collected and processes for program evaluation it has in place. To support the new approach, data was collected over the past two ABET accreditation cycles and organized in a way to illustrate best practices and ideas associated with their model.

2. Change Management

Considering that the focus of accreditation is continuous improvement, accreditation criteria and definition of terms become subjects to constant changes and updates (Fergus, 2016), (ABET, 2014), (ABET, 2015a). Expected time-frame for their implementation is usually in the review cycle that follows the change adoption. An option for public review prior to adoption is also available upon discretion of the adopting body. “Accreditation Alerts” page on the official ABET website is dedicated to tracking the ongoing changes (ABET, Accreditation Alerts, 2017b). Tracking of changes into ABET accreditation criteria starts with 2011-2012 reviews and follows per each consecutive academic year after. Proposed changes are posted for discussion and self-study on a separate “Updates” page (ABET, Updates, 2017c).

A similar process is offered by Engineers Ireland. They use Publication Archive page on the board’s website where changes taking place can be tracked per year starting 2002 (EI, Publications Archive, 2017d). Public enquiries are being launched there as well (EI, Current Consultations, 2017e).

Current developments in Engineers Australia accreditation criteria (EA, 2011a) are published in series of documents S01EA_Curr, S02EAE_Curr and G02EA_Curr (EA, 2011b).

Institute of Professional Engineers New Zealand (IPENZ) uses a designated page from its website called “News and Publications” to upload all accreditation policy and procedure updates

(IPENZ, 2017). The webpage is supported by a search engine by keyword, area, publishing date of the document. It uses a database of posted news and related publications including IPENZ related conference proceedings and samples of successful engineering practice.

In September 2015 Engineering Instruction and Accreditation Consultation Group is established by Engineers Canada. Its goal is to provide recommendations to the board for improvements to the accreditation system (EIACG, 2016). Engineers Canada publishes recently the first Notice of Significant Change in a specifically dedicated to recent accreditation updates section on their website called "Working Documents for Accreditation" (EC, Engineers Canada Accreditation Resources, 2017).

3. Accreditation Management

The information systems model needs to incorporate support for accreditation management processes. Kotter argues that broad-based empowerment and leadership supported by effective task delegation are significantly increasing communication and decision-making (Kotter, 1995). Concepts from different quality management systems have been already used to manage assessment and continuous improvement processes. Deming's 14-points on Total Quality Management as well as concepts and quality principals from the American Society for Quality and principals from ISO 9001-2015 quality management system have already been identified as applicable to an outcomes-informed CIP (Byron, 2016). An accreditation management is needed to gathers data from accreditation processes which is then analyzed to inform improvement. It is governed by the typical structure of a process-based system illustrated in Figure 16.

Figure 16. Process-Based System Basic Structure.

All process related tasks must align with the current accreditation policy and requirements; be informed by continuous reviews by users, GAC and external experiences; be informed by the principals of common continuous improvement and clearly assign roles and responsibilities.

Procedures must evolve with time to accommodate implementation of new LMSs (Blackboard, D2L), assessment data repositories (vendor platform, in-place GA repository, COOP Portal) or tools already in place (user made Excel based data sheets).All supporting documents and spreadsheets must be accessible (file or data Storage), clear (indicators and measurement tools), informative (reports and accurate (provide reliable and consistent data).

2.4.2 Tool Support

We discuss different types of tools used to support accreditation categorized on the following bases:

a) Man-Machine Interface (MMI), i.e. the tool uses software application(s) that passes information to user and implements system operator's instructions. Typically, the information is expected to be presented in graphical user interface (GUI) format.
b) Data collection from different sources;
c) Processing different data types (quantitative and qualitative);

d) Different data storage (LMS, Excel files, COOP portal, system database);

e) Support of historic data-trend analysis and generation of various report types at different levels (course, program, and faculty).

2.4.3 Tool Adoption

A major theme in the research is the large administrative burden placed on professors, and the role tool adoption plays, in ensuring that performance management processes and continuous improvement processes are embraced and engaged in. Looking for a long-term solution, major concern in our approach is to avoid the common misconception that forced implementation of a new and popular tool will ensure the performance management and continuous improvement processes are successful. Exploring the wide range of technology adoption issues discussed in the literature review in Chapter 2, provides a starting point. This section emphasizes specifically the gaps that result from (1) isolated approaches to adoption issues; (2) failure to address individual characteristics and expectations of different user interfaces; and (3) interoperability issues. A deductive literature review approach helped identify major limitations of TAM studies especially when implemented in academia. Exploring the use of external and major dependent/independent variables across different models, TAM failed to address the need for a system to work with other systems or tools already in place, without an additional effort on the user's part. Thus, we have identified the need to involve an additional latent variable – interoperability.

1. Isolated Approaches to Adoption Issues

A major weakness is often a focus on a specific target: either a single machine interface (MI) or a single human interface (HI). An integrated approach that provides an intersection of both human and machine interfaces for different roles and tasks will provide a better assessment. One needs to consider the effect of two sets of variables. The first set is machine interface oriented. It consists of criteria elements related to technical performance, cost, reliability, usefulness, usability, and interoperability. The second set combines all subjective variables related to different users (HI).

Course professors can use an interface differently depending on different factors like age, gender, grade-recording technique (pen-and-paper, Excel spreadsheet, LMS), or type of assessment they choose to use for the graduate attribute assessment. Thus, it becomes possible for different users to assign different efficiency levels for the same tool. If not part of the overall evaluation criteria, such highly subjective approaches will lead to a skewed evaluation of the overall tool performance. Professional experience, subject proficiency, course integration, understanding of outcomes-based assessment methodology and engineering profession mobility are all indicators of how knowledgeable the user is. In addition, there must be a match between the level of technical difficulty a software tool possesses and user capability to deal with it. This fact imposes an additional group of rather technical evaluation factors. Thus, the need to evaluate users on bases of professional knowledge, technical skills and personal attitude as was done Moser's model (Moser, 2007) shown in Figure 17 below.

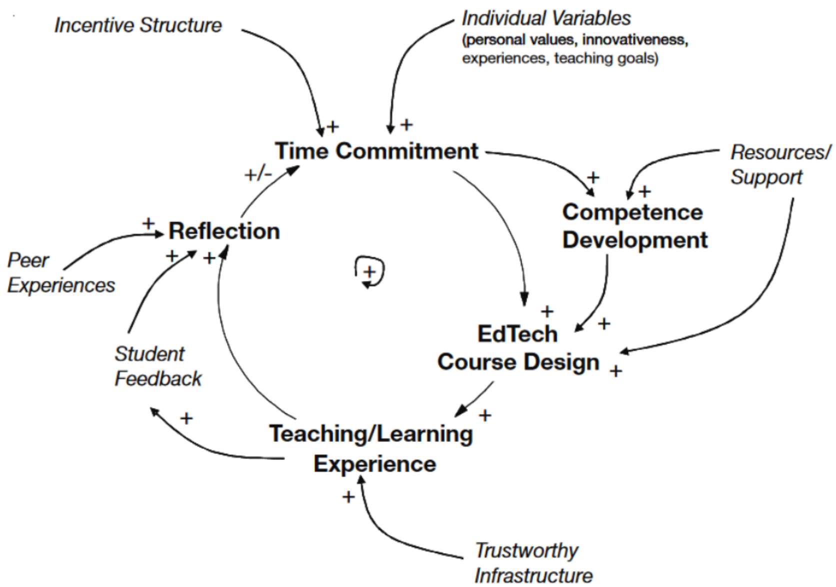


Figure 17. Faculty Technology Adoption Cycle

Source: *(Moser, 2007), p.66*

2. Lack of Differentiated Criteria for Distinct Users

Through the literature review, we identified that the existence of different actors/users interacting within the same tool was not addressed as well. Multiple assessors were mentioned in Queen's University software evaluation criteria to support measuring the ability of a tool to accept multiple assessment data (Kaupp & Frank, 2013), (Kaupp & Frank, 2014), (Kaupp & Frank, 2015). However, the existence of adoption issues for distinct users was not part of the criteria.

3. Interoperability

Most of the research on technology adoption issues list interoperability as a major challenge (Alharbi & Drew, 2014), (Kaupp & Frank, 2015), (Essa, 2010). And yet, interoperability is not involved in any of the proposed assessment tool evaluation criteria (Kaupp & Frank, 2015), (Harlen, 2007), (Essa, 2010). A major characteristic of the specific concept of evaluating these tools is the fact that they must support a process mandated by accreditation boards. Thus, professor adoption is critical, but can be coerced. In such s situation, interoperability with the work environment of the professors is imposed on the professor but has to remain a measured variable for the tool.

Chapter 3. A Systematic Approach for Performance Management of Engineering Education

3.1 Overview

Our proposed approach consists of the following four steps, which anyone responsible for the overall performance management of engineering programs at an educational institution should follow:

- First, a system architecture for engineering education performance management needs to be established that defines actors and system components; their inputs, outputs and responsibilities; and the related sources of data that can be used for performance management;
- Second, a common continuous improvement process (CCIP) needs to be established that defines how performance management takes place in a manner that ensures continuing evolution and improvement of engineering programs and whose structure enables integrated tool support.
- Third, a set of common key performance indicators (CKPI) needs to be established to standardize how programs are measured and enable comparisons between programs.
- Fourth, tool support for the actors involved in performance management needs to be established in terms of Performance Management Forms used as interfaces by different

actors for data collection, reporting and analysis to visualize the state of an engineering program and guide decision making in the continuous improvement process.

3.2 System Architecture

Figure 18 below shows a map of tools support for different actors involved in the process of collecting, analyzing and reporting data for GAA. This includes the academic platform (AP) supporting User Interfaces (UI1, UI2, UI3) for Faculty Administrators (FA), Program Coordinators (PC), and Program Professors (PP). Course Professors and Students focused on in-class evaluation are typically supported by a learning management system (LMS). The non-academic platform (NAP) supports Employers, COOP Office, Alumni and Students focused on external evaluation mechanisms that provide Other Sources of Data.

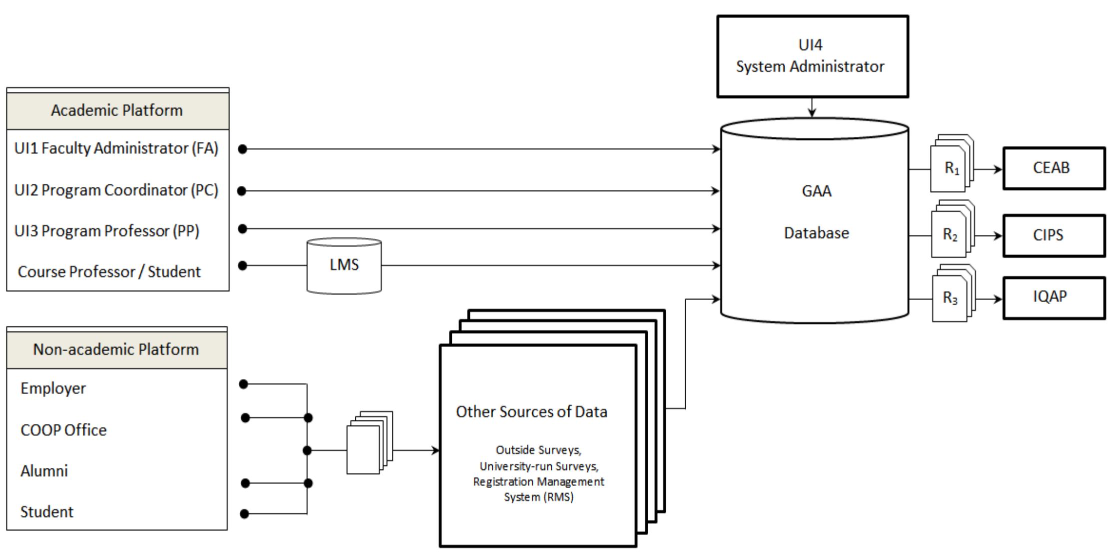


Figure 18. Map of Tools Support

Tool support needs to provide four types of user interfaces (UI1, UI2, UI3 and UI4) to the GAA Database, as well as machine interfaces (MI) for Learning Management System (LMS), and Other Sources of Data. The primary output provided by tool support are reports (R1, R2, and R3) to accreditation agencies (CEAB, CIPS, and IQAP). Most critically, these reports are used internally to inform the continual improvement process for each engineering program.

3.3 Common Continuous Improvement Process (CCIP)

To manage continuous improvement of engineering programs, it is most important to ensure a common process across each program in a faculty of engineering. Creating and implementing an improvement plan are managed by each Program as shown in Figure 19 below. At the base, each program collects Assessment Data (AD), processes AD, and generate reports in order to inform the continuous improvement process where in the program and how well students are acquiring the graduate attributes, they need to be successful engineers. Based on the information data the program will create and then implement an improvement plan. And then the cycle repeats to measure how successful the improvement plan is. While this works well for a single program, each program had its own set of performance indicators, which is problematic when trying to achieve consistent reporting at the faculty level that could support cross-program comparisons.

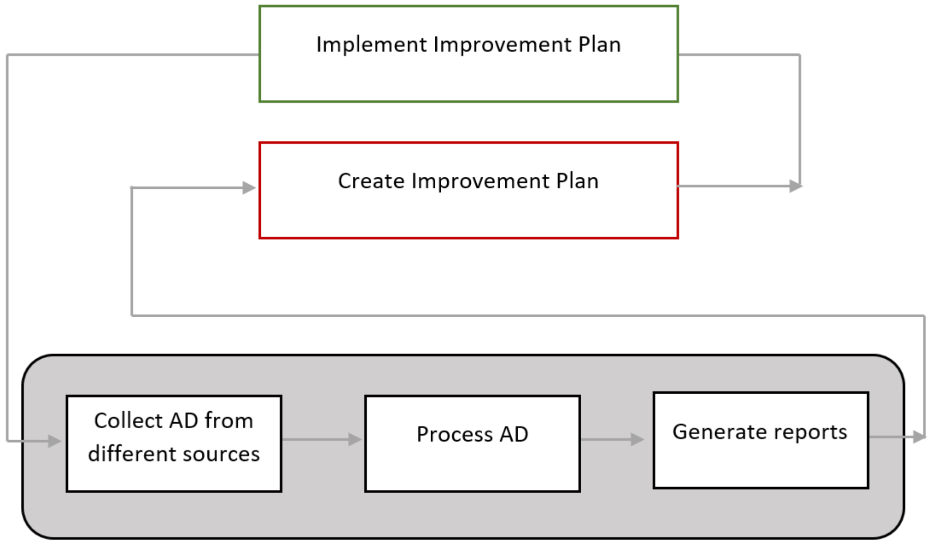


Figure 19. Tool Supported Improvement Cycle

The more top-down approach is to mandate a common continuous improvement process (CCIP) with a common set of indicators that can be shared across programs. Section 3.4 Common Key Performance Indicators will explain how a common set of indicators is created. The CCIP mandates a common program report that charts the common set of indicators across the 12 graduate attributes. The data for those indicators is obtained from measuring student achievement on the learning outcomes from individual courses in the program. Each program's aggregated data is processed and reviewed at three levels.

- Level I (Course Level): Learning Outcomes measured in courses and mapped to a common set of indicators;

- Level II (Program Level): Key Performance Indicators measured by the program and mapped to a common set of Graduate Attributes;

- Level III (Faculty Level): Graduate Attributes analysis for accreditation and program improvement.

To standardize and centralize documentation of the CCIP and management of GA data, we introduce a Graduate Attribute Data Repository (Figure 20) for supporting and standardizing a CCIP based on consistent, scheduled deliverables defined by templates. The documents, data and templates are grouped into folders as follows:

1. The Faculty CIP Resources and Meetings folder contains agendas and minutes from meetings of the Faculty CIP committee and relevant resources (research papers, notes on other university approaches, presentations etc.) that the committee has collected.
2. The Templates folder contains standardized templates for the documents that are used within each program to document, manage, and organize the CCIP for each program: Annual Report, Annual Meeting Agenda and Minutes, and CIP task notifications templates (which are used to ensure submission of data and completion of reports within scheduled deadlines).
3. The Program Folders (one for each program) store the data and documents for the continuous improvement process of each program. There are three programs shown in the figure as an example (Computer, Electrical and Software Engineering). The Common Courses folder contains the data and documents from courses that are common to all three programs

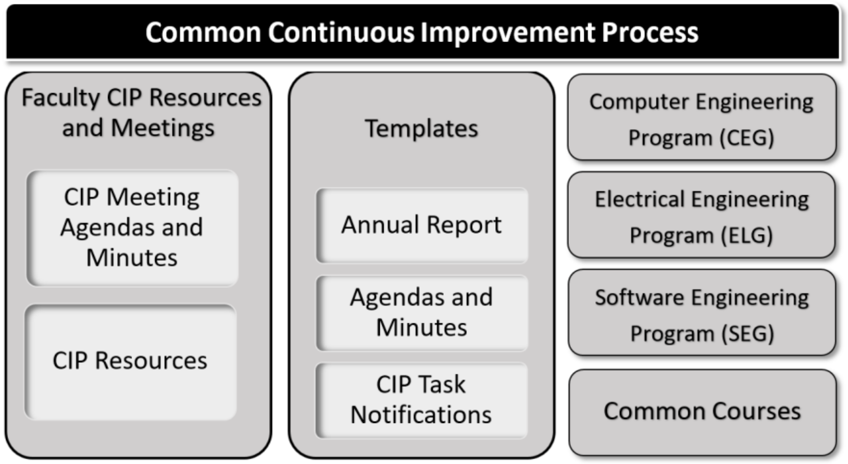


Figure 20. GA Data Repository to support CCIP.

Figure 21 below, shows a zoomed view of the organization structure of the Software Engineering Program folder. This organization is repeated and identical for each program. There is a sub-folder that manages and documents the CIP for each academic year (2014-2015, 2015-2016, and 2016-2017) since the last accreditation visit (Accreditation 2014).

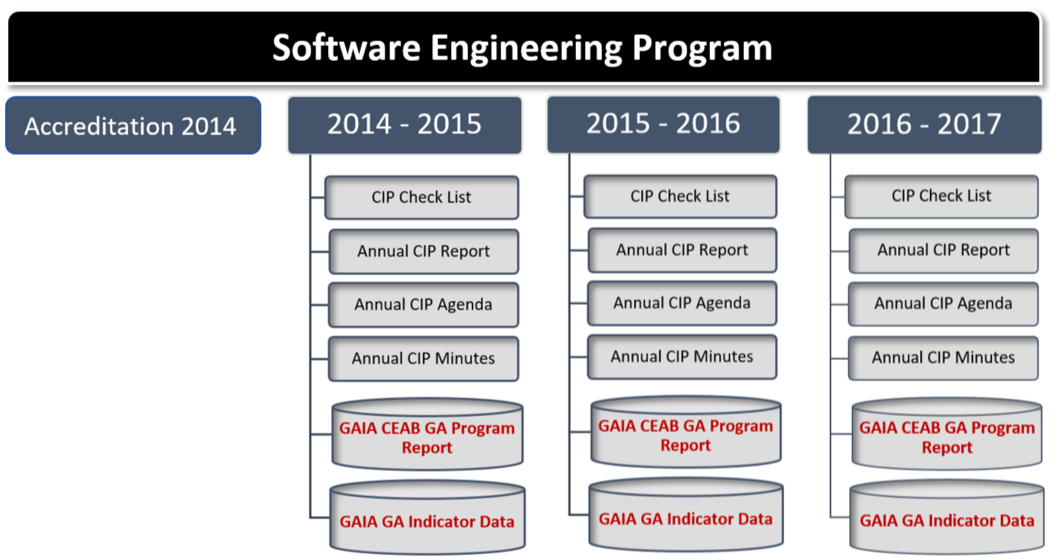


Figure 21. Software Engineering (SEG) Program View.

Within each year, there is a CIP Checklist that is used to keep track that all steps involved in the CIP for that year have been completed, including the collection of data, creation of documents, and notifications to ensure completion on schedule. Each program has an annual meeting to review last year's improvement plan and determine the improvement plan for the following year. This meeting is documented by the CIP Agenda, and CIP Minutes, while the status of the CIP (and its improvement plans) is documented in the CIP Report. There is also a data mart that stores the collected GA Indicator Data, and a data mart that stores the full details of the generated GA Program Reports.

3.4 Common Key Performance Indicators (CKPI)

If each program had its own set of performance indicators, it would be problematic when trying to achieve consistent reporting at the faculty level that could support cross-program comparisons. Typically, this results from a "bottom-up" approach in which professors for individual courses are asked to determine what graduate attributes they are addressing and how they are measuring student achievement of those graduate attributes. Each such measurement for a graduate attribute from individual courses is considered an indicator for that graduate attribute. This typically results in a program tracking a large number of indicators that are not only program specific, but often at a low level of detail specific to individual course learning outcomes. In other words, programs are collecting course-specific learning outcomes as performance indicators for their program, which makes it very difficult to compare graduate attribute achievement from one program to another.

On the other hand, a top-down approach can be taken that leads to a common set of program indicators that shared across programs. Vertical analysis across several programs allows for theoretical break-down of each program into three levels as show in Figure 22. It depicts a graphical presentation of a general vertical analysis per graduate attribute at three levels: Level I: Course Level Learning Outcomes; Level II: Program Level Performance Indicators; Level III: Accreditation Level Graduate Attributes (e.g. CEAB in Canada).

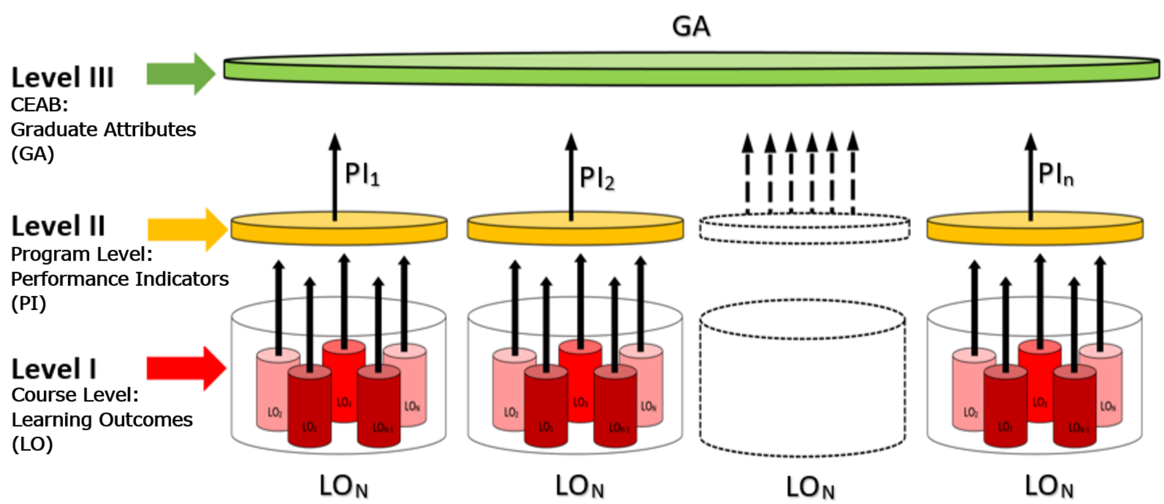


Figure 22. Vertical analysis per graduate attribute

Figure 23 below illustrates how such a vertical analysis helps implement a program improvement plan. The plan is targeting three courses (Course XXXX, Course YYYY and Course ZZZZ) to improve three graduate attributes (green ovals) in each course. Reports per each GA are composed from assessment data associated with three performance indicators (orange ovals) per graduate attribute. The red cylinders symbolize a collection of program-specific learning outcomes identified by course instructors that measure how well the students perform that can be mapped to the indicators. These are varieties of selected assessments in a form of tests, assignments, presentations or reports, each with a dedicated approved rubric.

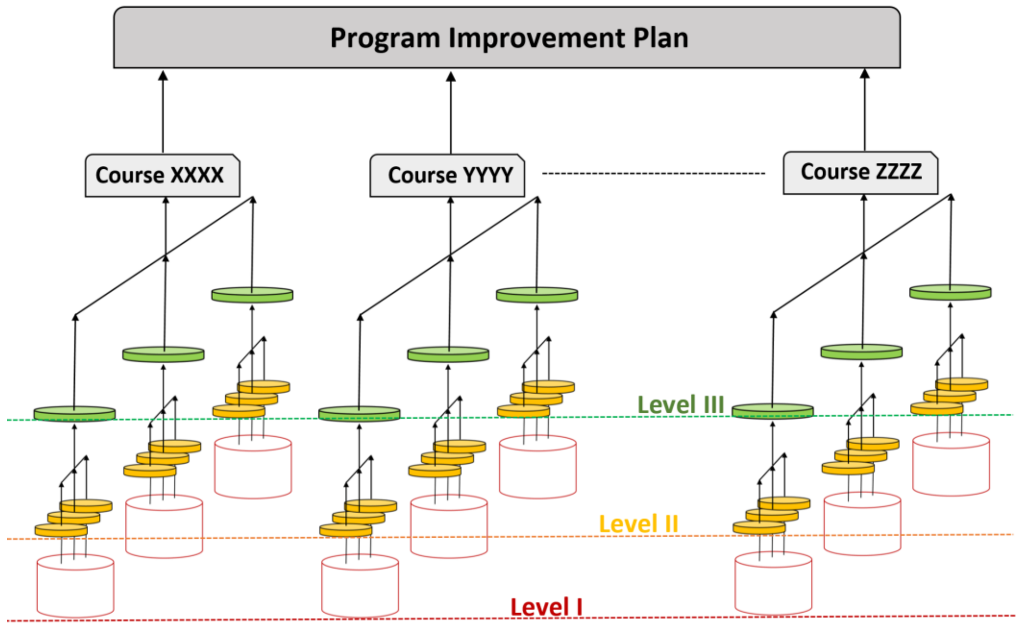


Figure 23. Vertical analysis per program.

Figure 24, below shows how this enables programs to measures GA achievement from courses (upward analysis) or informs program improvement plans (downward analysis). Inform Improvement is mandated by specifying Accreditation Requirements in terms of graduate attributes (GA). Each program reports on its GA Achievement by measuring a common set of Performance Indicators. These Performance Indicators are measured by assessing specific Learning Outcomes using Assessment Rubrics created specifically for each course. Measure Achievement is a mapping of course-specific Learning Outcomes into Program Indicators that report GA Achievement to accreditation agencies in a common standardized fashion.

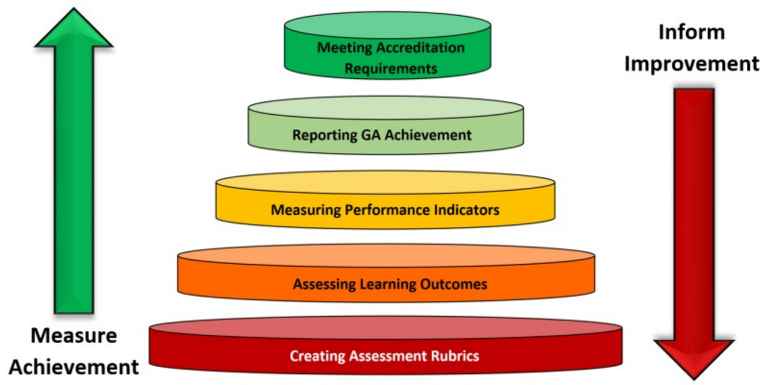


Figure 24. Use of vertical analysis for reporting

3.5 Performance Management Forms

Performance Management forms are used as interfaces for data collection, reporting and analysis to visualize the state of an engineering program and guide decision making in a CCIP. There are two fundamental types of forms, the Course Data Entry Form (CDEF) and Program Report Form (PRF), which are used to collect and analyze data at the Course level and the Program level respectively. When a program has a COOP option available to its students, a variation of the PRF is a COOP Program Report Form (PRF). It can be used to collect and analyze co-op data collected during the placement process, as well as student assessment data provided by employers who complete an Employer Evaluation for each student.

The development and implementation of a common set of key performance indicators (as described in section 3.4) makes it possible to generate a Common Program Report Form (CPRF) that allows programs to be analyzed and compared at the Faculty Level. Finally, The Cohort Program Report Form (C-PRF) tracks students' achievement by cohort so that one can see at a glance how the students from a specific cohort (e.g. students who started their program in 2014-2015) performed across all four years of their program.

The various Form interfaces are described in this section. A complete analysis of the data transformation and analysis techniques (DTAT) used is given in Chapter 5.

3.5.1. Course Data Entry Form (CDEF)

Data required for course-level analysis is directly entered into a course data entry interface (UI3) or by importing through a Machine Interface (e.g. CSV/XML/JSON via Web Service of Database Import, or SQL via JDBC/ODBC). Typically, assessment data is entered at the end of each semester. The CDEF provides (i) course data entry interface, (ii) course information sheet (syllabus), (iii) measurement rubric, and (iv) reports to show results and year over year historical trends for the course. Figure 25 and Figure 26 show a sample report in table and graph form respectively.

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USER INTERFACE DESIGN

GRADUATE ATTRIBUTE - CONTINUAL IMPROVEMENT DATA

SCALE (%)	
Percent Grades Exceed Expectations:	x ≥ 90
Percent Grades Meet Expectations:	80 ≤ x < 90
Percent Grades Marginal:	55 ≤ x < 80
Percent Grades Insufficient :	x < 55

COURSE DATA			
Course Name	STAGE III/WORK TERM III	Course Code	Work-Term (Fall)
BACK TO MAIN PAGE			CURRENT STATISTICS

List of collected GA / KPI	Semesters	Fall 2014	Fall 2015	Fall 2016	Fall 2017	Fall 2018	Fall 2019	Fall 2020	Fall 2018	Winter 2019	Fall 2019	Winter 2020	Fall 2020	Winter 2021
6.A-4	Exceed	33.3	44.4	35.5	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0
Contribute as an individual to a group initiative in a capstone project	Meet	66.7	44.4	54.8	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0
	Marginal	0.0	11.1	9.7	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0
	Insufficient	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0
	Requirements (Exceed + Meet)	Exceeded	Exceeded	Exceeded										
6.A-5	Exceed	33.3	33.3	45.2	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Demonstrate the ability to work effectively as a member and/or a leader in teams.	Meet	45.7	55.6	48.4	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Marginal	12.0	11.1	6.5	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Insufficient	9.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Requirements (Exceed + Meet)	Met	Exceeded	Exceeded										
7.B-1	Exceed	22.2	11.8	9.7	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Write individual and group reports to explain the acquired information related to an electrical engineering system, including detailed calculations	Meet	34.7	58.8	83.9	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Marginal	32.6	11.8	6.5	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Insufficient	10.5	17.6	0.0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Requirements (Exceed + Meet)	Not Met	Met	Exceeded										
7.B-4	Exceed	27.8	16.7	16.1	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Develop and perform individual and group oral presentations about engineering concepts	Meet	72.2	66.7	74.2	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Marginal	0.0	16.7	9.7	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Insufficient	0.0	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
	Requirements (Exceed + Meet)	Exceeded	Exceeded	Exceeded										

Figure 25. CDEF Table Report Form.

For each indicator (measured by a course learning outcome), there are four rows in Figure 25 that shows the percentage of students who Exceed expectations (green), Meet expectations (yellow), are Marginal (orange), or are Insufficient (red). Each row shows the percentage for each year in which the indicator is measured. There is also a fifth row that summarizes the overall achievement measured for the indicator. Dark green indicates that more than 80% of students meet or exceeded expectations. Light green indicates that more than 65% of students met or exceeded expectations. While red indicates clearly an indicator where student achievement is not satisfactory since fewer than 65% of students are meeting or exceeding expectations.

Figure 26 below, shows a different perspective. For a single semester (Fall 2016), it has a different colored column for each indicator measured in the course. One can easily compare indicators to see what percentages were Exceeds, Meets, Marginal or Insufficient.

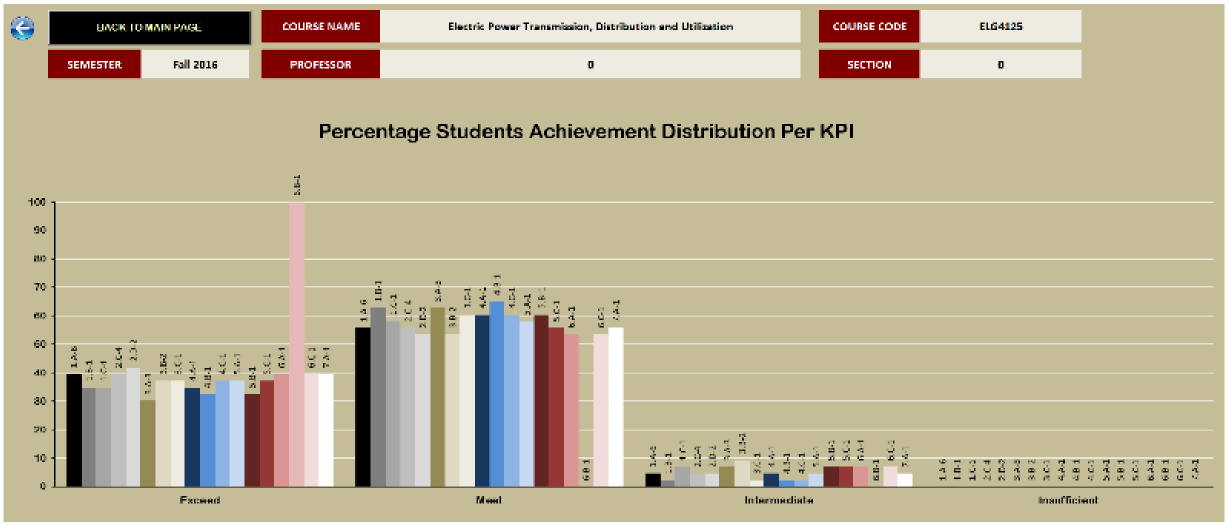


Figure 26. CDEF Graph Report Form.

Figure 27, provides a graphical presentation of a historic trend of data collected for the course for a particular indicator. It allows for easy comparison of achievement across accreditation cycle(s) and gives a better visualization of the overall graduate attribute assessment against meeting accreditation requirements.

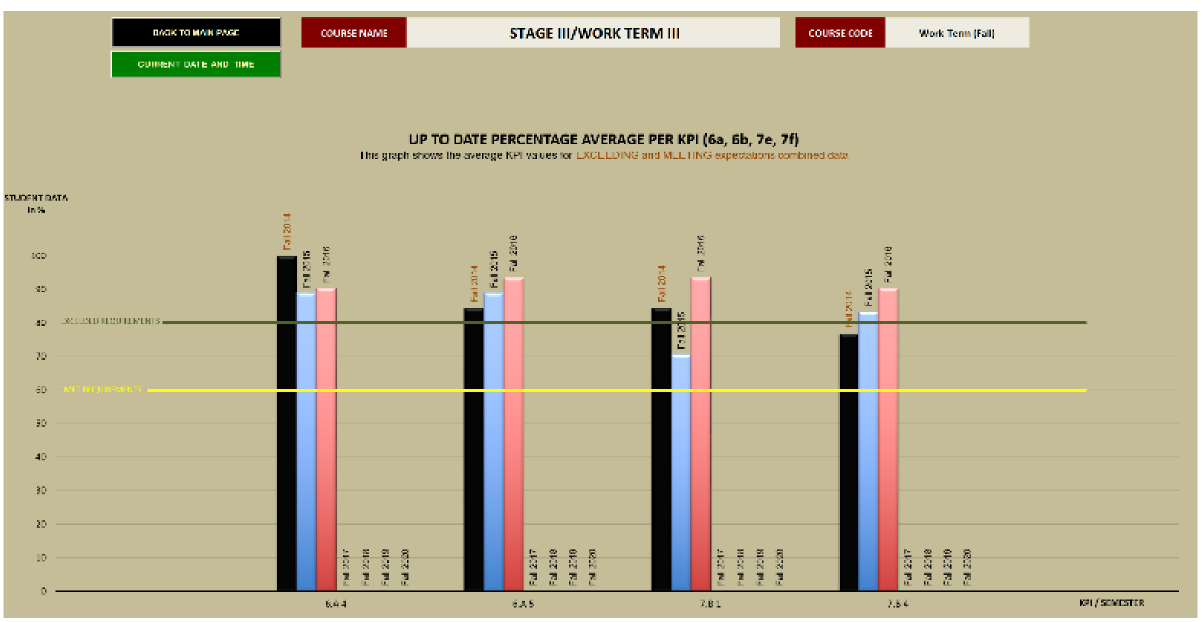


Figure 27. CDEF Current Statistics Report Form.

3.5.2. Program Report Form (PRF)

The Program Report Form (PRF) provides similar types of reports to measure achievement at the program level. These reports are used by the curriculum committee members to outline steps for program improvement. The PRF is read-only. It integrates the assessment data provided by the CDEF form for each course in the programs on a semester by semester basis. This component of the tool measures and reports the cumulative impact individual courses have on overall program performance. It is generated in table and graph form per graduate attribute. An example is shown in Figure 28.

a) b)

Figure 28. PRF generated report (a) table form, (b) graph form.

In Figure 28a, we see in a tabular layout, a section for each GA. In that section, one or more courses where the indicators for that GA are displayed. The indicator from a specific course is depicted similar to Figure 25. There are four rows showing what percentage were Exceeded (green), Met (yellow), Marginal (orange) or Insufficient (red) for each year it was measured. The indicator, each year is summarized as Green (>80% met or exceeded), Light green (65-80% met or exceeded), or red (<65%). At a glance, one can see how each of the course is contributing (or not contributing) to the Graduate Attribute on a year by year basis. This enables the program coordinator to see the historical trend for the indicator, as well as see how well it is addressed in different parts of the curriculum (Year 1 courses versus Year 4 courses).

3.5.3. Coop Report Form (COOP-PRF)

The COOP Report Form (COOP-PRF) is similar to the PRF, but it focuses on the indicators measured by data collected by employers (using Employer Evaluations) or by data collected during the placement process. All co-op assessment data is processed to produce three types of reports:

- **COOP-PRF (Type I)** is a historic trend of co-op GA assessment across the relevant indicators as measured by Employer Evaluation. Figure 29 below shows a sample graph. Indicators above the green line, indicate that at least 80% of students Exceeded or Met Requirement. Indicators below the red line did not do well, less than 60% of students Exceeded or Met the Requirement.

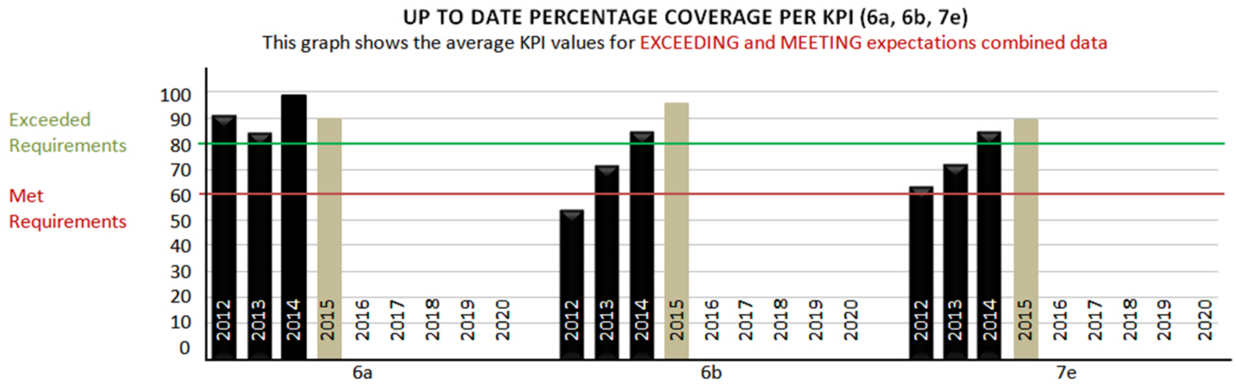


Figure 29. GAIA COOP-PRF (Type I Report).

- **COOP-PRF (Type II)** shows the same information in Figure 30, but for a specific year. It allows one to more clearly compare the indicators measured by Employer Evaluation for a given year.

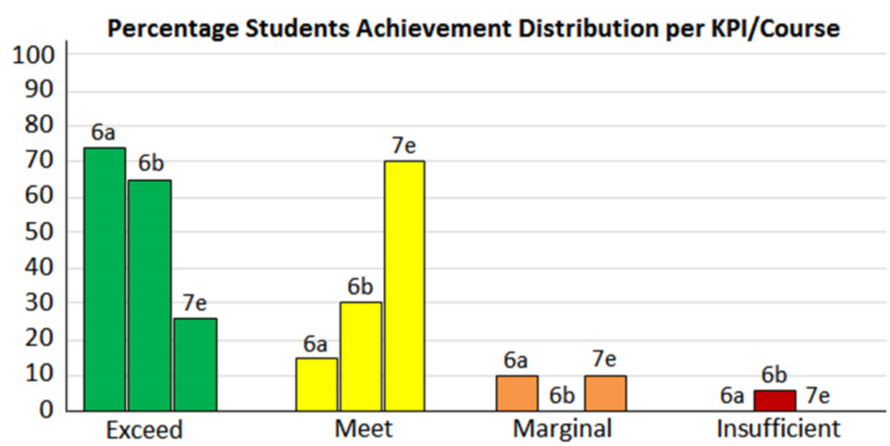


Figure 30. GAIA COOP-PRF (Type II Report).

- **COOP-PRF (Type III)** is the same data again, but this time it drills into the specific historic trend analysis for a single indicator measured by Employer Evaluation. It is illustrated on Figure 31 below.

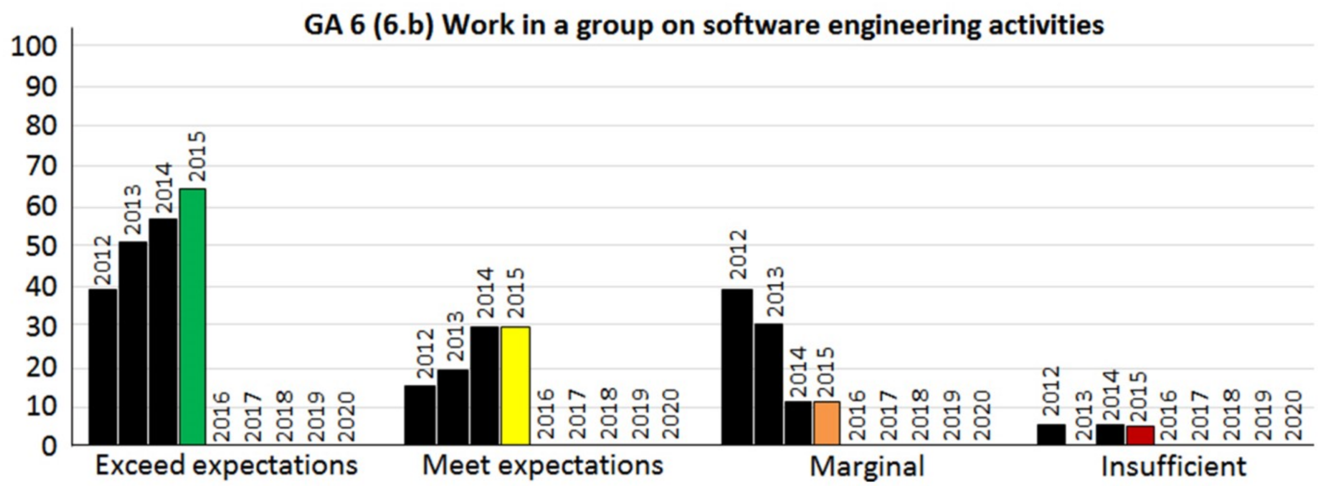


Figure 31. GAIA COOP-PRF (Graph Type III Report).

The report can be shown in tabular form, which drills in further to show how each work term was measured as shown in Figure 32. Typically, students must do a minimum of 3 work terms (after year 1, after year 2, after year 3). In this case course 1 corresponds to the work term that first year students do, while course 2 corresponds to the work term that second year students do.

GA 6 (KPI 6b)	Individual and team work Work in a group on software engineering activities					
Scale: 55|80|90	Fall	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
Course 1	Exceed	89.4	55.3	55.1	71.4	
	Meet	6.5	30.8	31.9	21.4	
	Marginal	4.1	13.9	8.1	7.1	
	Insufficient	0.0	0.0	4.9	0.0	
Requirements		Exceeded	Exceeded	Exceeded	Exceeded	
Requirement Scale: 60|80		95.9	86.1	87.0	92.2	
Scale: 55|80|90	Fall	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
Course 2	Exceed	40.0	50.6	55.3	65.0	
	Meet	15.2	18.7	29.4	29.4	
	Marginal	39.2	28.7	10.2	10.2	
	Insufficient	5.6	0.0	5.1	5.0	
Requirements		Not Met	Met	Exceed	Exceed	
Requirement Scale: 60|80		55.2	71.3	84.7	94.6	

Figure 32. COOP-PRF (Tabular Type III Report).

There is one COOP report that is not based on Employer Data. In Figure 33, the COOP Placement Data Report is shown. Students go through an interview and matching process to obtain a work term. This measures how successful students are, which indirectly measures how well students are prepared in terms of professionalism by the program. If students are placed automatically in the first round of the matching process, they exceed expectations. If they are eventually placed with help by the COOP office, they meet expectations. If they participated fully and interviewed for jobs but were not successful, they were marginal. Otherwise they were insufficient. Figure 33 shows what percentage met or exceeded expectations by successfully obtaining a work term placement in their first year of the program.

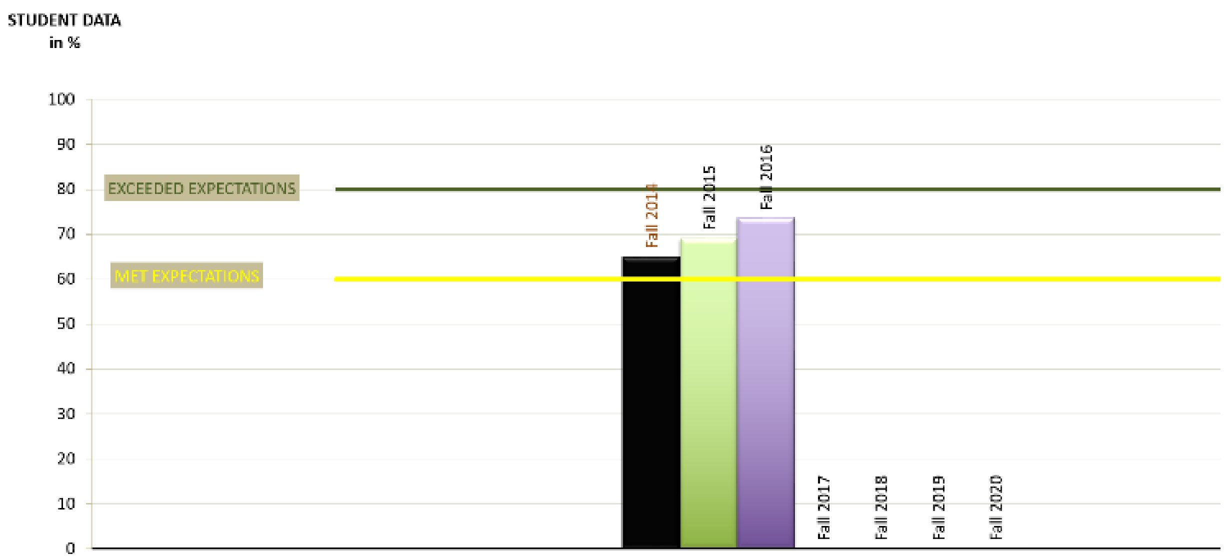


Figure 33. COOP-PRF Placement Data Report Form.

3.5.4. Common Program Report Form (CPRF)

The Common Program Report Form (CPRF) is similar to the PRF, but it maps all the data from the Course Data Entry Form (CDEF) into a set of Common Key Performances Indicators (CKPI) as described in section 3.4. The Data Transformation and Analysis Technique that accomplishes this is described in detail in section 5.5. In this section, we describe how the form can be used to compare programs. This report provides historic trends analysis of GAA data achievement for each course within the program, just like the CPRF with the same color coding with the same graphical and tabular reports. However, the report aggregates data from courses based on the mapping into the set of CKPI.

An example of reports that compare Software Engineering (SEG) and Electrical Engineering (ELG) programs is shown in Figure 34. Each program is looking at a report for the indicator 2a. Apply Techniques for Graduate Attribute 2. Problem Analysis. The data is coming from different learning outcomes from different courses and undoubtedly measuring the performance of students on a different set of techniques for each program. However, at the faculty level, one can directly compare the two programs and understand how well students are able to Apply Techniques for Problem Analysis. If there is a problem with one program, one can drill into the specific course or courses to see what is going on.

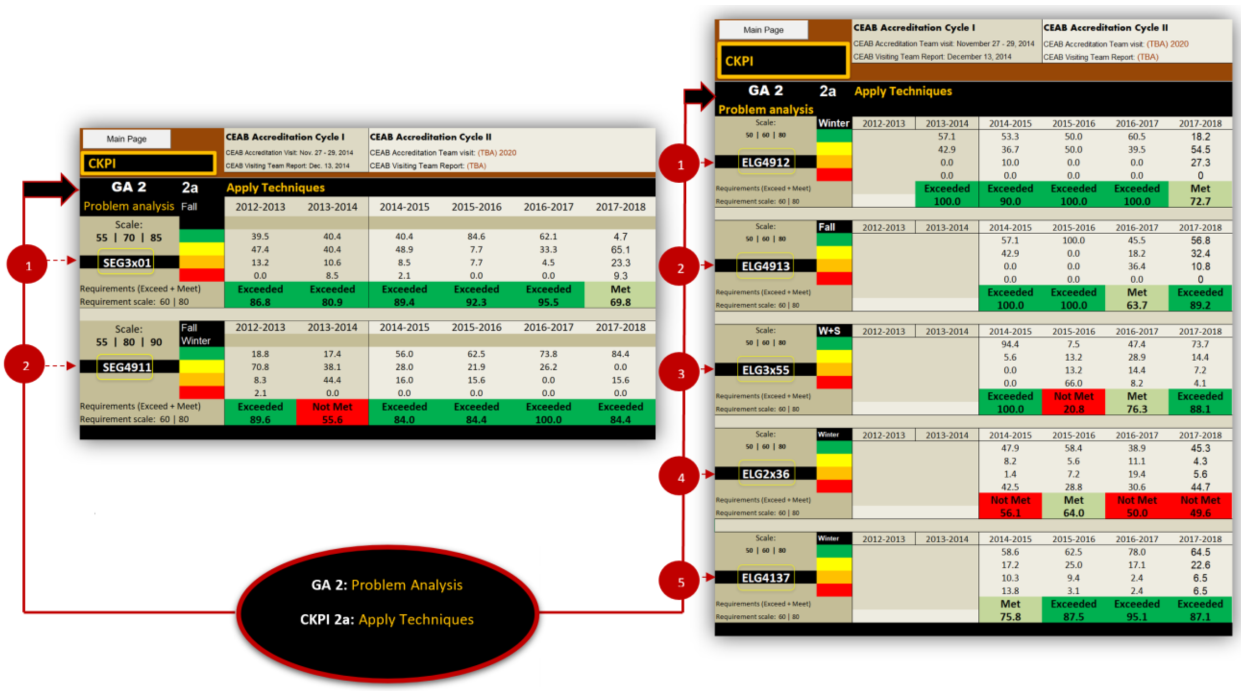
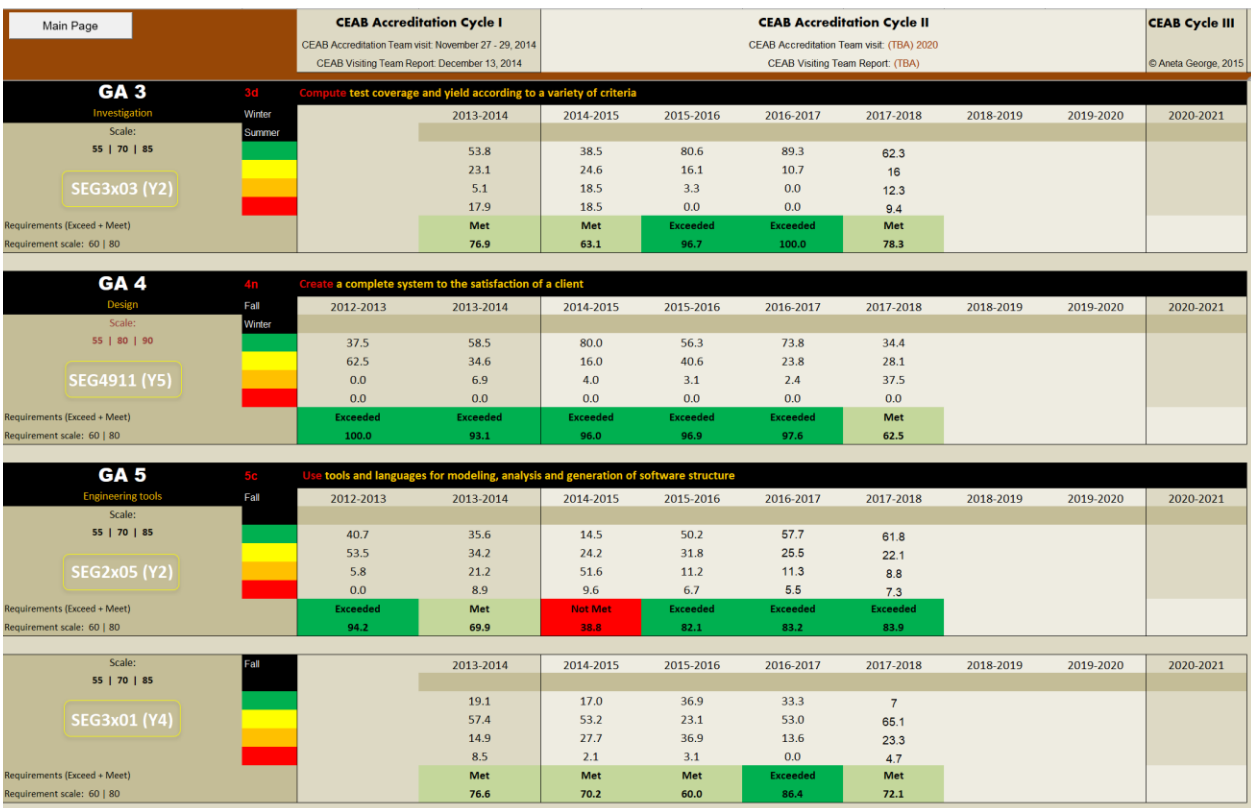


Figure 34. Common Program Report Form (CPRF)

3.5.5. Cohort Program Report Form (PRF-C)

The Cohort Program Report Form (PRF-C) is a series of three reports that provides a "cohort" view that is very different from the "snapshot" view that the PRF provides. The Data Transformation and Analysis Technique that accomplishes this is described in detail in section 5.5.

In the PRF, one is seeing a "snapshot" view for a given year. In Figure 35, for the year 2017-2018, we are seeing the performance of students in all the courses that were taught during the year 2017-2018. However, the courses shown are taken in different years of the program. This example is for a software engineering with mandatory coop, so it is a five-year program. You can see that SEG4911 is taken in year 5, while SEG3x01 is taken in year 4, and SEG2x05 and SEGx03 are taken in year two. That means for year 2017-2018 we are seeing results from 3 different cohorts of students (year 2, year 4 and year 5). While the information is there it is hard to visualize how the students from a particular cohort are doing. We know that the students who are going to graduate in 2017-2018 met expectations in their fifth-year course SEG4911 (y5), but we have to look closely to realize the red flag on SEG2x05 (y2) in 2013-2014 also applies to them. The “snapshot” PRF is very good for showing how well the program has been improving from year to year, but it is not very good for showing at graduation, how well a particular cohort performed during the time they spent in the program.



Main Page

CEAB Accreditation Cycle I
CEAB Accreditation Team visit: November 27 - 29, 2014
CEAB Visiting Team Report: December 13, 2014

CEAB Accreditation Cycle II
CEAB Accreditation Team visit: (TBA) 2020
CEAB Visiting Team Report: (TBA)

CEAB Cycle III
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GA 3 Investigation	3d	Compute test coverage and yield according to a variety of criteria								
	Winter Summer		2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Scale: 55 | 70 | 85			53.8	38.5	80.6	89.3	62.3			
SEG3x03 (Y2)			23.1	24.6	16.1	10.7	16			
			5.1	18.5	3.3	0.0	12.3			
			17.9	18.5	0.0	0.0	9.4			
Requirements (Exceed + Meet)			Met	Met	Exceeded	Exceeded	Met			
Requirement scale: 60 | 80			76.9	63.1	96.7	100.0	78.3			

GA 4 Design	4n	Create a complete system to the satisfaction of a client								
	Fall Winter	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Scale: 55 | 80 | 90		37.5	58.5	80.0	56.3	73.8	34.4			
SEG4911 (Y5)		62.5	34.6	16.0	40.6	23.8	28.1			
		0.0	6.9	4.0	3.1	2.4	37.5			
		0.0	0.0	0.0	0.0	0.0	0.0			
Requirements (Exceed + Meet)		Exceeded	Exceeded	Exceeded	Exceeded	Exceeded	Met			
Requirement scale: 60 | 80		100.0	93.1	96.0	96.9	97.6	62.5			

GA 5 Engineering tools	5c	Use tools and languages for modeling, analysis and generation of software structure								
	Fall	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Scale: 55 | 70 | 85		40.7	35.6	14.5	50.2	57.7	61.8			
SEG2x05 (Y2)		53.5	34.2	24.2	31.8	25.5	22.1			
		5.8	21.2	51.6	11.2	11.3	8.8			
		0.0	8.9	9.6	6.7	5.5	7.3			
Requirements (Exceed + Meet)		Exceeded	Met	Not Met	Exceeded	Exceeded	Exceeded			
Requirement scale: 60 | 80		94.2	69.9	38.8	82.1	83.2	83.9			

Scale: 55 | 70 | 85	Fall		2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
SEG3x01 (Y4)			19.1	17.0	36.9	33.3	7			
			57.4	53.2	23.1	53.0	65.1			
			14.9	27.7	36.9	13.6	23.3			
			8.5	2.1	3.1	0.0	4.7			
Requirements (Exceed + Meet)			Met	Met	Met	Exceeded	Met			
Requirement scale: 60 | 80			76.6	70.2	60.0	86.4	72.1			

Figure 35. “Snapshot” Program Report Form.

There are three reports specifically developed for the purpose of analyzing a specific cohort: the Cohort-Program Report Form per Graduate Attributes (C-PRF/GA), the Cohort-Program Report based on the Course Progression data (C-PRF/CP), and the COOP-Progress Report Form per cohort (COOP-PRF/C).

- **The Cohort-Program Report Form per Graduate Attributes (C-PRF/GA)** is illustrated in Table 1 below. The report arranges averaged student achievement (Dark Green Exceeded means that >80% meet or exceed expectations, Light Green means 60-80%, Red means less than 60%). For each GA, we can see which courses were used to measure the GA and the actual percentage.

Table 1. Cohort-Program Report Form per Graduate Attributes (C-PRF/GA)

Graduate Attribute	COURSES			Meeting Accreditation Requirements	GA Achievement Data in %
GA1	SEG3101			Exceeded	84.0
GA2	SEG3101	SEG4911		Exceeded	84.4
GA3	SEG3103			Met	63.1
GA4	SEG4911			Met	76.9
GA5	SEG2105	SEG3101	SEG3102	Not Met	55.1
GA6	SEG2105	SEG4105	SEG4911	Exceeded	82.3
GA7	SEG4911	SEG2911		Exceeded	87.2
GA8	SEG4911	SEG1911		Exceeded	80.4
GA9	SEG2911			Met	69.9
GA10	SEG2911			Met	60.0
GA11	SEG4105			Met	70.2
GA12	SEG4911	SEG1911		Exceeded	86.3

Course color codes indicate the year the course was taken within the program as follows (note that Software Engineering, SEG, is a mandatory coop program that takes 5 years to complete):

- red shading is used for Year 5 courses
- peach shading is used for Year 4 courses
- green shading is used for Year 3 courses
- grey shading is used for Year 2 courses
- blue shading is used for Year 1 courses

- **The Cohort-Program Report based on the Course Progression data (C-PRF/CP)** tracks students' achievement as students progress in their program on a yearly basis. It uses summative average GA achievement per year and allows for comparison of GAA against end of year average course assessment data. The information provided is used for follow-up on assessment data consistency and assessment techniques accuracy. A sample C-PRF/CP report using simulated data is illustrated in Table 2.

Table 2. Cohort-Program Report Form per Graduate Attributes (C-PRF/CP)

	Cohort Progression (years)				
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Course Average	80.5	83.8	75.3	84.7	91.4
GA Average	80.4	72.6	68.0	82.4	84.6
Courses	SEG1911	SEG2105	SEG2106	SEG3101	SEG4911
		SEG3103	SEG2911	SEG3102	SEG4105
		SEG3125		SEG4145	

Data from both cohort reports are used for comparison allowing for evaluation within a process of continuous improvement and provide a historic data trend for further curriculum development.

- **The COOP-Progress Report Form per cohort (COOP-PRF/C)** is based on data arranged per year as students progress in their program. Such a report increases reliability of data analysis on employability and adds consistency to the professional skills assessment provided by COOP employers. Table 3 below illustrates a COOP-PRF/C type of report, based on SEG COOP program sequence. The course progression in those reports is approved by the program GA Committee for reporting on GAA.

Table 3. COOP Progress Report Form per Cohort (COOP-PRF/C)

Cohort Progression (years)	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Meeting Accreditation Requirements	Exceeded	Not Met	Met	Exceeded	Met
COOP Courses	SEG 1911	COOP Placement	SEG 2901	SEG 3901	SEG 3902

Chapter 4. Case Studies

Our experimentation and evaluation of tool support for performance management of engineering education has taken place over a period of 5 years (2014-2018). It began with the CEAB accreditation visit at the University of Ottawa in November 2014 and the efforts required to collect and process GAA data using the forms provided by CEAB. Since then, we have followed an iterative process of evaluation and prototyping as we developed our systematic approach for tool-supported performance management of engineering education.

Each case study results in an improved theory to reduce identified gaps as we developed our tool-supported systematic approach. Each case study involved collaboration with the engineering programs at EECS as they did performance management of their program as iterative involvement of action research (AR) elements within the DSR. I participated in each case study in the role of "system administrator" (see Figure 18, Chapter 3, Section 3.2 System Architecture) as well as acting in the role of tool developer for the prototypes constructed in Case Study 2, 3 and 4, and finally acting in the role of researcher when evaluating each case study.

4.1 CEAB Guidelines and Tool Support

In this case study we describe the experience and results of implementing GAA based on CEAB Guidelines and the CEAB-provided Excel forms during the 2014 accreditation of EECS programs at the University of Ottawa. An initial version of our systematic approach for tool-supported performance management had been induced from our systematic literature review, which served as a "lens of analysis" to structure our description of the case study and report on the results in terms of the gaps that our research was focused on addressing.

4.1.1. Overview

In 2014 CEAB Accreditation, uOttawa EECS had to follow CEAB guidelines and use CEAB tools (spreadsheet plus questionnaire) to document performance management of its programs.

CEAB adopted graduate attributes (GA) and continual improvement (CI) as additions to the existing accreditation criteria in 2008 and provided a buffer period of 6 years for engineering programs to accommodate the change. In support of the accommodation process, all programs being accredited within the period between 2008 and 2013 were not evaluated against compliance with GA and CI criteria (EC, 2016). Since 2014 as part of adding outcomes assessment to accreditation criteria, CEAB mandates each engineering program to cover 12 specific graduate attributes at different level of complexity as students progress within the program. Furthermore, an evidence for using the findings to inform continual improvement of engineering programs must be demonstrated (EC, 2014).

4.1.2 System Architecture

Although CEAB guidelines suggest that a broad range of actors should be involved (alumni, students, employers, profs) and a broad range of sources of data should be used (surveys, LMS, etc.), in fact the only actors involved were program professors and course professors (final grades for courses outside the programs, 2-3 component grades within a course for courses inside the program). Figure 36 below clearly highlights the gap from the ideal Map of Tool Support presented in Figure 18, Chapter 3.2. Dark grey shading identifies the missing elements.

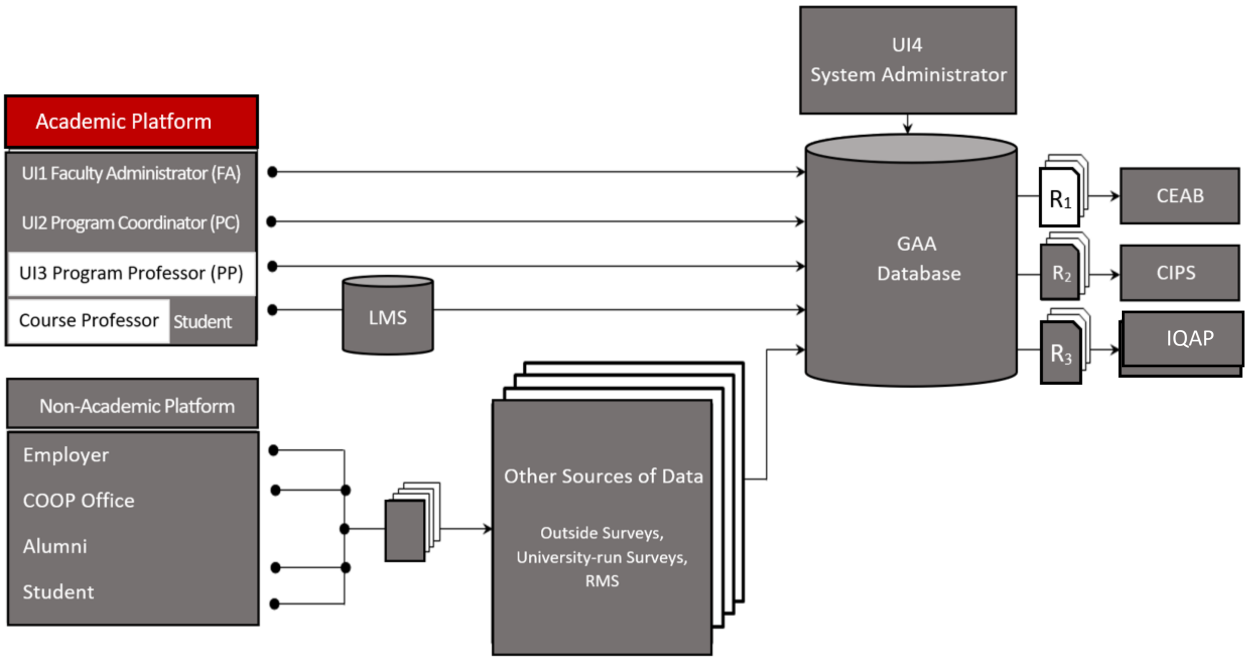


Figure 36. GAIA Phase Zero Tool Support Map

4.1.3 Continuous Improvement Process

At this stage a structured CIP did not exist. Ad hoc effort of program coordinators to identify and collect "learning outcome data" to populate CEAB spreadsheet was used instead and an initial annual program committee meeting (professors only) was held where CEAB spreadsheet was reviewed using a sample of one indicator per graduate attribute.

4.1.4 Key Performance Indicators

Figure 37 shown below, illustrates the structure of the GA Report per Program document mandated by CEAB. It consists of six documents located on a separate sheet of an Excel workbook.

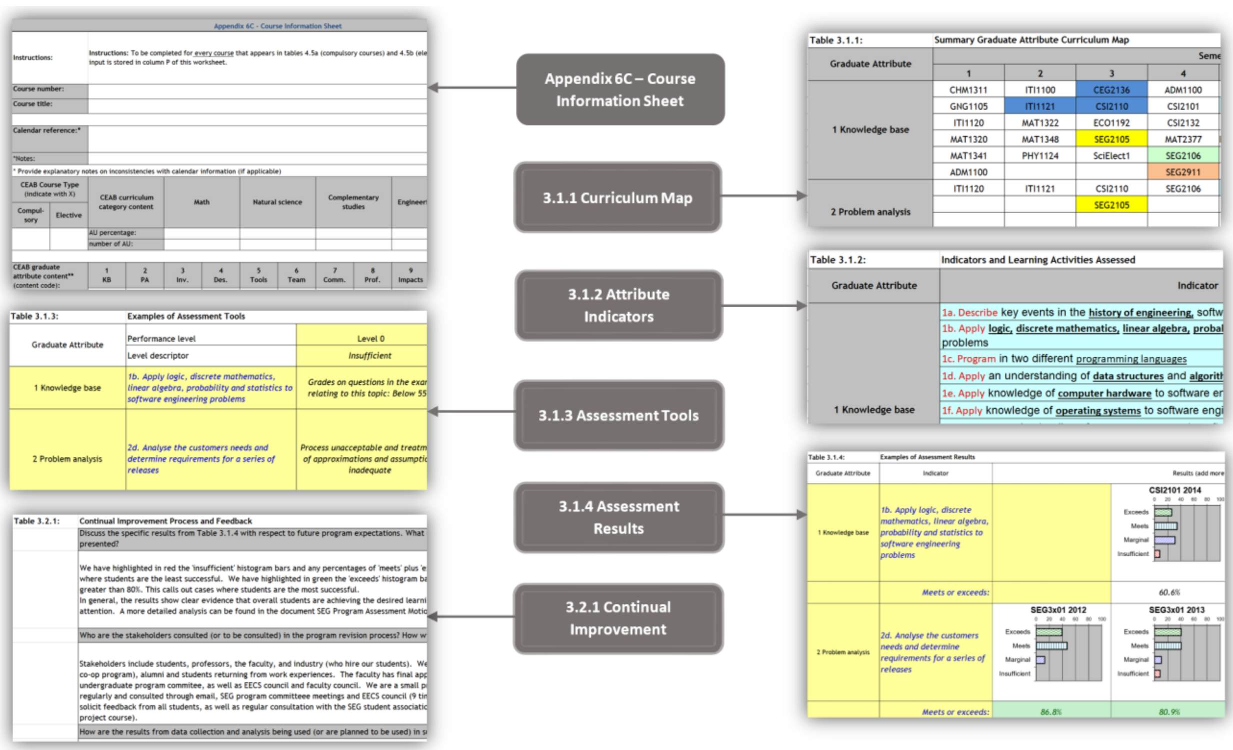


Figure 37. Structure of 3.1.1_3.1.2_3.1.3_3.1.4_3.2.1 GA Report Form at Program Level

Color-coded Blooms taxonomy vocabulary is used to identify categories and sub-categories of cognitive processes to encounter knowledge. The action words (highlighted in red) in Fig. 36 are based on the Revised Taxonomy developed by a team of cognitive psychologists, curriculum developers, instructors and researchers (Anderson, Krathwohl, & Bloom, c2001). The revised taxonomy classification of cognitive processes is illustrated on Figure 38 below.

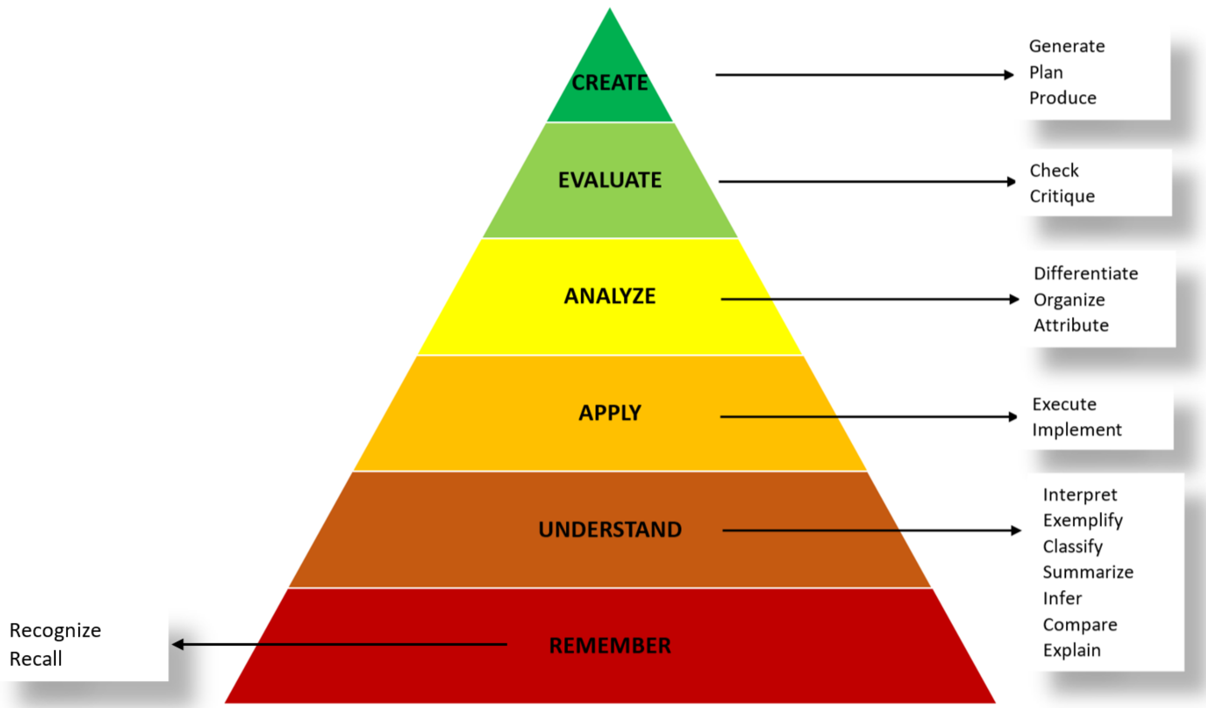


Figure 38. Revised Taxonomy Classification of Cognitive Process

No indicators, however, were specified by CEAB. Instead each program decided on its own indicators, based primarily on learning outcomes measured in courses, and mapped these to the 12 graduate attributes mandated by CEAB. One sample indicator for each graduate attribute was selected for analysis to establish a minimum process of continuous improvement based on performance management reporting.

4.1.5 Performance Management Forms

The CEAB provided two forms: (A) GA report document to be used per program, and (B) program assessment report sheet (called "Appendix 6E") expected to be filled in by completion of a data collection cycle. Typically, form B is being used by the end of a semester and/or fiscal year. No data collection form, or tracking document of any kind was provided. In order to collect the necessary GAA data from each course a custom-designed Excel spreadsheet was developed (see Fig. 42). Data analyses and implementation of results into a program improvement plan identified the need for several components which were not provided by the prototype at this stage. It utilizes four documents to collect and report on GA data and inform a continuous improvement process – (A) GA data collection spreadsheet per course, (B) GA report document per program (SEG_3.1.1_3.1.2_3.1.3_3.1.4_3.2.1), (C) course information sheet (called "Appendix 6C"), and (D) program assessment report (called "Appendix 6E"). We follow the order above to report on advantages and disadvantages each document possesses.

A) GA report document per program:

Pros:

- Provides data on course specifics - academic year, semester, language, section, instructor's name, number of students, average final grade for the course and number of full teaching assistants;
- Lists the graduate attributes and their respective indicators the course is used to report on;
- Provides a course level report in a table form on GA achievement in each of the four categories – exceed expectations, meet expectations, marginal and insufficient.

Cons:

- The spreadsheet per program lacks the ability to generate combined GA report;
- It does not allow for tracking course results per individual GA based on selected measurement tool;

- Does not support identification of selected/used measurement tool(s);
- It does not support historic trend data within program reporting for comparison;
- No raw data is collected. Reports are based on GA achievement calculated by instructors and clustered into the four categories of exceed expectations (above 85%), meet expectations (70-85%), marginal (55-70%) and insufficient (below 55%);
- The document does not allow to distinguish between GA data collected using different measurement tools;
- Spreadsheet per course does not support work-term experience qualitative assessment data, thus there are no reports on GA reflecting students' performance during COOP work terms at this stage.

Screenshot from a sample GA data collection sheet per course is provided in Figure 39 below.

SEG3103 / SEG3503 - Software Quality Assurance					
Graduate Attribute - Continual Improvement Data					
Data in this spreadsheet is used to track progress towards the various graduate attributes as students progress through the program					
Please add one column for each section of the course. Each course has a separate tracking spreadsheet.					
Year	2013	2013		2014	2014
Semester	S	S		W	S
Language	E	F		E	E
Section					
Professor	xxxx	xxxx		xxxx	xxxx
Num Students	16	7		17	22
Average Final Grade	73.87	81.29		74.5	72.22
Num Students Failed	1	0		1	1
Number of full Tas	0.75	0.5		0.5	1
GA4 i					
Design and implement appropriate **tests** and testing infrastructure for a variety of software types					
Measurement instrument: Assignment on application of various testing approaches					
Percent Grades Exceed Expectations: >=85% range	81.25	100		64.71	27.27
Percent Grades Meet Expectations: 70-84.99% range	6.25	0		29.41	31.82
Percent Grades Marginal: 55-69.99% range	6.25	0		0	9.09
Percent Grades Insufficient Below 55%	12.5	0		0	31.82

Figure 39. Sample GAIA Stage Zero GA Data Collection Sheet per Course.

The University of Ottawa is the largest bilingual (English-French) post-secondary institution in the world and world's first university to introduce French immersion undergraduate programs. By 2014 its Engineering Faculty has 2956 English/French speaking students enrolled in undergraduate engineering programs (UO, 2014). Considering the bilingual structure and the vast number of enrollments, most of the courses are introduced to several sections simultaneously. As shown on Fig. 43 course SEG3x03 is given to two different sections – English speaking students (SEG3103) and French (SEG3503) speaking accordingly. This required adding an extra feature combining the scores of the both sections in order to report on GA achievement for the course. The yellow cells in Figure 40 illustrate the final GA data produced in result. This is the data that has been manually transferred to the GA report sheet per program.

SEG3103 / SEG3503 - Software Quality Assurance						
Graduate Attribute - Continual Improvement Data						
Data in this spreadsheet is used to track progress towards the various graduate attributes as students progress through the program						
Please add one column for each section of the course. Each course has a separate tracking spreadsheet.						
Year	2013	2013		2014	2014	
Semester	S	S		W	S	
Language	E	F		E	E	
Section						
Professor	xxxx	xxxx		xxxx	xxxx	
Num Students	16	7		17	22	
Average Final Grade	73.87	81.29		74.5	72.22	
Num Students Failed	1	0		1	1	
Number of full Tas	0.75	0.5		0.5	1	
GA3 d						
Compute test coverage and yield according to a variety of criteria						
Measurement instrument: Assignment on White Box Testing and Code Coverage measurement using Code Coverage Tools						
Percent Grades Exceed Expectations: >=85% range	56.25	100	69.6	52.94	54.55	53.8
Percent Grades Meet Expectations: 70-84.99% range	12.5	0	8.7	41.18	4.55	20.5
Percent Grades Marginal: 55-69.99% range	6.25	0	4.3	0	9.09	5.1
Percent Grades Insufficient Below 55%	31.25	0	21.7	0	31.82	17.9

Figure 40. GAIA Phase Zero Additional Feature for Multiple Sections

B) GA report document per program (SEG_3.1.1_3.1.2_3.1.3_3.1.4_3.2.1)

Pros:

- Curriculum map using colour codes to identify courses related to specific graduate attributes is created. It is easy to follow and upgrade as the program further develops and new courses are added;
- Indicators per each GA are assigned with clear description of learning activities and colour-coded Bloom's taxonomy vocabulary to easily identify educational goals;
- Assessment tools per performance level are being identified;
- Boundaries per performance level are set at 55/80/90% for capstone project and at 55/70/85% for the other courses;

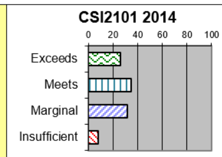
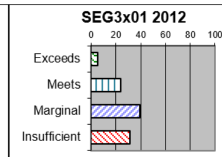
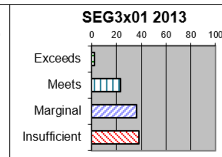
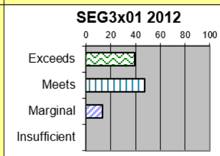
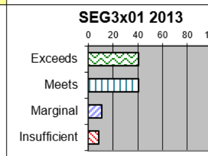
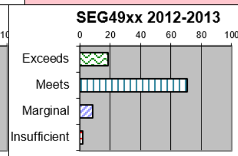
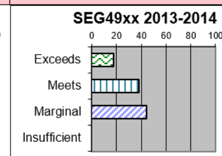
- The continual improvement process and feedback report are conveniently located in Table 3.2.1. The structure proposed in the form of responds to four assigned by CEAB questions is proven successful.

Cons:

- The structure of the table used for 3.1.3 Assessment Tools does not allow to specify different boundaries per course. They can only be assigned per GA and its respective performance indicator. Thus, the scale of 55/80/90% used for the capstone project is not visible on the spreadsheet and the program GA report on 3.1.4 Assessment Results;
- Report per GA at program level appears on 3.1.4 Assessment Results tab in graph form with data reflecting meets and exceeds expectation categories only. The CEAB accreditation criteria of 60-80% is not indicated on the graph or in the tables which complicates comparison between GA data across academic years;
- The graphs are allocated horizontally across the spreadsheet and being added as the GA assessment progresses with time allowing the document to extend unreasonably especially when several courses are being used to report on the same GA;

Table 4 below illustrates an example of assessment results as part of a GA Report Form per SEG program.

Table 4. GA Report Form per program. Phase Zero screenshot.

Graduate Attribute	Indicator	Results (add more columns as required)				
1 Knowledge base	1b. Apply logic, discrete mathematics, linear algebra, probability and statistics to software engineering problems					
	Meets or exceeds:		60.6%	28.9%	25.5%	
2 Problem analysis	2d. Analyse the customers needs and determine requirements for a series of releases					
	Meets or exceeds:	86.8%	80.9%	89.6%	55.6%	

The graphs generated above are based on manually transferred data from the GA Data Collection Sheet per Course submitted by each professor. The data source tables are located at the bottom of the same spreadsheet (GA report form per program) and de facto are system administrator created duplicates of the GA Data Collection sheet per course. The reference data for generating the graphs for GA1, Indicator 1b is illustrated on Table 5.

Table 5. Data source for GA1b from Table 4.

1b. Apply logic, discrete mathematics, linear algebra, probability and statistics to software engineering problems				
	F2014	F2012	F2013	F2014
	CSI2101	SEG3x01 2012	SEG3x01 2013	SEG3x01 F2014
Exceeds	26.0	5.3	2.1	10.6
Meets	34.6	23.7	23.4	38.3
Marginal	31.5	39.5	36.2	27.7
Insufficient	7.9	31.6	38.3	23.4

C) Course information sheet (Appendix 6C)

To reflect ongoing changes in the course information sheet the document had to be emailed to instructors (or updated by an administrator) and uploaded back to the respective database repository. Alongside the required GA data spreadsheet per course, updating this document as well, was seen as additional task and added to the negative attitude towards the whole process of GA data collection. The CEAB called the form Appendix 6C.

D) Program assessment report (Appendix 6E)

Meant to outline findings and approaches to close identified gaps by proposing action plan for continuous program improvement (motions, initiatives and analysis), the document is discussed and approved during a program committee meeting. The approach is identified as successful. The form was called Appendix 6C.

4.1.6 Results

Manual tasks, ad hoc results, no consistency between programs mark the main characteristic of this stage. Insufficient participation of actors and failure to use all types of data sources adds to complexity and gradually supports the development of resistance among users. Annual meeting and CEAB spreadsheet, however, is successful in establishing a minimal process and tool for performance management bringing self-reflection and focus on a mandated continuous improvement process. Furthermore, that process needs to be sustainable as data will be collected every semester on all courses and processed and reviewed at least once a year, not just once every six years for accreditation.

New accreditation support documents are developed in respond to the CEAB call for implementing outcomes-based assessment through reporting achievement on 12 graduate attributes and informing continuous program improvement. This requires mapping of GA to existing learning outcomes (LO). Course curriculum map was developed for that purpose. During this initial stage of the experiment 4-level assessment evaluation criteria was developed and the first reports on GA achievement at course and program level are generated. Course information sheets are structured reflecting accreditation units (AU), level of introduction per GA and course specifications. The R1 report form was provided by CEAB. In order to collect the data needed for the report, an Excel spreadsheet (UI3) (shown in Figure 39) was developed so that program-specific courses professors could provide data. For courses outside the program, final grades were used.

At its initial stage the research is purely inductive. In the process of analyzing GA data, gaps related to the current tool's ability and reporting performance were identified, thus the need for development of an efficient systematic approach for tool-supported performance management emerged. A detailed systematic literature review was performed and the case study was used to evaluate how well the theory explained the gaps in the current practice.

4.2 GAIA Phase I: A systematic approach for tool-supported performance management for uOttawa Software Engineering

4.2.1. Overview

The gaps identified during Phase Zero become the focus of GAIA Phase I - better interfaces for actors, historic trend analysis and better integration with courses for professors. Since 2014 COOP becomes mandatory for SEG thus the coverage of qualitative data extracted from external data sources (COOP office and Employer Evaluation Form) becomes a necessity for reporting for accreditation and for informing a CIP. In this phase of the tool development, the case study is still carried out solely with the software engineering program.

4.2.2 System Architecture

At this stage of GAIA's development we expand the range of actors involved adding alumni, students, employers, profs and COOP in annual meeting and a broad range of sources of data used (employee surveys, COOP job placement statistics). Involving System Administrator assures consistency of the process and supports development of GAA database. Figure 41 below highlights the gap from the ideal Map of Tool Support presented in Figure 18, Chapter 3.2. Dark grey shading identifies the elements missing.

Overall, in terms of systems architecture we succeeded in 1) providing better support for all actors by involving UI4, GAIA System Administrator (SA); 2) establishing more consistent process, still not formally defined though; 3) including all stakeholders (alumni, students, coop) in annual meeting; 4) providing a better version of CEAB report to review, with more supplementary data and analysis; 5) including a review of the tools support and process itself, not just graduate attributes. However, system developments and improvement are still being informed by the needs of SEG program only.

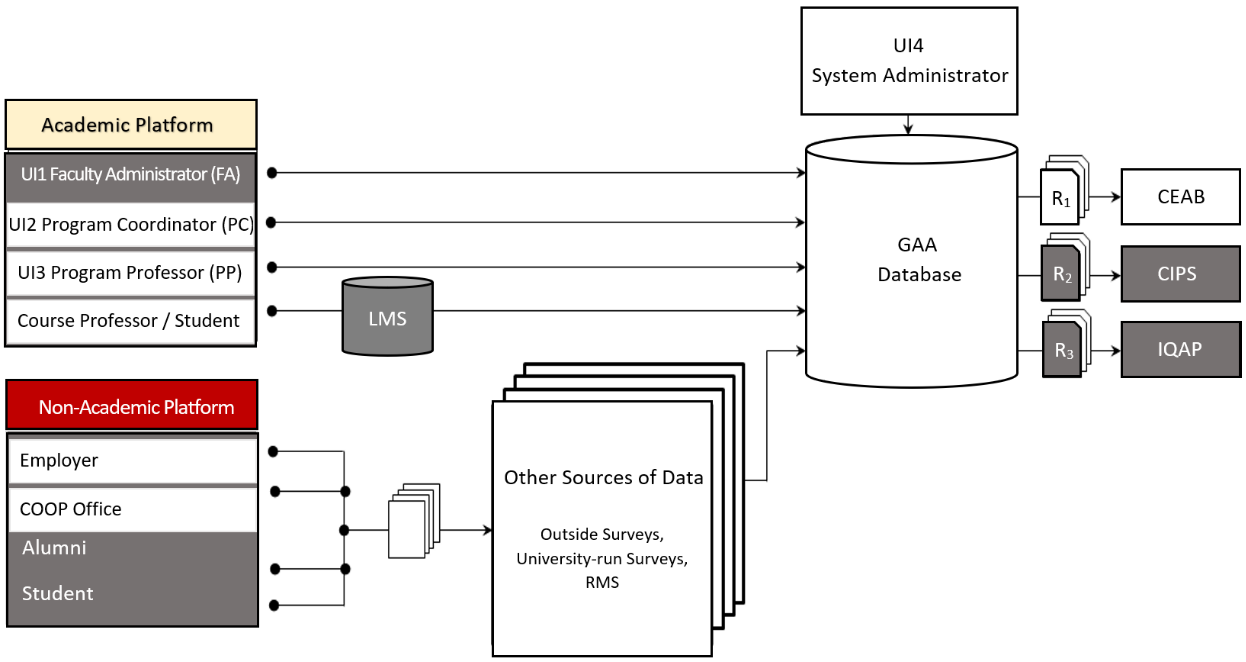


Figure 41. GAIA Phase I Tools Support Map

4.2.3 Continuous Improvement Process

While still not formally defined, a more systematic and continuous process was established for program improvement driven by the need to collect, process and analyze data each semester to produce reports for the annual program committee meeting where the results were reviewed and actions to address were planned. The improved tool support for this is described in sections 4.2.4 and 4.2.5.

An example of a program improvement as a result of the improved GAIA system support was the introduction of a new course SEG2900 Professional Communication and Responsibility. The need for this course was driven by feedback from employers and the COOP office as well as the development of an indicator for graduate attribute 8 Professionalism.

4.2.4 Key Performance Indicators

During this phase a new indicator is measured in first year as students prepare and attempt to secure a job for their first work-term. An agreed by the program Graduate Attributes Committee measurement criteria for exceed, meet, marginal and insufficient achievement for the KPI is determined as follows:

- Exceeded expectations – job secured in first round of COOP interviews for first work term at end of year one.
- Meet expectations – job secured with supplemental help after first round.
- Marginal achievement- students interviewed but were unable to find a job
- Insufficient – students not allowed to interview because they are on academic probation.

The course addresses communication skills, professional skills, and software engineering culture and experience that were identified as lacking. It also fostered teamwork and a sense of professional community and professional development that were applied to improving academic results as well. First year university is a year of transition for students, and the same skills that better prepared them for coop were also relevant to academic studies.

As per CEAB guidelines, the goal would be to have 60 to 80 per cent of all students meet or exceed expectations for this indicator. In 2014 before the course was introduced only 57.8% of students met or exceeded expectations. When the new course was under development and trialed in 2015 61.6% of students met or exceeded expectations and in 2016, when the course was established as an official part of the curriculum, 71.9% of students met or exceeded expectations.

In addition to the COOP placement data from employer evaluation forms (EEF) was used for GAA to measure engineering tools (GA 3.1.5), individual and team work (GA 3.1.6), communication skills (GA 3.1.7), professionalism (GA 3.1.8), economics and project management (GA 3.1.11) and life-long learning (GA 3.1.12). The Employer Evaluation Form (EEF) exclusively developed for that purpose, by the CO-OP Office at University of Ottawa in consultation with the Software Engineering Graduate Attributes Committee (GAC). It lists eleven skills students are expected to demonstrate during their work-term. Employers are evaluating student performance against five-level scale as Exceptional (A+), Excellent (A, A-), Very Good (B+, B), Good (C+, C), Needs Improvement (D+, D) and Not Satisfactory (E to F). Space is provided for employers to add comments that describe an exceptional gift, ability or specific skill for the workplace task in which a student performed above expectations. Alternatively, this spot is used to comment on the need of further development of particular skill to better match employers needs and expectations. Most of the employers use it to justify the extent to which they rate student performance. Figure 42 below shows part of a completed form to illustrate the above.

Exc.	Excellent		Very Good		Good		Needs Improvement		Not SF	N/A
A+	**A**	**A-**	**B+**	**B**	**C+**	**C**	**D+**	**D**	**E-F**	
Produces work meeting quality expectations within an appropriate timeframe										
Comments	• Very motivated, not afraid to add ideas. • He added tasks.									
Demonstrates effective and resourceful problem-solving skills										
Comments	• Applied Java FX, researched it and figured out how to use it.									
Shows interest in work tasks										
Comments	Mentioned he is learning a lot.									
Applies technical/scientific/theoretical concepts to tasks										
Comments	• CSI and SEG love to code. They should take the time to think things through and document.									

Figure 42. EEF - Skills evaluation.

Figure 43 shows the section located at the end of EEF document where employers outline identified strengths and areas for development to inform improvement of student work-place performance. Students can view this evaluation in their COOP Navigator account.

Employer's Comments on the Students' Strength and Areas for Development	
Strength	Areas for Development
1. Strong software skills	1. Design skills
2. Researching, self-learning	2.

Figure 43. EEF - Strengths and areas of development.

The goal of a work-term evaluation is to contribute to student development, so the data is being quantified to allow for measuring CEAB graduate attributes. The EEF is mapped to Key Performance Indicators (KPIs). Table 6 shows the GA map to measure individual and team work (GA 3.1.6), communication skills (GA 3.1.7), professionalism (GA 3.1.8) and life-long learning (GA 3.1.12).

Table 6. COOP GA/KPI map

Skill Evaluated by Employer	Skill Number in EEF	Related KPI
Produces work meeting quality expectations within an appropriate timeframe	S.1	GA 3.1.8 (KPI 8d)
Demonstrates effective and resourceful problem-solving skills	S.2	GA 3.1.12 (KPI 12a)
Shows interest in work tasks	S.3	GA 3.1.12 (KPI 12e)
Applies technical/scientific/theoretical concepts to tasks	S.4	GA 3.1.12 (KPI 12d)
Demonstrates a professional work ethic	S.5	GA 3.1.8 (KPI 8e)
Works well in a group	S.6	GA 3.1.6 (KPI 6b)
Works well independently	S.7	GA 3.1.6 (KPI 6a)
Shows dependability	S.8	GA 3.1.8 (KPI 8g)
Is receptive to and integrates feedback	S.9	GA 3.1.8 (KPI 8f)
Communication skills: Verbal	S.10	GA 3.1.7 (KPI 7e)
Communication skills: Write	S.11	GA 3.1.7 (KPI 7f)

4.2.5 Performance Management Forms

Two new performance management forms are being introduced during Phase I – (A) Course Data Entry Form (CDEF), and (B) Program Report Form. CDEF serves UI3 (refer to system architecture description in section 3.2), and PRF serves UI2 respectively. The two forms are being used to replace and improve the CEAB mandated forms for program reporting and course information sheet described in 4.1.5. The Course Data Entry Form (CDEF) is applicable per course and Program Report Form (PRF) per program respectively. Each form is implemented as a macro-enabled Excel Spreadsheet that is delivered and collected through a web interface.

A) Course Data Entry Form (CDEF):

Pros:

- Provides data on course specifics - academic year, semester, language, section, instructor's name, number of students, average final grade for the course and number of full teaching assistants;
- Lists the graduate attributes and their respective indicators the course is used to report on;
- Provides a course level report in a table and graph form on GA achievement in each of the four categories – exceed expectations, meet expectations, marginal and insufficient.
- Allows for tracking course results per individual GA based on selected measurement tool;
- Support historic trend data reporting for comparison;
- Enables very fine granularity raw data to be collected which allows for the system to perform all calculations simultaneously.
- Reports based on GA achievement and clustered into the four categories of exceed expectations (above 85%), meet expectations (70-85%), marginal (55-70%) and insufficient (below 55%) is performed by the system. Implementation of any user effort is being eliminated.
- The form enables the distinction between GA data collected using different measurement tools;

- The form supports processing work-term experience qualitative assessment data, and generates reports on GA reflecting students' performance during COOP work terms.
- The new forms are backwards compatible with the CEAB mandated forms and can generate the specific documents required by CEAB, but they provide many additional features (including historic trend analysis) and they simplify the task of entering course data for professors.
- The CDEF accommodates qualitative and quantitative data.

B) Program Report Form (PRF)

Pros:

- The PRF can be accessed from the home page of each engineering program on the GAIA website or distributed by email by the system operator.
- It allows for measuring the cumulative impact data input has on program performance.
- It generates all types of graphs and reports needed to inform program improvement.
- PRF has links to Curriculum Map (CEAB 3.1.1), Attribute Indicators (CEAB 3.1.2), Assessment Tools (CEAB 3.1.3), Assessment Results Data (CEAB 3.1.4), continual improvement CEAB document, and a sample Course Information Sheet (Appendix 6C). It also has links to graphical presentations of each KPI assessment and shows the contribution each course has in its measurement.
- The tool generates reports in table and graph forms.

Cons:

- Both forms are macro-based which creates issues when with different OS;
- Both forms are being distributed by the system administrator;
- Data submission tracking is needed.
- The two forms do not allow for cross-program comparison and analysis;

4.2.6 Results

In order to better accommodate employers' expectations and improve students' work-term performance, a new course SEG1911 Professional Communication and Responsibility, has been created for the Software Engineering (COOP) program. The course is an introduction to the responsibilities of software engineers to their employer, their profession and public safety, with emphasis on the development of skills in oral and written communication. Students practice presentations and writing technical reports, business letters, web pages, and safety guidelines. Introduction to source code management and version control is also covered.

The need for this course was driven by feedback from employers and the COOP office as well as a KPI for graduate attribute 8 Professionalism, as it was measured in first year as students prepared and attempted to secure a job for their first work-term. An agreed by the program Graduate Attributes Committee measurement criteria for exceed, meet, marginal and insufficient achievement for the KPI is determined as follows:

1) Exceeded expectations – job secured in first round of COOP interviews for first work term at end of year one.

2) Meet expectations – job secured with supplemental help after first round.

3) Marginal achievement- students interviewed but were unable to find a job

4) Insufficient – students not allowed to interview because they are on academic probation.

The course addresses communication skills, professional skills, and software engineering culture and experience that were identified as lacking. It also fostered teamwork and a sense of professional community and professional development that were applied to improving academic results as well. First year university is a year of transition for students, and the same skills that better prepared them for coop were also relevant to academic studies.

The first year the course was piloted showed immediate improvement. The COOP office, employers, and the software engineering student society all saw noticeable improvements. The percentage of students on academic probation went from 33% to 22% and the number of students placed in the first round went from 22% to 39%. We have been successful in integrating performance measurements from COOP work experience into assessment of graduate attributes. In particular, we were able to improve our GAIA tool by adding support for generating quantitative outcomes from qualitative inquiries.

We established a procedure for COOP program review with consultation of appropriate stakeholders, including the COOP office and key employers, leading to continual improvement of the program. Measuring the quality of pre-graduation co-op work experience against five quality-based PEO criteria through the SEG1911 course was achieved.

Among the major advantages of the proposed assessment technique is the fact that the process does not require a substantial amount of effort or time to implement. GAIA reduces the amount of administration work required to organize, process and analyze the assessment data. It improves visualization of the results and produces easy to read outcomes-based analyzed tables and graphs. The system leverages existing feedback mechanisms for work-term performance thus making it easy to use, process and analyze.

During this stage we are able to improve users' attitude thus their performance implementing much simpler and fewer manual tasks, more systematic collection, storage and automatic processing. Better participation of actors and use of all types of data sources was achieved. We still lack consistency between programs but systematic sound trend analysis and statistics. Major achievement during GAIA's Phase I stage is establishing a sustainable tool supported process on a continuous basis to deliver to annual meeting. As a result, EECS decides to roll GAIA out two more programs.

4.3 GAIA Phase II: Common Process and Indicators

4.3.1. Overview

Phase II of the research is concerned with the rollout of multi-program and faculty level common view support. The focus of this case study is to improve the GAIA prototype by adding Faculty level support that addresses two major CEAB accreditation requirements consistently across all programs in the faculty:

1. Assess student achievement for all 12 GA with data collected to measure performance of students at different stages throughout entire program using common KPIs;
2. Implement and document common continuous improvement process based on ongoing GA assessment.

3. In the School of Electrical Engineering and Computer Science, a committee was tasked to implement a common Continuous Improvement Process (CIP) across all three engineering programs: electrical (ELG), computer (CEG), and software (SEG).

4. Reports are built when data access in the system. If a course joins GAIA for graduate attribute assessment at a later stage, respective graphs and reports are being developed accordingly. Missing data for previous years remains blank and does not affect future calculations.

5. During Phase II, a web-based prototype of GAIA was developed and test-piloted.

4.3.2 System Architecture

At this stage of the project, standardized processes across all EECS programs have been implemented. We still involve same range of actors (alumni, students, employers, professors and COOP) and use same range of data sources. Academic platform input is from Excel or CSV files, and non-academic (COOP) assessment data is being fed to the system through employee surveys, job placement/hiring statistics.

During GAIA Phase II we involve UI1, the faculty administrator. His role is supported by the development of common performance indicators across the three programs which allows for reporting at faculty level using a Common Program Report Form (PRF). It simplifies the cross-program comparison and allows for better informing the improvement process. At this stage using CKPI-based report, EECS is able to reinforce a common improvement process as well. In a similar fashion with our previous case studies, Figure 44 below describes the missing peripheral between the current tool's Phase II stage and the ideal Map of Tool Support (Figure 18, Chapter 3.2) we are trying to build. Dark grey shading is used again to identify the lacking components. During Phase II we were not able to find a solution to the problem of direct data transfer from the university LMS to the CDEF. Users continue using their own CSV or Excel files to copy-paste or indirectly load the assessment data using ODBC with CSV/Excel files as mediator. In terms of reporting for program quality assurance bodies, no IQAP type of report is generated.

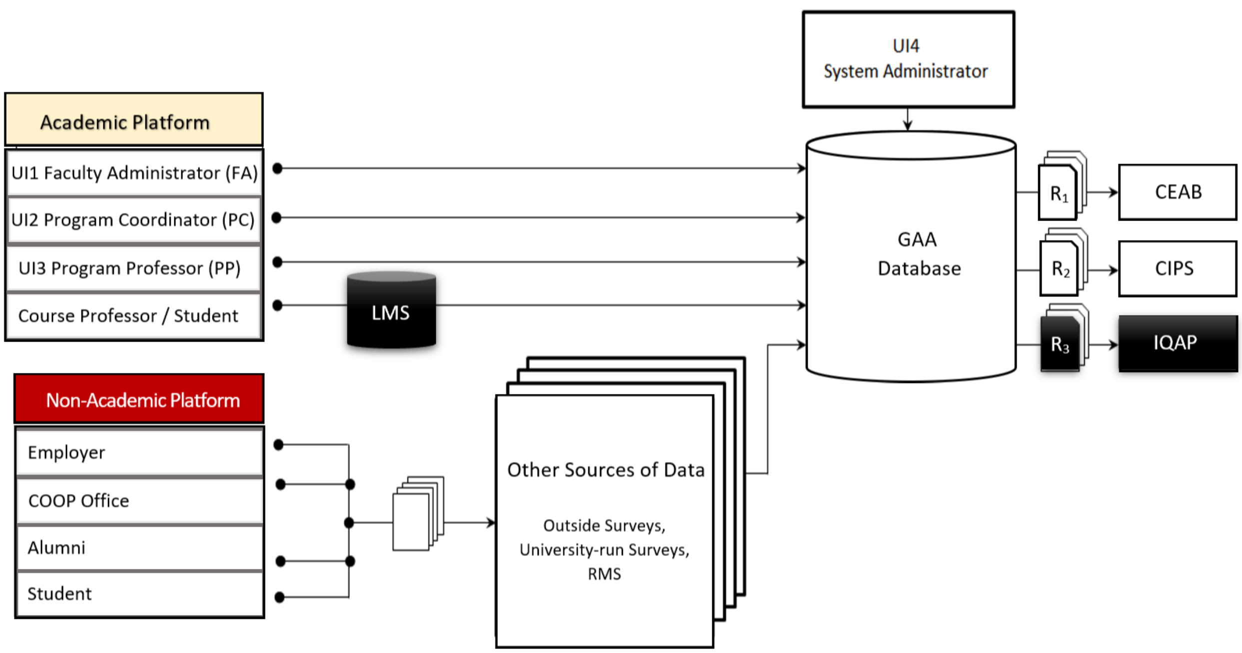


Figure 44. GAIA Phase II Tools Support Map.

A web prototype of GAIA is developed during this stage. HTML is used to display report forms and accreditation related pages to users. Assessment data is stored in SQL database. Web services are provided under IIS and Apache Tomcat. Initial security level is assured through individually assigned username and password. The security level provided for the prototype is in accordance with the University of Ottawa IT security policy (UO, New IT Security Policy, 2016). The web interface provides links to: (1) the three EECS programs – ELG, CEG, and SEG, (2) all CEAB accreditation related documents, (3) all GAA data files for the three programs and their respective courses selected to report for accreditation, and (4) related CIPS Accreditation files and official documents. A screenshot of the web prototype is shown on Figure 45 below.

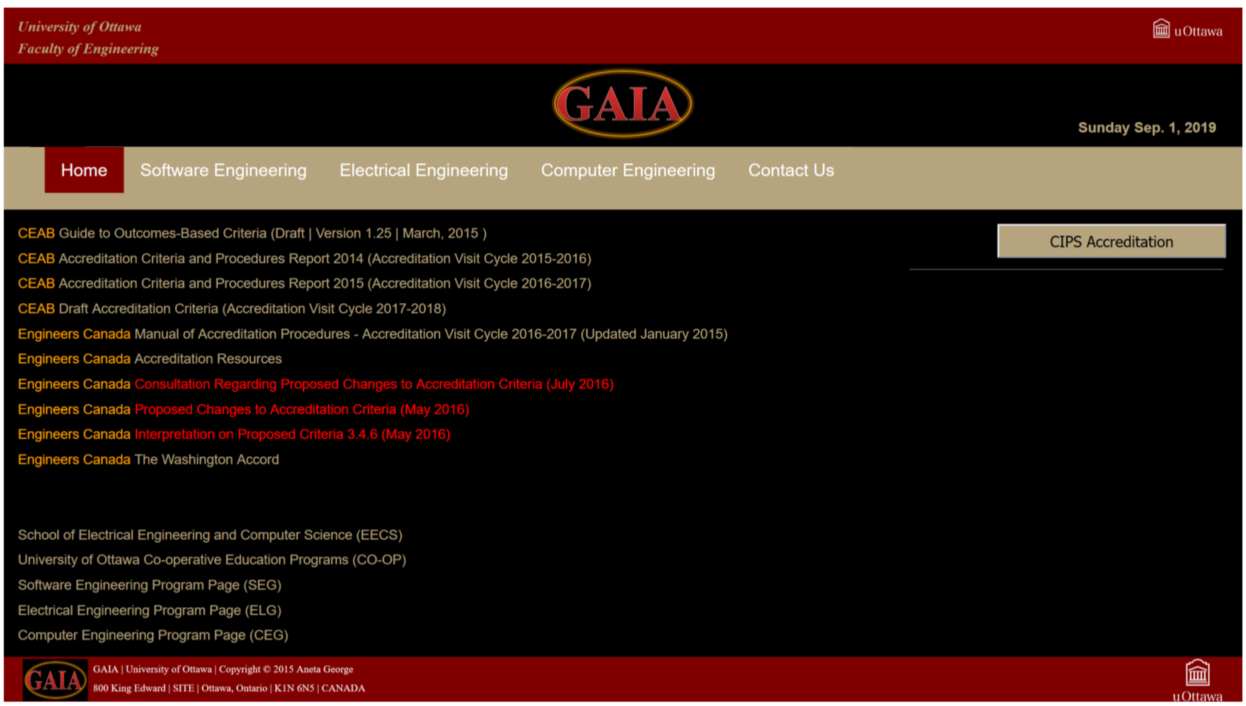


Figure 45. GAIA web-based prototype. Home page.

All the performance management forms (PRF and CDEF) can be downloaded through the web version of GAIA. Clear identification is provided for the forms aimed for UI1 and UI2 (PRF). The CDEF are sorted by semester and each download button is called as the course code and number. Users are given access to a respective form according to their roles and responsibility. A screenshot of the page for Software Engineering Program is illustrated on Figure 46 below. At its prototype stage the model was tested by selected users.

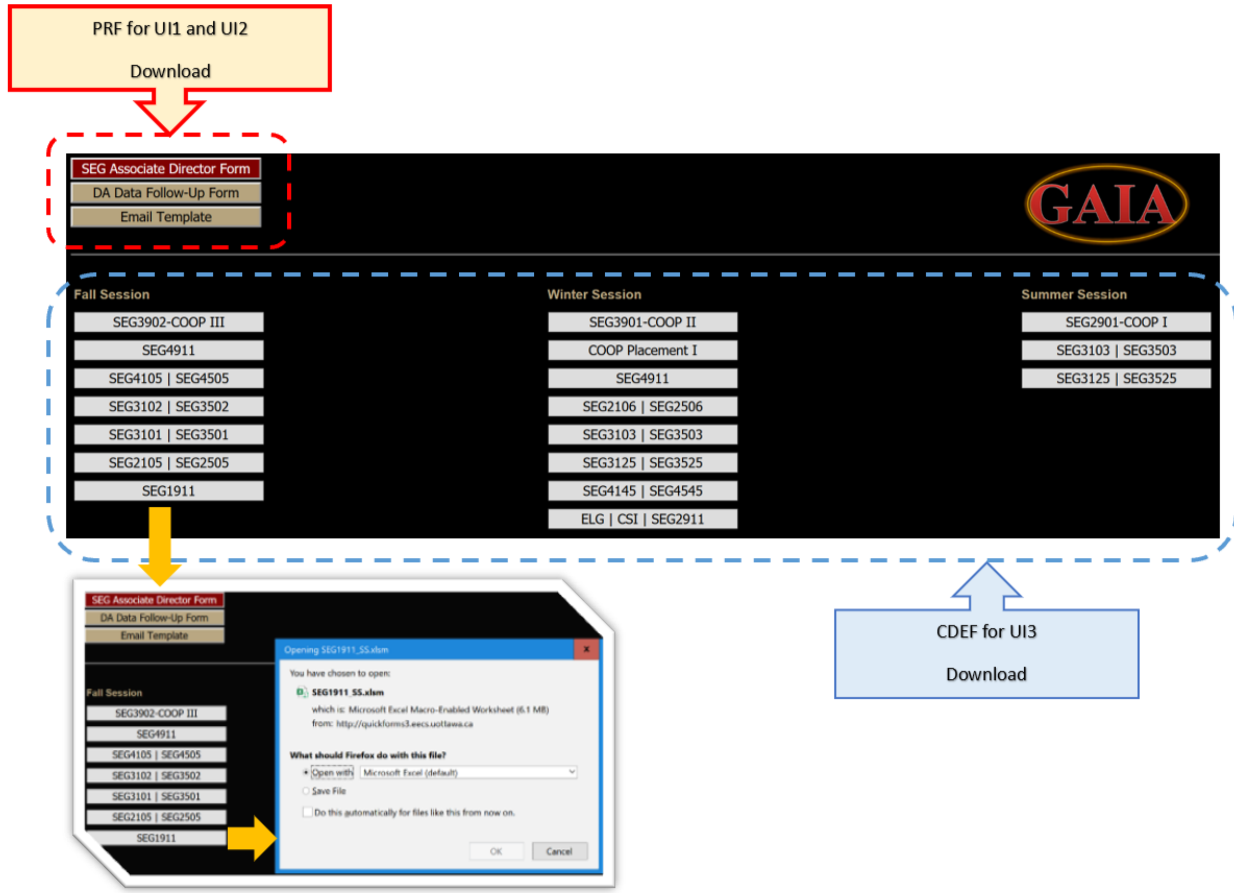


Figure 46. GAIA web-based prototype. SEG page.

Overall, in terms of systems architecture we succeeded in: (1) providing better support by adding UI1 to already existing UI4, GAIA System Administrator (SA), (2) establishing consistent formally defined common process, (3) inclusion of all stakeholders (alumni, students, coop) in annual meeting, (4) we have included common KPI in the GA reporting, and (5) web-based prototype of GAIA was developed and pilot-tested. At this stage we have two new programs joining SEG - electrical engineering (ELG) and computer engineering (CEG) programs. These programs do not have a mandatory COOP, so the work-term data is reported based on the number of hired students. No COOP placement reports are run for ELG and CEG programs.

4.3.3 Continuous Improvement Process

GAIA can collect, process and analyze data to report graduate attributes against program expectations. It follows and supports the established process of informing continuous program improvement and development we have in place at the University of Ottawa. The reports created by GAIA help each Program Curriculum Committee establish a procedure for ongoing program review leading to actions on program improvement. Figure 47 illustrates the program evaluation and improvement cycle.

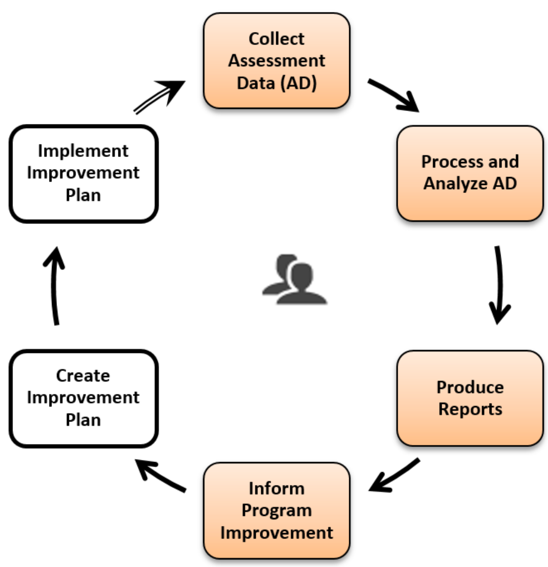


Figure 47. Program evaluation and improvement cycle.

The actions performed directly in GAIA are presented in shaded ovals. The white ovals show respective program improvement steps typically initiated and coordinated by the members of Program Curriculum Committee based on GAIA reports.

In Figure 48, we illustrate how a more top-down approach mandated by a common CIP leads to a common set of indicators that can be shared across programs. The Faculty Continuous Improvement Process mandated a common program report that would chart a common set of indicators across the 12 graduate attributes. The data for those indicators were obtained from measuring student achievement using the usual course-level learning outcomes, but those learning outcomes were compiled into the common set of high-level indicators specified in the Program Reports, rather than the program-specific low-level indicators proposed by course professors.

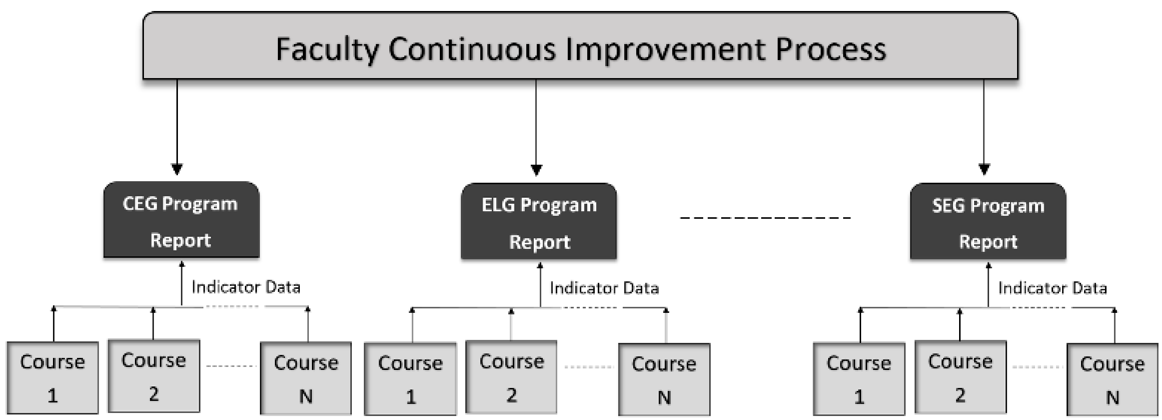


Figure 48. Faculty Continuous Improvement Process.

During this phase, a CIP Checklist is implemented. It is used to keep track that all steps involved in the CIP for that year have been completed. It includes the data collection, GA and CIP committee meeting, CIP reports at program level, and notifications to ensure completion on schedule. The key documents and data stored are:

1. Annual CIP Report
2. Agenda/Minutes of Annual CIP meeting
3. GA Program Report
4. GA Indicator Data

The annual CIP Report and meetings are mandated and defined by the Faculty. The GA Program Report is generated by the GAIA tool based on GA Indicator data, and includes tables 3.1.1 (Curriculum Map), 3.1.2 (Attribute Indicators), 3.1.3 (Assessment Tools), 3.1.4 (Assessment Results), and 3.2.1 (Continual Improvement Process and Feedback) as mandated by CEAB. It also includes additional reports in tabular or graph form. These are historic trend analysis per course and per program, analysis per GA across several course, analysis per GA at a program level, and cross-program comparison at faculty level. GA Indicator Data is assessment data collected, managed and archived by GAIA tool from program courses, COOP and other sources.

4.3.4 Key Performance Indicators

The horizontal analysis performed across all 3 EECS programs described in Section 3.4 resolved the concerns for data duplication and allowed for reasonable unification of program KPIs into common, generic KPIs. We analyzed the 12 graduate attributes defined by CEAB (CEAB, 2017) to determine what generic indicators for the graduate attributes would be appropriate to apply. Top-down data mining of assessment data collected from shared across programs courses gave a different aspect to the task. It was determined that common courses taught by different instructors among different EECS programs create potential data quality drop as a result of redundancy, duplication or inconsistency across implemented assessment criteria.

Evaluating the efficiency of our program-based process for data collection and analysis the following problems were encountered:

A) Repeated submission of same course assessment data;

B) The use of different program developed performance indicators imposes completion of multiple Course Data Entry Forms (CDEF) by the same instructor;

C) In order to produce program-oriented assessment data, the instructor needs to filter student assessments prior to CDEF data entry.

D) In terms of implementing program improvement, improvement plans proposed by one program have to be imposed over a cohort of students from different programs sharing the same course. Considering the fact that results reported according to the process described in (B) differ per students from different programs, a unified approach would be inconsistent and unreliable.

The problems identified are summarized in Table 7 below.

Table 7. Problem identification.

Course Code	**Repeated Submissions** (per program)	**Multiple CDEF** (different indicators)	**Filtered Assessment** (program differentiated data)
CEG2x36	x	x	
CEG3x85	x	x	
ELG2911	x		x
ELG2x36	x	x	
ELG3x55	x	x	
SEG2x05	x		x
SEG2x06		x	

The proposed common performance indicators resolve those problems. It led to structural unification of the courses which eliminated those problems. Instructors complete single CDEF measuring common indicators for the programs involved with data unified per cohort. Once submitted GAIA populates the CDEF data into the respective Associate Director Form (ADF) for generating the report.

As a result, we were able to transform the large number of low-level indicators previously defined - 203 (CEG), 196 (ELG) and 72 (SEG) - into a consistent faculty level framework of 27 new common indicators. As shown in Table 8 below, there were usually significantly more indicators defined for each GA, then there were courses relevant to the GA (as defined in the Curriculum Map for the program). This reflected the bottom-up course-driven approach to identifying indicators.

Table 8. Indicators Comparison – Indicators (Courses)

Graduate Attribute	Program Indicators (Courses)			New Common Indicators
	CEG	ELG	SEG	
GA 1	25(6)	23(15)	11(9)	4
GA 2	21(7)	21(15)	8(7)	2
GA 3	16(7)	16(14)	7(7)	2
GA 4	24(8)	19(14)	12(7)	3
GA 5	23(8)	24(13)	7(7)	2
GA 6	14(6)	15(10)	2(12)	2
GA 7	19(5)	17(12)	7(10)	2
GA 8	14(4)	14(8)	7(7)	2
GA 9	12(3)	12(9)	2(4)	2
GA 10	9(2)	9(8)	1(4)	2
GA 11	12(3)	12(8)	4(6)	2
GA 12	14(2)	14(6)	4(7)	2

The bottom-up approach led to tracking course-based learning outcomes rather than program-level performance. At faculty level, we did top-down analyses and as result, there was a much smaller number of new common indicators. Typically, there would be at least 3 courses measuring the indicator based on whether the treatment of the graduate attribute was introductory, applied or advanced.

Table 9: New Common Indicators framework.

GA	New Common Indicators Description
GA 1 Knowledge base	a) Math b) Science c) Other Engineering d) Program-Specific Engineering
GA 2 Problem Analysis	a) Apply Techniques b) Model Formulation
GA 3 Investigation	a) Simulation and Prototypes b) Requirements and Risk Assessment
GA 4 Design	a) Design Principles and Process b) Open-Ended Design Projects c) Standards and Safety Compliance
GA 5 Use of engineering tools	a) Selection and Use b) Adapt and Extend
GA 6 Individual and team work	a) Ability to work individually b) Ability to work in a group
GA 7 Communication skills	a) Written b) Verbal
GA 8 Professionalism	a) Licensing and Legal b) Client Experience and Work Ethic
GA 9 Society and environment	a) Engineering Effects and History b) Triple Bottom Line Sustainability
GA 10 Ethics and equity	a) Ethics b) Equity
GA 11 Economics and project mgmt.	a) Economics b) Project Management
GA 12 Life-long learning	a) Research and Resources b) Self-directed

The 27 common indicators are listed in Table 9 above. We considered the official CEAB description per graduate attribute and CEAB accreditation requirements for number of academic units (CEAB, 2014). Thus, the four indicators related to GA1 (Knowledge Base) match accreditation requirements for minimum hours (called AUs – Academic Units) of instruction in different types of knowledge. And the indicators GA 6, 7, 9, 10, and 11 are a straight forward separation of the two aspects inherent in the description of the graduate attribute. For example, GA 11 has Program Management and Economics. The dual importance of theoretical analysis and practical experience in engineering is reflected in the dual aspects of GA 2, 3, 4, 5, 8, and 12. Finally, GA 4 (Design) has the extra aspect of safety and standards which is fundamental to engineering as a profession.

To better illustrate our approach, we use an example that shows how GA 5 is treated for the three programs - Computer (CEG), Electrical (ELG) and Software (SEG) engineering. The NCI (New Common Indicators) column in Figure 49 shows an indicator map for GA 5: Use of engineering tools. As displayed in the figure, assessment of LOs will be used to measure the two new indicators 5a (selection and use) and 5b (adapt and extend). The map for ELG program also discloses two indicators, which do not belong to GA 5 – 3a and 2b (highlighted in yellow in the figure). During the analysis, it was identified that they map the old 5.A-11 and 5.C-6 ELG indicators onto the new common indicators related to GA 3 and GA 2 respectively. In GAIA, they will be used when creating reports on their corresponding GA.

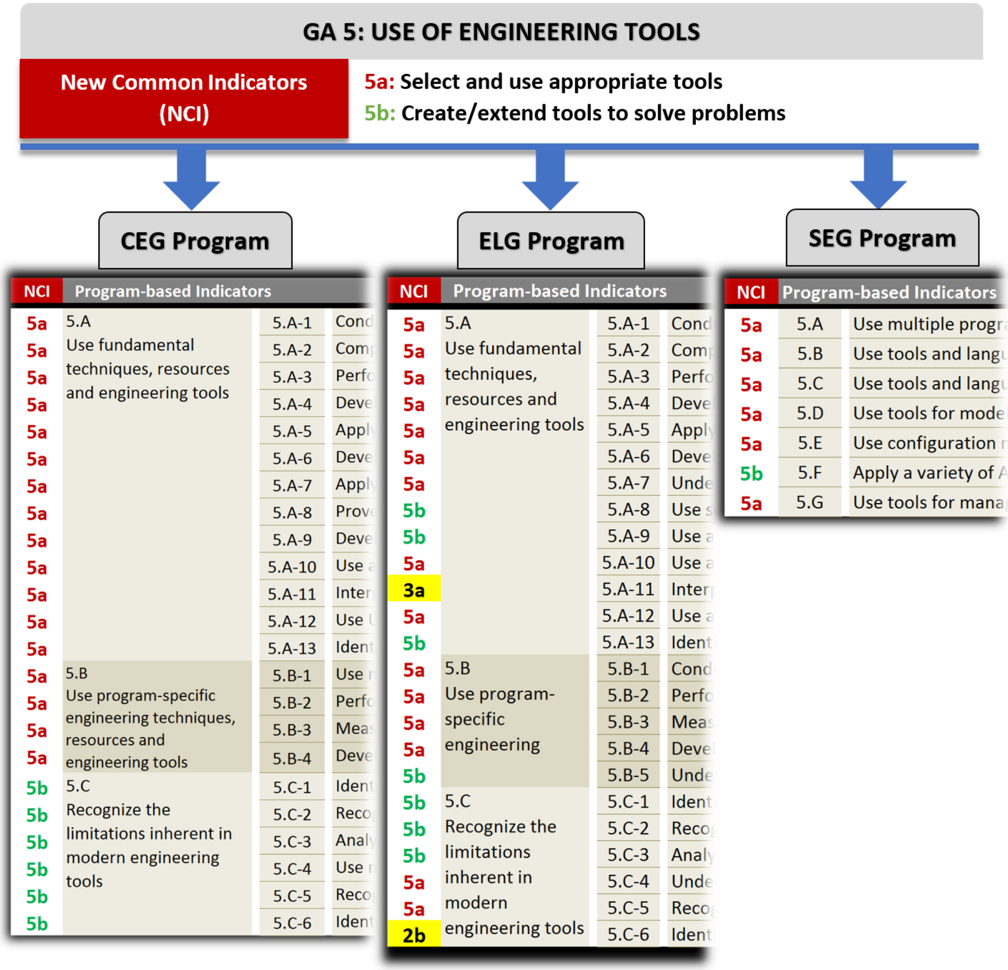


Figure 49. Indicator map for GA 5

For measuring indicators 9a and 9b for GA 9 (Impact of engineering on society and environment), we recognized the two aspects (theory vs practice) for investigation, design and problem analysis and added the additional element of standards when measuring design. The other "soft" skills have two aspects to them which we also split out (program management and engineering economics, ethics and equity, impact and sustainability).

4.3.5 Performance Management Forms

At this stage the user interface for CDEF remained unchanged. Several database modifications to support reporting using Common Key Performance Indicators (CKPI) took place.

A Common Program Report Form (CPRF) is introduced. Its implementation is supported by respective DW adjustments.

All reports have undergone cosmetic modifications to improve visibility.

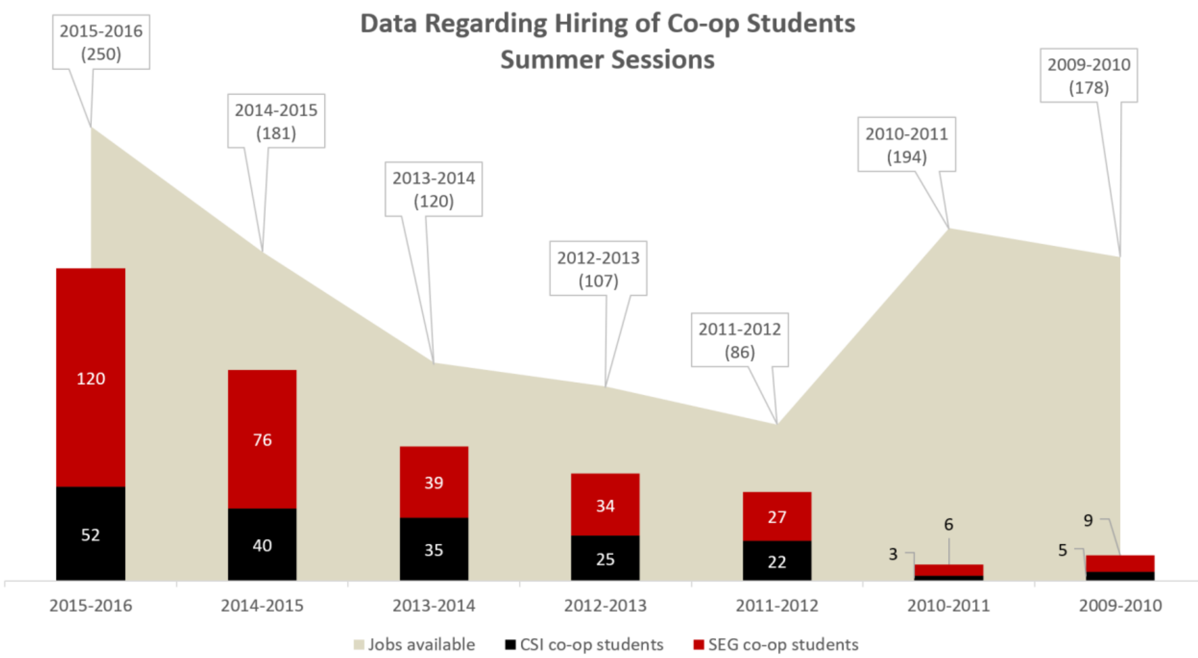


Figure 50. COOP hires vs COOP jobs availability. Sample data.

Pros:

- At this stage the tool is able to generate several types of reports to serve two different accreditation bodies - CEAB and Canadian Information Processing Society (CIPS). This includes supplementary COOP reports that indicates a relation between jobs availability and number of COOP students hired per fiscal year. We used random data to generate a sample of such report. The report is depicted in Figure 50 above.
  - All reports and data analysis are based on CKPI.
  - Both performance management forms, CDEF and CPRF can be downloaded through a web interface.
  - Modifications to improve the usefulness of the tool took place. The main page of the CDEF now allows access to data entry sheets per semester and various reports generated by the system. Each report can be selected by clicking on the related button from the Main Page of the form. A screenshot is displayed in Figure 51.

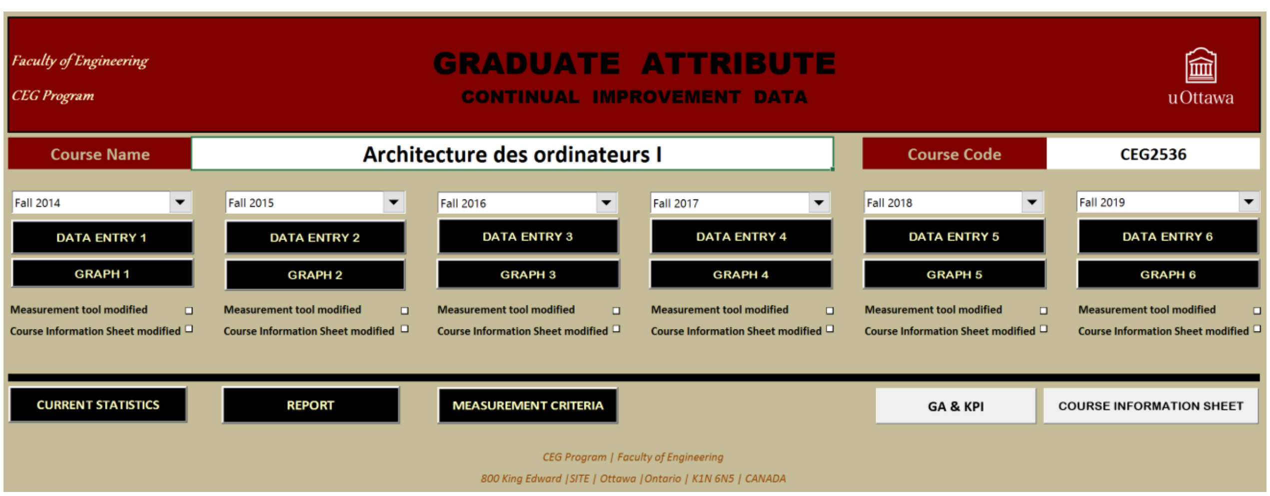


Figure 51. CDEF Performance Management Form. Main Page.

Drop-down menus allow for their easy selection. The course instructors enter assessment data directly or can copy-paste from their own grade sheets.

- CDEF accommodates quantitative and qualitative data which allows the same form to be used by both academic platform and non-academic platform users. This feature is especially useful when collecting assessment data related to students' work-terms.
- Handling of GAA data from shared courses is improved – all sections of a course (bilingual included) are being referred to the same CDEF. A common measurement criteria and respective common measurement instruments are being agreed upon.

Cons:

- CDEF is not able to handle direct data transfer from the university Learning Management System. Users still need to use their own CSV or Excel files.
- Cross-program comparison can only be performed based on the current year/semester data. GAIA cannot generate a single report tracking graduate attribute achievement per cohort.
- Two-semester courses (i.e. capstone) cannot be reported using a single form. Although related issues are being reported by the CEG and ELG 4th year professors, we were not able to resolve then at this stage.
- Although the tool can generate varieties of reports at that stage, there are still no IQAP specific reports spawn by GAIA.

- An ongoing issue with the common courses (i.e. GNG) remains as well. Being “common” those courses compile of students from different programs. Isolating the assessment data per course is a challenging and time-consuming task the users still perform manually. At this stage GAIA uses the overall GNG scores as an addition to all programs which students are taking the course.

4.3.6 Results

Support for faculty level reporting in GAIA has resulted in a more structured and consistent approach to graduate attribute assessment across all three programs and increased the ability of the three programs to interact and leverage common elements. At the same time, the definition of a common continuous improvement process with a set of clearly defined and scheduled deliverables and associated templates, has reduced the management burden and ensured a level of consistency and completeness in the process.

We focused on the difference between low-level detailed indicators driven by course learning outcomes and high-level generic indicators driven by a common continuous improvement process at the program level. An analysis of the curriculum maps for each program indicated that the original low-level indicators were more numerous than the number of courses relevant to each graduate attribute. Using fewer high-level indicators allowed us to more easily compare how successful each program is at addressing the different aspects of GAs. From there we are still able to drill into courses and learning outcomes to inform program improvement.

The online prototype of GAIA was pilot-tested by selected users and several issues related to security, space and upload/download speed are identified. The online prototype of the tool is still under development. Further modifications of the online prototype are being identified and specifically outlined as future work.

4.4 GAIA Phase III: Cohort Reports and Project Courses

4.4.1 Overview

The traditional approach to GAA for accreditation has always focused on the "snapshot" view provided by the PRF. However, to truly assess what level of graduate attributes a group of graduating engineers has achieved, a "cohort" view is more appropriate. In this phase, fine-grain data granularity which the GAIA database is built on, and improved ETL processes allow for a second layer of data transformations that we used to experiment with different types of "cohort" views to see which would be more useful to program coordinators. This phase is an experimental phase as accreditation bodies do not currently mandate or attempt to take a cohort view of GAA. These reports have not yet been fully integrated into the GAIA tool that is in use by EECS professors at the University of Ottawa. At this experimental stage, GAIA Phase III of the project is mainly related to data warehouse modifications that support generating those reports. The modifications are specified in detail in Chapter 5, Section 5.4 Cohort Program Report DTAT.

Furthermore, a secondary CDEF performance management form for two-semester project courses was developed. Respective DW transformations were implemented. It has been fully integrated into the GAIA tool and is currently used for reporting GAA data for the two-semester capstone project course in CEG and ELG programs at EECS.

4.4.2 System Architecture

There are no significant changes in terms of system architecture. We were able to improve interoperability of the tool and simplify the LMS data import process. Thus, the LMS block in the tool support diagram on Figure 52 below is shaded in grey. We still need to look for a more integrated solution.

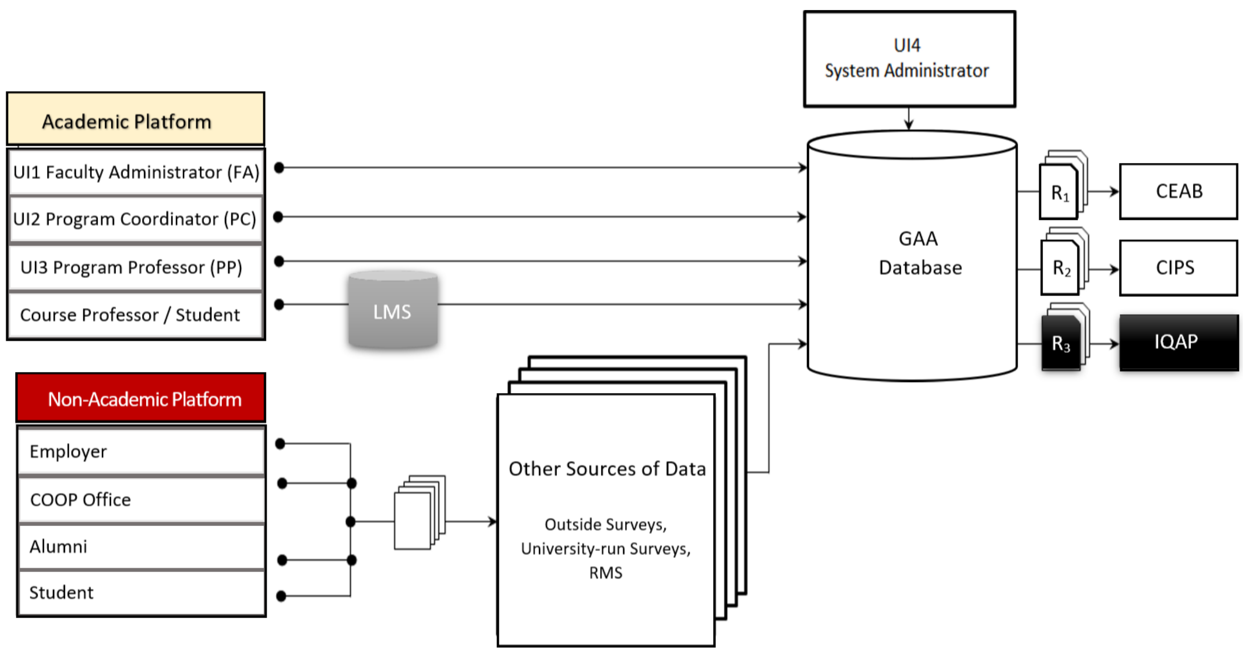


Figure 52. GAIA Phase III Tools Support Map.

4.4.3 Continuous Improvement Process

The system collects, processes and analyses the data, producing initial reports informing achievement at the level of individual courses and individual work-terms. When the data from all aspects of the program has been collected, GAIA accumulates the results and generates final reports that inform achievement at the level of the entire program. Based on those reports all the EECS Program Curriculum Committees create program improvement plans and assure their implementation. Generating reports per cohort closes the loop in preparation for the upcoming 2020 accreditation and continue supporting the CCIP across the EECS programs.

The complete cycle performed at course, program and faculty level by the UIs (including non-academic platform) is indicated on Figure 53.

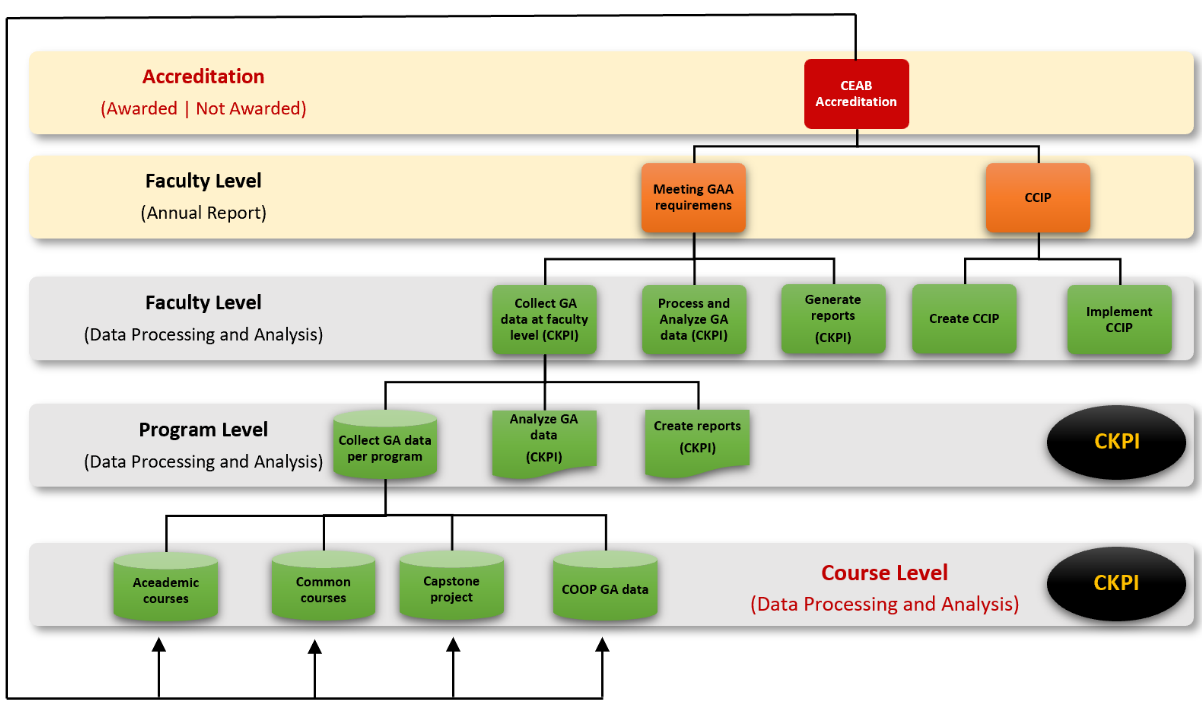


Figure 53. Program evaluation and common continuous improvement cycle.

4.4.4 Key Performance Indicators

The tool continues using the CKPI. All reports are being generated using the CKPIs.

CKPI are used for generating all cohort reports. They are compatible with CPRF and can be processed to support program comparison and inform CCIP.

The new supplementary CDEF performance management form developed during this phase is based on CKPI and is compatible with CPRF.

4.4.5 Performance Management Forms

The new reports track students' performance based on assessment data collected and analyzed for the same student cluster as students progress within their respective program. To ease the referrals process we identify each cluster by a program code and cohort number. GAIA is being used by the electrical, computer and software engineering programs, thus the codes are ELG, CEG or SEG respectively. The number refers to the year students started the program. For example, SEG Cohort 2016 refers to a student cluster registered in software engineering program in 2016 (i.e. 2016 was their Year 1 within the program).

GAIA allows for comparison between cohorts by generating two specifically developed for that purpose reports – Graduate Attribute Report per Cohort (GAR/C) and Course Progression Report per Cohort (CPR/C). The former arranges averaged GA data per attribute, latter tracks students' achievement as student progress in their program. Data from both cohort reports are used for comparison allowing for sustainable CIP evaluation and provide a historic data trend for further curriculum development. Furthermore, a COOP Progress Report per cohort (COOPR/C) is generated. It adds reliability in analyzing students' employability and professional skills assessment provided by employers. Tables 10 (a, b, c) below illustrates the datum of cohort reports. It is based on SEG course sequence selected by the program GA Committee to report on GA achievement. Color codes indicate the relative level of the course within the program as follows:

- blue shading is used for Year 5 courses
- green shading is used for Year 4 courses
- peach shading is used for Year 3 courses
- magenta shading is used for Year 2 courses
- no shading is used for Year 1 courses

Table 10a: Graduate Attribute Report per Cohort (GAR/C)

	Graduate Attribute											
	GA1	GA2	GA3	GA4	GA5	GA6	GA7	GA8	GA9	GA10	GA11	GA12
Courses	SEG 3101	SEG 3101	SEG 3103	SEG 4911	SEG 2105	SEG 2105	SEG 2911	SEG 4911	SEG 2911	SEG 2911	SEG 4105	SEG 4911
		SEG 4911			SEG 3101	SEG 4105	SEG 4911	SEG 1911				SEG 1911
					SEG 3102	SEG 4911						

Table 10b: Course Progression Report per Cohort (CPR/C)

	Academic Year				
	Year 1	Year 2	Year 3	Year 4	Year 5
Course	SEG1911	SEG2105	SEG2106	SEG3101	SEG4911
		SEG3103	SEG2911	SEG3102	SEG4105
		SEG3125		SEG4145	

Table 10c: COOP Progress Report per Cohort (COOPR/C)

Academic Year				
Year 1	Year 2	Year 3	Year 4	Year 5
SEG1911	COOP Placement I	SEG2901	SEG3901	SEG3902

We use the SEG course data to illustrate the mechanism of data sorting for generating the three types of cohort reports. To follow the course progression within a cohort GAIA combines a historic trend data per respective courses according to the course sequence of the specific engineering program (i.e. software engineering in this sample). To generate GAR/C GAIA for cohort N, GAIA uses Year (N) data for SEG4911 and SEG4105, Year (N-1) data for SEG3101, SEG3102 and SEG4145; Year (N-2) data for SEG2106 and SEG2911; Year (N-3) data for SEG2105, SEG3103, SEG3125; and Year (N-4) data for SEG1911. This is illustrated in Table 11 below.

Table 11. Use of historic trend data for generating cohort reports (GAR/C and CPR/C)

Cohort (Year)	Course	Graduate Attribute
GA Data (N)	SEG4911	2, 4, 6, 7, 8, 12
	SEG4105	6, 11
GA Data (N – 1)	SEG3101	1, 2, 5
	SEG3102	5
	SEG4145	11
GA Data (N – 2)	SEG2106	xxx
	SEG2911	7, 9, 10
GA Data (N – 3)	SEG2105	5, 6
	SEG3103	3
	SEG3125	xxx
GA Data (N – 4)	SEG1911	8, 12

Furthermore, a new performance management form was developed during this phase. It is a variation of the original CDEF, but meant to process two-semester assessment data. It was specifically developed for the capstone project which is completed over two courses (Part I and Part II). Capstone takes two semesters to complete and uses a compiled final grade. The course is taught simultaneously to two different cohorts and takes place over the length of two semesters – Fall/Winter and Winter/Fall respectively. This affects the data entry and data processing technique. To minimize the confusion and simplify the data entry process the main page for this document is organized per cohort. Such organization allows for easy recognition of selected cohort and provides a better visualization for aggregated achievement reporting. Figure 54 shows a three-cohort sample data entry sheet prepared for section starting CEG Project I in Winter and continuing with CEG Project II next Fall.

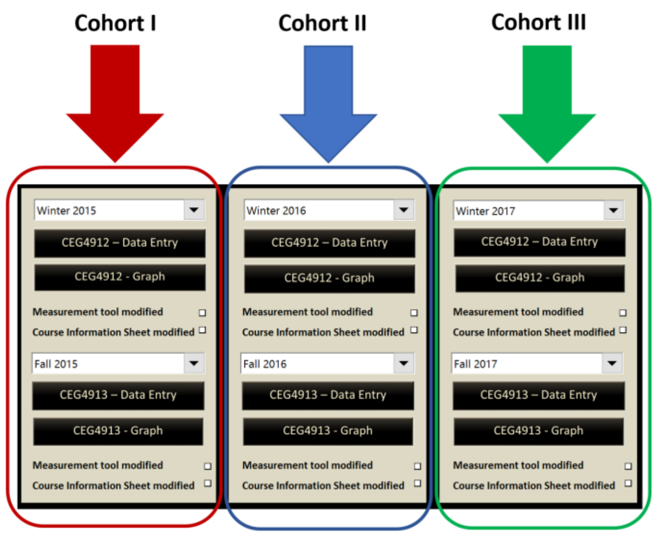


Figure 54. Supplementary CDEF for two-semester course. Cohort view.

Figure 55 illustrates a form prepared to accommodate assessment data till Fall 2020. Data can be entered and viewed at any time per any semester in the interval between Winter 2015 and Fall 2020. Selection or cohort can be done using VBA empowered drop-down menu buttons.

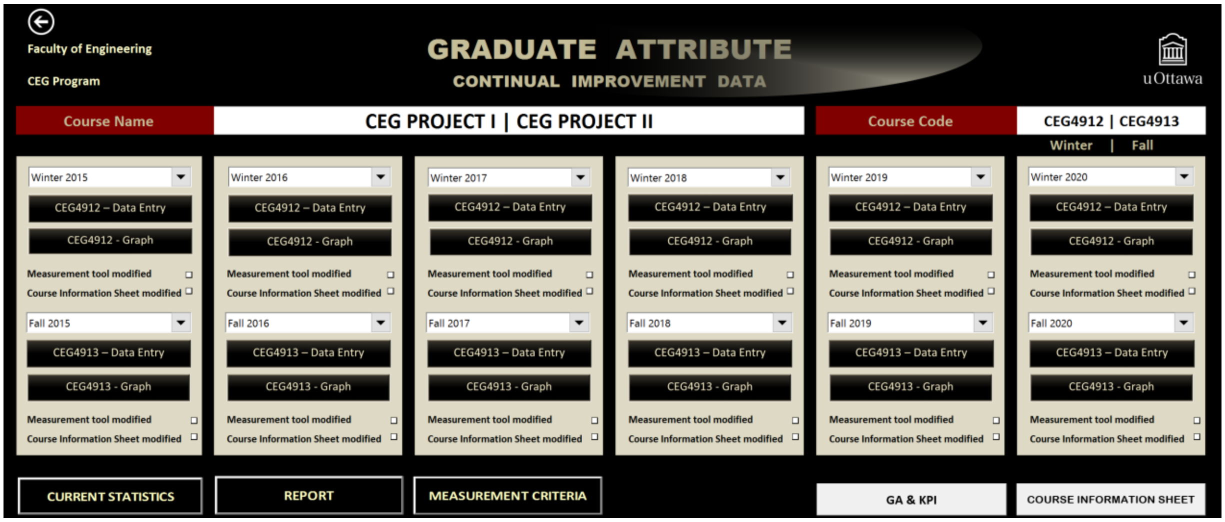


Figure 55. Supplementary CDEF for two-semester course. Main Page.

Students with assessment data recorded in this sample sheet start their Project I in Winter and complete Project II in Fall next academic year. There are separate reports generated for Winter and Fall sessions respectively to allow for better comparison and closer follow-up on student achievement. One semester sample report is generated and illustrated in Figure 56.

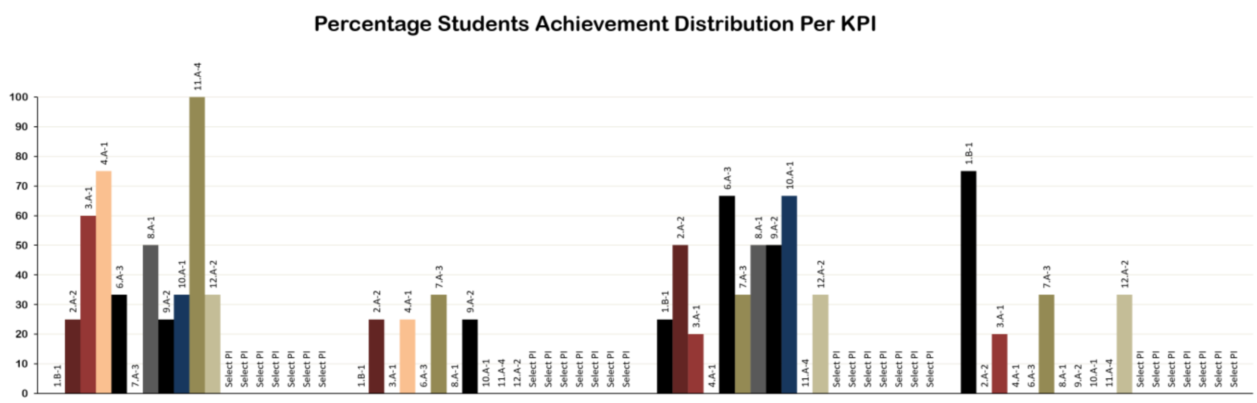


Figure 56. Assessment data report per semester.

Data from the two semesters is combined to generate a compiled data report for Fall in table form (see Figure 57) and in graph form (see Figure 58). They are generated using a slight modification of the original Course Data Entry DTAT (described in section 5.1).

	2012-2013	2013-2014	Winter 2015	Fall 2015	Winter 2016	Fall 2016
Exceed	62.0	57.1	52.4	52.4	52.4	31.8
Meet	33.5	42.9	47.6	47.6	47.6	31.8
Intermediate	4.5	0.0	0.0	0.0	0.0	36.4
Insufficient	0.0	0.0	0.0	0.0	0.0	0.0
Requirements	Exceeded	Exceeded	Exceeded	Exceeded	Exceeded	Met
Data Check	95.5	100.0	100.0	100.0	100.0	63.6
Exceed	76.2	57.1	52.4	100.0	35.5	45.5
Meet	23.8	42.9	47.6	0.0	25.7	18.2
Intermediate	0.0	0.0	0.0	0.0	38.8	36.4
Insufficient	0.0	0.0	0.0	0.0	0.0	0.0
Requirements	Exceeded	Exceeded	Exceeded	Exceeded	Met	Met
Data Check	100.0	100.0	100.0	100.0	61.2	63.6
Exceed	38.1	57.1	31.8	51.9	52.4	18.2
Meet	61.9	42.9	31.8	38.1	44.6	63.6
Intermediate	0.0	0.0	36.4	10.0	3.0	18.2
Insufficient	0.0	0.0	0.0	0.0	0.0	0.0
Requirements	Exceeded	Exceeded	Met	Exceeded	Exceeded	Exceeded
Data Check	100.0	100.0	63.6	90.0	97.0	81.8
Exceed	35.5	38.1	75.0	52.4	45.5	31.8
Meet	25.7	61.9	25.0	47.6	18.2	31.8
Intermediate	38.8	0.0	0.0	0.0	36.4	36.4
Insufficient	0.0	0.0	0.0	0.0	0.0	0.0
Requirements	Met	Exceeded	Exceeded	Exceeded	Met	Met
Data Check	61.2	100.0	100.0	100.0	63.6	63.6

2012-2013	2013-2014	2014-2015	2015-2016
62.0	57.1	52.4	42.1
33.5	42.9	47.6	39.7
4.5	0.0	0.0	18.2
0.0	0.0	0.0	0.0
Exceeded	Exceeded	Exceeded	Exceeded
95.5	100.0	100.0	81.8
76.2	57.1	76.2	40.5
23.8	42.9	23.8	21.9
0.0	0.0	0.0	37.6
0.0	0.0	0.0	0.0
Exceeded	Exceeded	Exceeded	Met
100.0	100.0	100.0	62.4
31.1	57.1	50.0	35.3
61.9	42.9	50.0	54.1
0.0	0.0	0.0	10.6
0.0	0.0	0.0	0.0
Exceeded	Exceeded	Exceeded	Exceeded
93.0	100.0	100.0	89.4
35.5	38.1	43.9	38.7
25.7	61.9	36.7	25.0
38.8	0.0	19.4	36.4
0.0	0.0	0.0	0.0
Met	Exceeded	Exceeded	Met
61.2	100.0	80.6	63.7

Figure 57. Compiled data report for two-semester course. Table form.

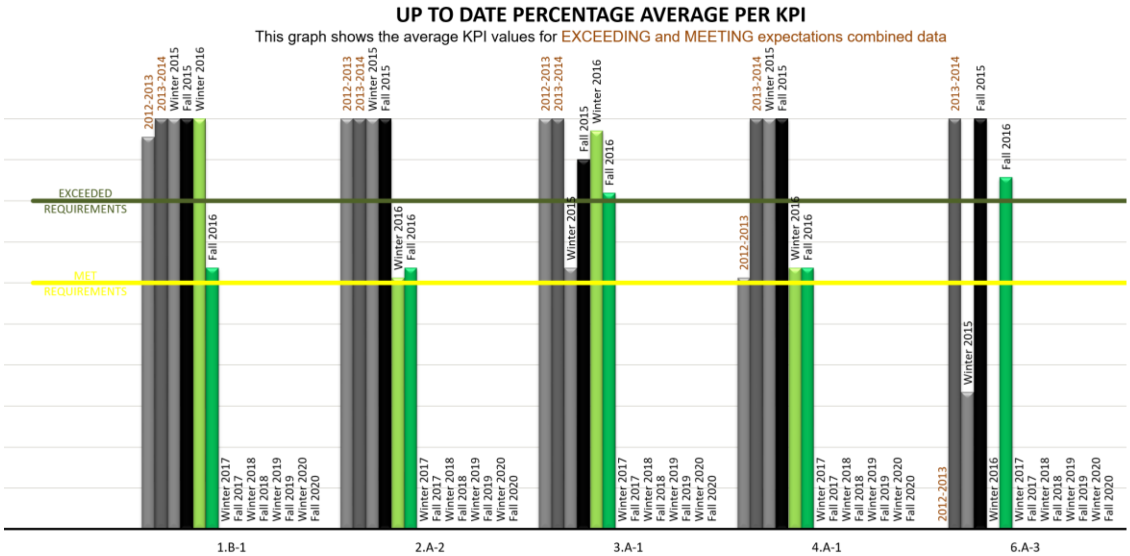


Figure 58. Compiled data report for two-semester course. Graph form.

To assure sustainability and consistency of cross-program data comparison and analysis, GAIA does not allow changes of the margins to be done by the user. All margins and categories set by CEAB or the Program Curriculum Committee have been hard-coded.

Pros:

- The tool can generate several types of cohort reports. This includes COOP reports per cohort.
- All reports and data analysis are based on CKPI.
- A complementary two-course CDEF performance management form is developed. It is compatible with CPRF and allows for real-time report generation at program and faculty level.

- The main page of the one-semester CDEF and two-semester CDEF allow for access to data entry sheets per semester and all the reports generated by the system. They can be accessed using the respective button on the Main Page of the form.
- Both CDEFs accommodates quantitative and qualitative data.

Cons:

- The issue about CDEF not able to handle direct data transfer from the university Learning Management System has only been partly resolved. The task remains as future work.
- The issue with the tool's ability to generate IQAP specific reports has been improved, but a lot of work remains to be done. Currently the DW allows for generating the reports but no specifics are being discussed.
- An ongoing issue with the common courses (i.e. GNG) still remains.

4.4.6 Results

Developed as a web-based tool, the system allows for easy access and data sharing across courses and programs. An excel-based interface minimizes and, in many cases, eliminates the need for expensive and time-consuming training. The use of VBA allows for creating easy user-friendly interface and quick access to varieties of automatically generated reports and forms.

As every software product, GAIA is facing ongoing stages of development and improvement. In its current state, it is set to collect data up to 2020-2021 academic year and is able to perform as expected for the upcoming accreditation. Any ongoing updates are to be implemented accordingly.

Chapter 5. Data Transformation and Analysis Techniques for Reports

The expectation from instructors to provide assessment data and perform data analysis to be used for reporting for accreditation were identified as major difficulty, constraint and in several cases a reason for rejection to follow the process (Radloff A. , de la Harpe, Dalton, Thomas, & Lawson, 2008), (Saunders & Mydlarski, 2015). The use of commercially purchased tools was proven expensive in terms of product cost, and the cost of training and time involved (Dew, Lavoie, & Snelgrove, 2011). By developing and implementing data warehouse modifications supported by compatible data transformations (ETL), we manage to address those issues. Furthermore, the fine-grained data granularity supports tracking the correlation between data selected for GA reporting and the mapping into common KPI. As indicated in the system architecture model, data for GAA is provided either by a simple copy-paste of course data by professors (using interface UI3), or by direct feed (LMS, external data sources) through a machine interface. In order to provide the reports used by professors, program coordinators and faculty administrators a series of data transformations are needed. In this chapter we present DTATs we developed to perform data transformations in support of the reports implemented in the GAIA prototype developed as part of our case studies in Chapter 4. For each performance management form specified in Chapter 3, Section 3.5 we have a corresponding subsection here to describe the data transformation and analysis techniques used.

5.1 Course Data Entry DTAT

The data transformations and analysis for Course Data Entry uses Excel processing and reporting of tabular data. The course data entry form (CDEF) stores the data for a course in a VBA Excel file with a measure for each student, for each indicator measured by the course, for each semester the course is taught. Students' data is displayed in rows, and indicators are organized by columns. A worksheet is allocated per each semester. The reports are generated in separate worksheets and use Excel-based transformations and calculations to aggregate in tables and graphs the year by year trends of GA achievement. They compute the percentage of students allocated into four categories (Exceed Expectations, Meet Expectations, Marginal or Insufficient) based on their achievement. Color coding is used to highlight the status of each indicator for each semester.

We discuss two specific for the Course Data Entry DTATs:

1) Conversion of qualitative data to quantitative. An example of this DTT is described in 5.2 COOP Report DTAT.
2) DTAT to support weighted, combined assessment for a particular indicator. We are discussing this type of DTAT below.

To assure better evaluation of student achievement for a particular indicator, many instructors used data combined from several assessment tools (assignment, survey, test, lab, report). In such cases instructors had to record and average the data separately, prior to entering it into CDEF. Support for weighted calculation per component in the Course Data Entry DTAT eliminated this time-consuming task. CDEF allows combining of up to three components per KPI, including weighted calculation per component. Table 12 below shows a sample of such a data entry sheet. The calculation to combine the three components into a single measurement (based on the weights) is done automatically by GAIA.

Table 12. Weighted Grading Data Entry

GA		**GA 6**		
KPI		**KPI 6a**		
KPI Component		**6a 1**	**6a 2**	**6a 3**
Assessment Tool		Q. 1	Q.2	Q.3
Weight (%)		**10%**	**5%**	**7%**
Assessment Out Of		25	5	10
1	Data Entry 1	20	4.5	7.5
2	Data Entry 2	24	5	6
…	……	…	…	…
i	Data Entry$_i$	21	3	9

Instructors define the assessment tool used to measure each component and enter its weight in the overall KPI grade. The system performs automatic checking during the data entry to ensure the sum of weights assigned per component does not exceed 100%. If detected, the cell becomes red, indicating the mistake. Course instructors enter maximum score ("Assessment out of") per component and raw grades per each student (“Data Entry1, 2, …”). The index $\boldsymbol{i}$ indicates the number of students. At its current stage GAIA accommodates up to 2000 students.

Using the values entered the tool performs a matrix transformation to calculate the overall grade per KPI. The respective mathematical manipulation performed by the tool is described below. The following notation apply:

→ $\boldsymbol{C_{ij}}$ represents the student grade per component, bounded within the interval $0 \leq C_{ij} \leq MS$,

$$\text{where} \begin{cases} \boldsymbol{i} = 1 \dots m \text{ (number of students)}, \\ \boldsymbol{j} = 1 \dots n \text{ (number of KPI components)} \end{cases}$$

→ $\boldsymbol{W_j}$ represents the weight per component, where $\boldsymbol{j}$ = 1, 2, 3 and $\sum_{j=1}^{3} W_j$

The data entered in the form is mapped into the following matrix:

$$\begin{pmatrix} W_1 & W_2 & W_3 \\ C_{ij} & C_{ij} & C_{ij} \\ C_{ij} & C_{ij} & C_{ij} \\ \cdots & \cdots & \cdots \\ C_{ij} & C_{ij} & C_{ij} \end{pmatrix}$$

In the next stage, the tool separates the matrix elements and generates two separate matrices - matrix C from the components scores and diagonal matrix W from the weight values.

$$C_{ij} = \begin{pmatrix} C_{ij} & C_{ij} & C_{ij} \\ \cdots & \cdots & \cdots \\ C_{ij} & C_{ij} & C_{ij} \end{pmatrix}_{\substack{i=1\ldots1000 \\ j=1,2,3}} \qquad W_{3\times3} = \begin{pmatrix} W_1 & 0 & 0 \\ 0 & W_2 & 0 \\ 0 & 0 & W_3 \end{pmatrix}$$

To calculate the resultant KPI score per student, the tool performs $\sum_{j=1}^{3} W_j C_{ij}$ for $\boldsymbol{i} = 1 \ldots 1000$.

$$A = C \times W = \begin{pmatrix} C_{ij} & C_{ij} & C_{ij} \\ \cdots & \cdots & \cdots \\ C_{ij} & C_{ij} & C_{ij} \end{pmatrix} \times \begin{pmatrix} W_1 & 0 & 0 \\ 0 & W_2 & 0 \\ 0 & 0 & W_3 \end{pmatrix}$$

$$\therefore \quad C = \begin{pmatrix} W_j C_{ij} & W_j C_{ij} & W_j C_{ij} \\ \cdots & \cdots & \cdots \\ W_j C_{ij} & W_j C_{ij} & W_j C_{ij} \end{pmatrix}_{\substack{i=1\ldots1000 \\ j=1\ldots3}}$$

GAIA handles uniform distribution (all weight values are equal), step distribution (one of the weight values is different), and linear distribution (all weight values are different).

5.2 Program Report DTAT

Each CDEF feeds data to a PRF that generates GA reports at the program level. Figure 13 below shows the relation between the two GAIA forms. Reports are built on data from last four years (2012–2015). Furthermore, GAIA is set up to accumulate data and generate analysis and reports until year 2020.

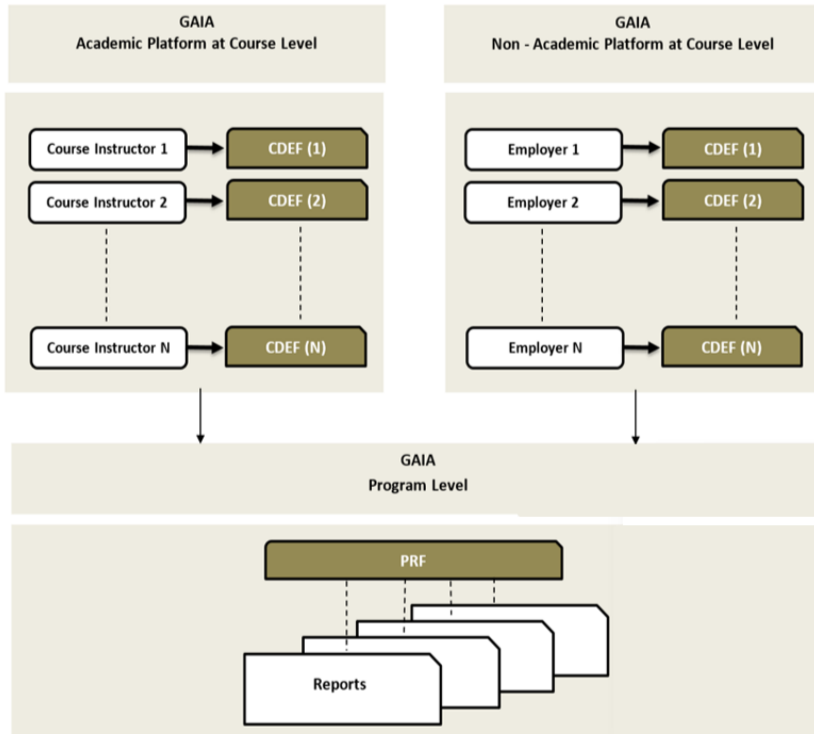


Figure 59. GAIA Platforms Components and Related Performance Management Forms.

Assessment data required for course-level analysis is directly entered into an Excel-based Course Data Entry Form (CDEF) by UI3 or fed into the form through ODBC compliant sources by the end of each semester. There is one CDEF data file for each section of each course offered in a semester. In order to combine all the CDEF data files from all the sections from all semesters into a single Program Report Form (PRF), the two-step transformation shown in Figure 60 is performed.

The table in the top right corner of the figure labeled "COMBINED DATA", shows the data that is displayed in the PRF for one KPI for one course for one GA on a year by year basis.

The circled column in the combined data table entitled “2016-2017” shows what percentage of students in a course were measured as “Exceeds”, “Meets”, “Marginal” or “Insufficient” for the KPI as well as indicates the total percentage that met or exceeded expectations for the indicator.

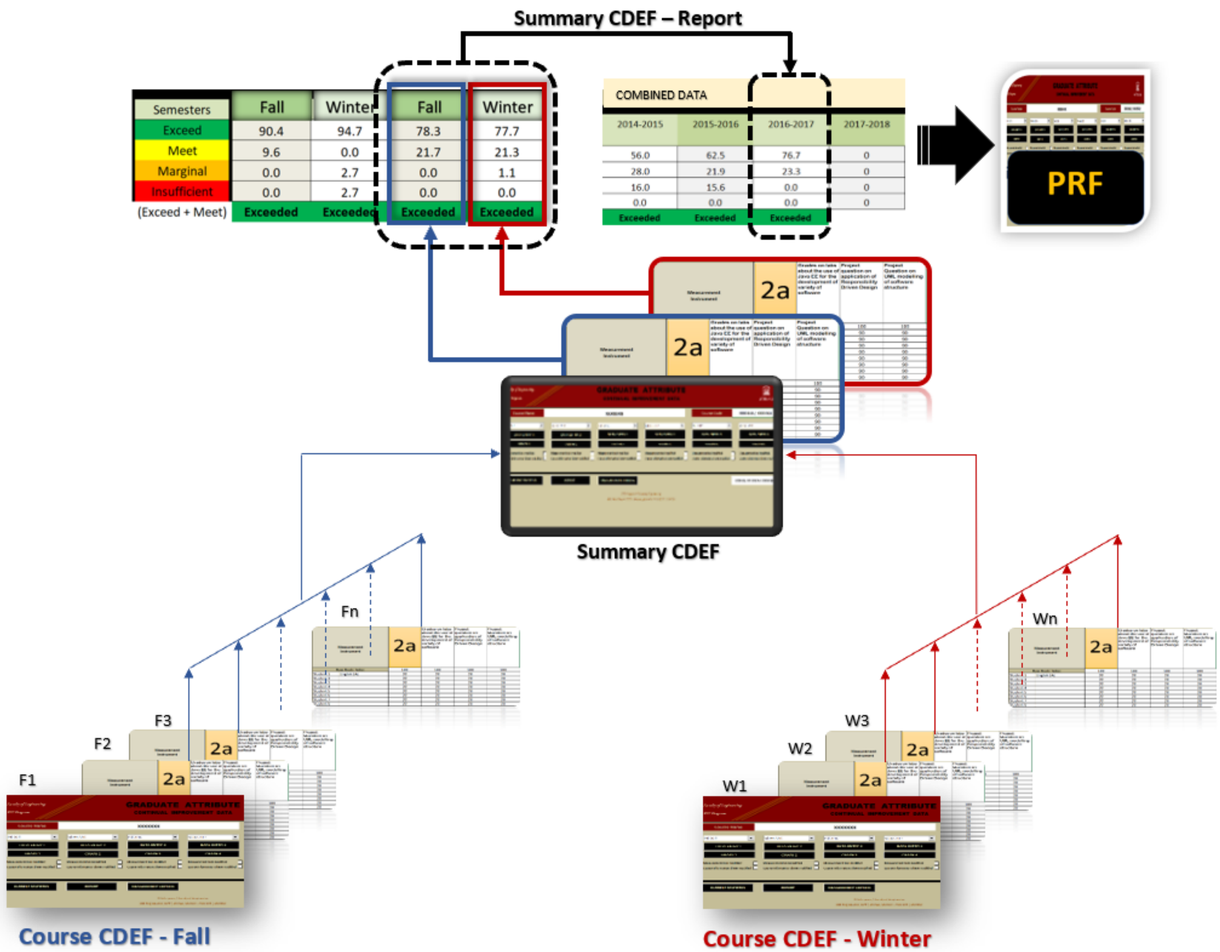


Figure 60. Program Report DTAT.

In order, to generate a respective combined data table for each indicator, we use a Summary CDEF form for the course that combines all the CDEF forms for each section of the course offered during the academic year. It is possible to have n number of sections of the course taught in the

Fall semester (illustrated on Fig. 60 as Fn) and respectively, n sections of the course taught in the Winter semester (illustrated on Fig. 60 as Wn). At uOttawa, there are always at least 2 sections, since courses are typically taught in both, in French and in English. In this particular example we track the DTAT using a sample performance indicator 2a (in yellow rectangle on Fig. 60). Each Fall section has its own Course CDEF file, and each of the CDEF files has a column for indicator 2a. The 2a data columns are concatenated into a single 2a data column that appears in the Summary CDEF file for the course. In the top left corner of Fig. 60 the summary column (highlighted by a blue rectangle) displays in percentage of Exceeds, Meets, Marginal and Insufficient the aggregated 2a data for the Fall semester. Similarly, all the 2a data columns from the Winter Course CDEF files are concatenated into a single 2a data column. The aggregate data for Winter is displayed in the top right corner of Fig. 60, highlighted by red rectangle. A column is assigned for each semester in a fiscal year, thus the columns in the Summary CDEF file could be as many as three.

In the second step of the transformation, the semester columns for an indicator for a course are combined into a single summary column for the indicator for a course for the year. This has to be repeated for each indicator measured in each course for the year.

In summary, once course-level analyses are performed, a course-summary data per GA required for program-level analysis is transferred from CDEF into a VBA Excel-based PRF for analysis. No secondary data entry by the user is needed. At this stage the PRF generates real-time reports at program level.

5.2 COOP Report DTAT

Granularity, partitioning and respective DW design modifications were needed to support the COOP Report Form. The data comes from the non-academic platform, not from courses, although it is stored in the same Excel file structure (CDEF). Work-term qualitative assessment data is provided by the employers through Employer Evaluation Form (EEF). The form is filled-in and submitted by the employer online through the University of Ottawa COOP Portal. Employers are evaluating student performance against five-level scale as Exceptional (A+), Excellent (A, A-), Very Good (B+, B), Good (C+, C), Needs Improvement (D+, D) and Not Satisfactory (E to F). Data from the EEF is extracted and processed by the COOP office. The process is managed through a specifically developed for COOP application hosted on the COOP Navigation Portal. Once received, work-term assessment data is processed and aggregated into differentiated reports by placement and end of work-term evaluation. Detailed analysis is available per work-term and program. COOP office also provides a historic trend of work-term assessment data per program. A part of sample report used by GAIA is shown in Table 13 below.

Table 13. Clustered COOP Assessment Data.

(Source: University of Ottawa COOP Portal)

		Exceptional	Excellent		Very Good		Good		Needs Improvement		Not satisfactory
#	Question	A+	A	A-	B+	B	C+	C	D+	D	E to F
1	Produces work meeting quality expectations within an appropriate timeframe	8	15	5	3	0	0	0	0	0	0
2	Demonstrates effective and resourceful problem solving skills	7	11	8	3	2	0	0	0	0	0
3	Shows interest in work tasks	10	14	6	1	0	0	0	0	0	0
4	Applies technical/scientific/theoretical concepts to tasks	9	10	9	2	1	0	0	0	0	0

COOP assessment data is extracted from the COOP portal and loaded in GAIA using ODBC call-level interface that allows ODBC-compliant application to access the respective database. GAIA is CVS and MS Excel-based, thus supported by the respective ODBC driver.

The need for additional transformation arises from the fact that the GAA data arrives at GAIA's data warehouse at too high level of granularity. As Table 12 indicates, assessment data is accumulated into grade level clusters giving count per grade rather than individual student scores. To enable GAIA to process information, perform analysis and create reports, data is being disintegrated first and then processed for de-quantization. The design modifications we have applied, allow for splitting the data into smaller data units suitable for further analyses and processing before it is stored at the DW. This is illustrated in Figure 61 below.

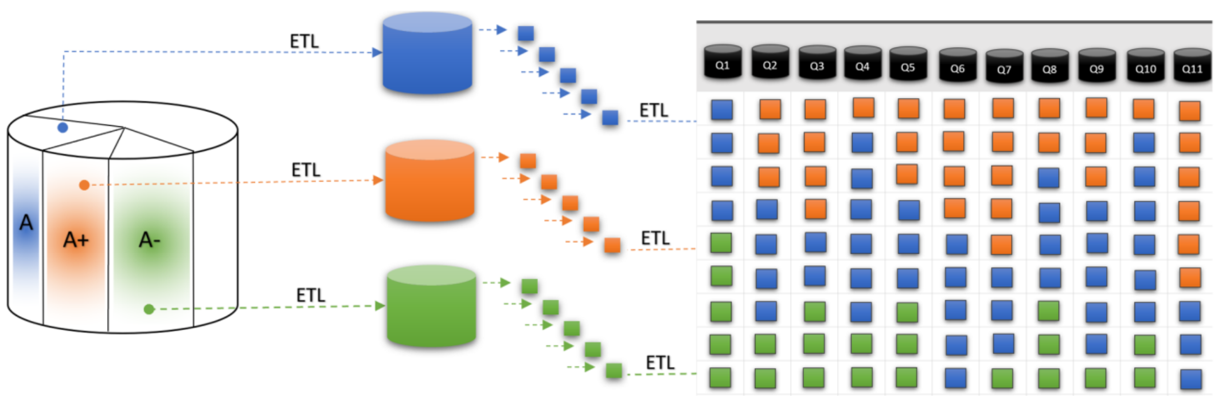
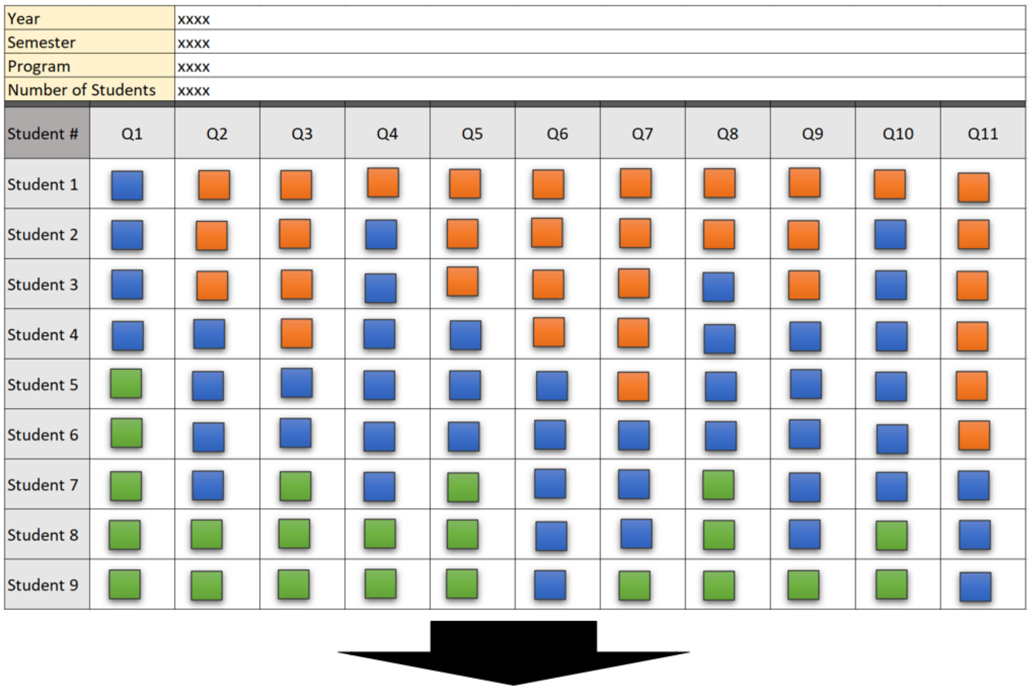


Figure 61. GAIA Bake-down of accumulated assessment data.

GAIA DF work-flow ETL is designed to allocate the defragmented data in the respective data marts. A complementary add-in allows for simultaneously generated report listing the individual COOP grades per program and session after the task is executed. The data in that report is viewed in table form with no student identifiers. A 9-student sample report of this form is illustrated in Figure 62 below.



Year	xxxx
Semester	xxxx
Program	xxxx
Number of Students	xxxx

Student #	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Student 1	A	A+	A+	A+	A+	A+	A+	A+	A+	A+	A+
Student 2	A	A+	A+	A	A+	A+	A+	A+	A+	A	A+
Student 3	A	A+	A+	A	A+	A+	A+	A	A+	A	A+
Student 4	A	A	A+	A	A	A+	A+	A	A	A	A+
Student 5	A-	A	A	A	A	A	A+	A	A	A	A+
Student 6	A-	A	A	A	A	A	A	A	A	A	A+
Student 7	A-	A	A-	A	A-	A	A	A-	A	A	A
Student 8	A-	A-	A-	A-	A-	A	A	A-	A	A-	A
Student 9	A-	A-	A-	A-	A-	A	A-	A-	A-	A-	A

Figure 62. COOP Assessment Data per Student. Sampler Report.

5.3 Common Program Report DTAT

Since the data existed and had been collected using program specific indicators, we performed an analysis and transformation to map the existing indicators into a common set of indicators to allow for the comparison of programs. To establish a consistent framework across the programs, we performed the theoretical break-down of each program into the following three sub-levels - Level I: Learning Outcomes, Level II: Performance Indicators, and Level III: Graduate Attributes.

To simplify the model, we look at two programs - Program A and Program B. Program A has respective indicators IA_i, where $1 \leq i \leq 7$, and Program B has indicators IB_k, where k is within the boundaries $1 \leq k \leq 7$. Both programs are compared for the same graduate attribute, which we call GA_{SAMPLE}.

Figure 63 illustrates the 3-stage process of developing the common key performance indicators: (1) initial stage illustrates indicators that are not being clustered, (2) second stage shows how the initial similar indicators have been clustered to form the three new common indicators, (3) final stage illustrates the new common indicators CA_m, where $1 \leq m \leq 3$.

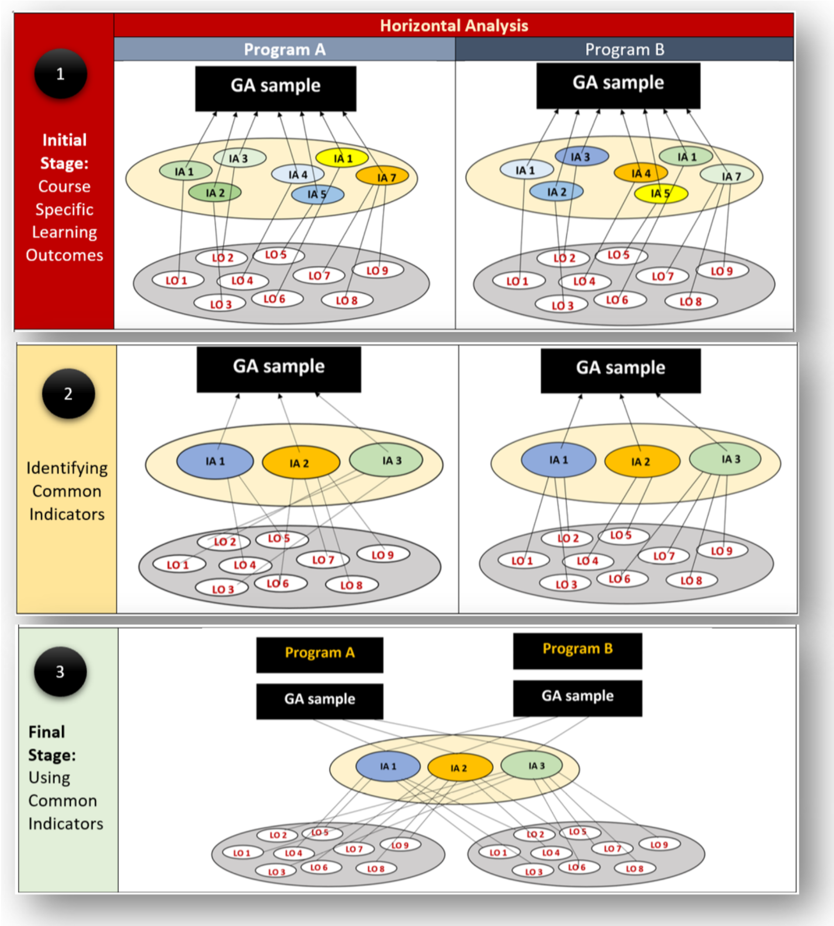


Figure 63. Common Key Performance Indicators. Horizontal Analysis.

An arrangement of this kind allows for looking into a consistent framework with a number of platforms that allows for minimizing the load and implementing a standardized common approach for GA data collection, analysis and reporting.

The number of learning outcomes (LO) typically ranged from 8 to 12 depending on the course and the professor's choices. They are closely related to established grading rubric and target the possession of particular skills and knowledge. Several LOs are combined to report per performance indicator (PI). Up to 8 PIs are used to report on one graduate attribute (GA).

The discussed structure serves 12 graduate attributes mandated by the CEAB. The proposed GAIA DW architecture allows for system implied unification of similar LOs which decreases the number of PIs used for reporting. Using bus architecture within the respective data marts enables automation of the process and allows for implementation of different dimensional models. A uniform approach is achieved through a master suite of unified dimensions and facts. We use a bus matrix to map measurement instruments (MI) to learning outcomes (LO), performance indicators (PI) and graduate attributes (GA). A sample bus matrix where MI1 through MI6 are assigned to six LO is shown in Table 14 below.

Table 14. Sample bus matrix.

	MI1	MI2	MI3	MI4	MI5	MI6
LO	x	x	x	x	x	x
PI	x		x		x	
GA			x			

Identified similarity between different LOs allowed for their joint use for reporting on unified PIs that were common to all programs. In this particular example, data for PI1 (reported by LO1 through MI1) and PI2 (reported by LO2 through MI2) are combined to produce a report on $PO1_{New}$ (representing a union of PO1 & PO2). Similarly, LO3 and LO4 used for reporting on PI3 and PI4 respectively, were unified for reporting on $PI2_{New}$ (representing a union of PI3 & PI4). The same configuration is applied to LO5 and LO6 now reporting on one unified $LO3_{New}$. Consequently, $PI1_{New}$, $PI2_{New}$ and $PI3_{New}$ become common key performance indicators across the three programs and are named as CKPI1, CKPI2 and CKPI3 respectively. As such, CKPI1, CKPI2 and CKPI3 are used to report on GA1 for each program within the faculty. The discussed sample-based transmission from PI to CKPI is illustrated in Figure 64 below.

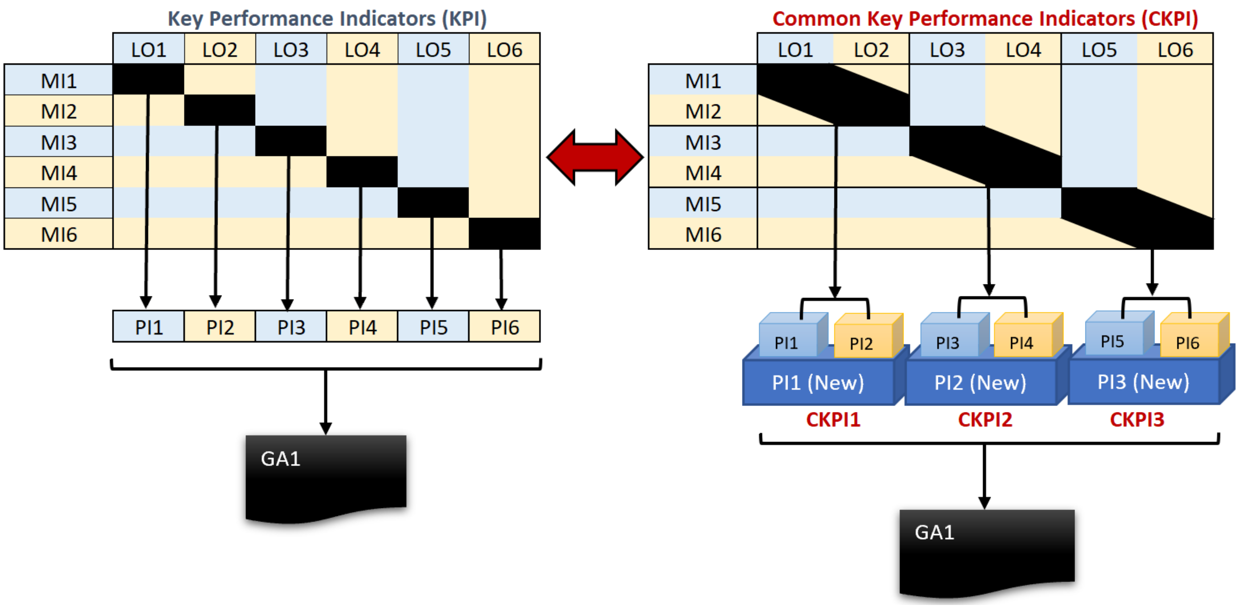


Figure 64. PI to CKPI 3-PIs Sample Transformation.

It is important to mention that no changes to already established MIs or data collection forms/methods took place, thus no additional effort or training on the user's side is needed.

Similar tables were developed for each course within each program within the faculty.

5.4 Cohort Program Report DTAT

In order to support continuous data flow and ongoing data exchange within the faculty, we revised the data warehouse framework and reconfigured the ETL processes in place, aiming for a better-informed decision support system backed-up by historic trend analysis. When GAIA was created, in 2015 with a common approach towards collecting a subject-oriented, integrated, time-variant, non-volatile data, we were able to transform the previous operational data into a data warehouse that supports timely and more accurate decision-making process (Cobb, 1996).

The unique purpose of the graduate attribute assessment data enforced the use of the two classic warehouse designs - Ralph Kimball's subject-specific aggregated dimensional data warehouse architecture (Kimbal & Ross, 2013) illustrated in Fig. 50, followed by Bill Inmon's top-down approach (Immon, 2005) shown in Figure 65.

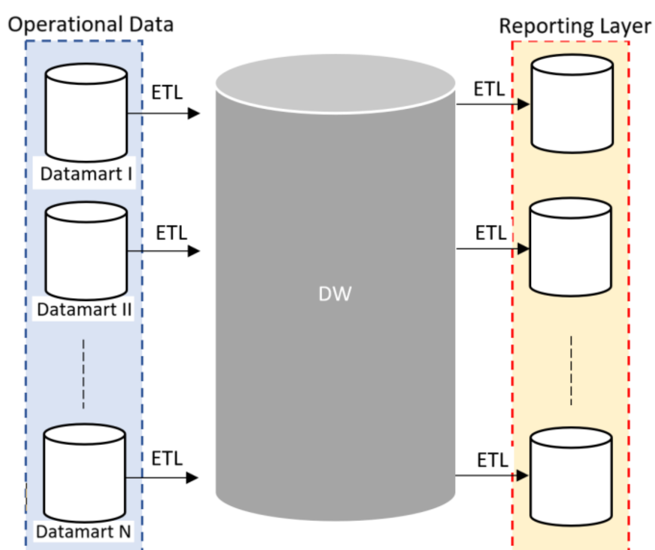


Figure 65. Kimball data warehouse design implemented in GAIA.

In the Kimball design, each data mart at operational level is used to fetch the source data, generalize it, prepare and cleanse for the data warehouse (DW) load. The operational data store (ODS) uses a 3NF schema. A data mart is typically allocated per course within a program and holds the respective graduate attribute assessment data. It processes a finest granularity dynamic data that support the real time (RT) or near real time (NRT) reporting on assigned time intervals (usually by the end of a semester when the data is being extracted from the sources).

The data located here is a subject of constant updates. ODS being fed by the various DB sources to generate the NRT reports per course is illustrated in Figure 66.

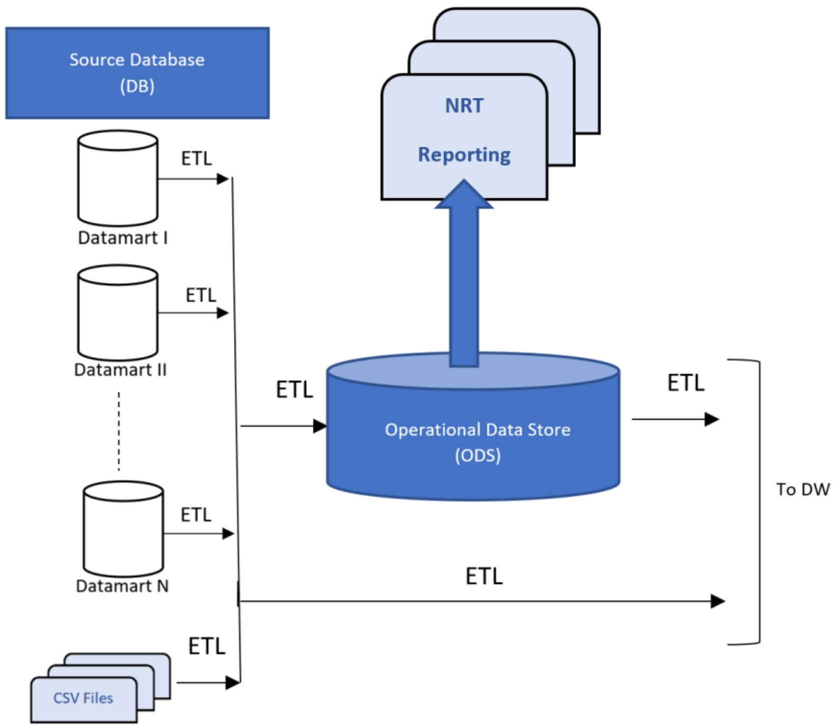


Figure 66. Near real time (NRT) reports generating framework.

At this stage we deal with very detailed subject specific data that refers to Level I data (Learning outcomes, LO) used for generating reports related to Level II (Performance Indicators, PI). Any data identified during the cleansing as outdated is directly replicated into the Class-1ODS specifically assigned for that purpose. Such a type of data is not a subject of any transformations and is simply passed to the DW where it is classified for historic trend analysis respectively.

Any qualitative data, typically provided by the employer through an Employer Evaluation Form (George & Peyton, 2016), is being extracted from the University of Ottawa COOP Portal and loaded into Class-2 ODS undergoing transaction replication in order to fit for DW. Class-3 ODS is used for integrated transactions across programs and are allocated win the multidimensional (per program) GAIA DW model. All data marts use a star schema which is specifically successful for generating reports per graduate attribute at the program level. A sample of star schema is simulator generated for the purpose of this paper. It is illustrated on Figure 67 below.

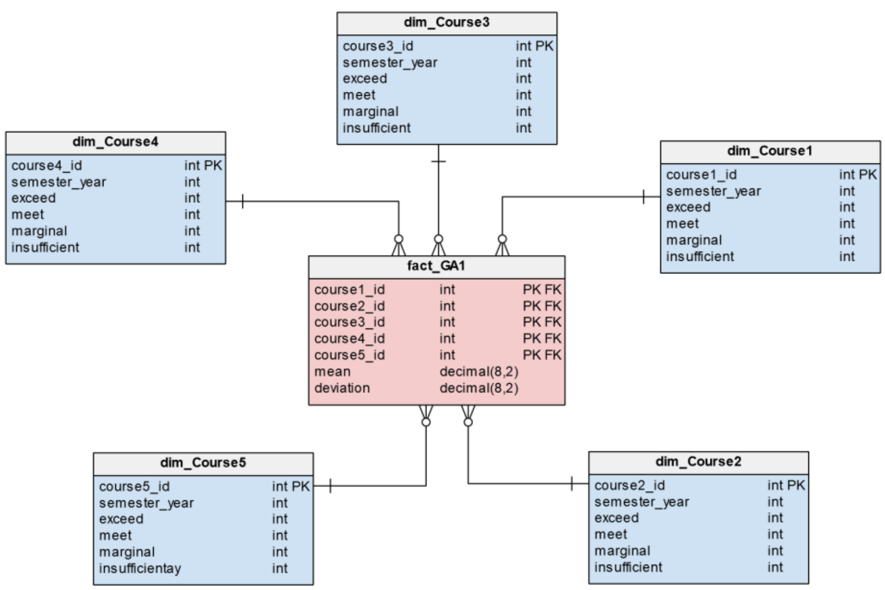


Figure 67. ODS sample star schema.

The different levels of data granulation used by GAIA ease the process of dimensional modeling. A dimension table is assigned per each course. Its attributes are selected as needed. The sample uses as attributes the four-level scale for assessing graduate attribute achievement we have adopted at the School of Electrical Engineering and Computer Science. Furthermore, the different levels of data granulation used by GAIA eased the process of dimensional modelling by providing the suitable granulation. To minimize the redundancy, we generated the reports per course directly from the Operational Data (see Figure 66).

A galaxy schema that shares several dimension tables (i.e. several data marts) was used for generating aggregated reports on graduate attribute achievement per program. The DW layer is

where we differentiate the assessment data into historic trends silos. This classified static data is used to perform more complex queries related to a secondary data differentiation to generate the cross-programs reports per cohort. At this stage we overlap the existing DW from Kimball's model with a 3NF data warehouse following ahead the top-down centralized Inmon data warehouse modeling approach. The DW serves from now on as a centralized data repository. ETL processes feed the data into 3NF dimensional data marts each one serving a particular reporting purpose as illustrated in Figure 68 below. Class-4 ODS data marts aggregate and analyze the DW data to produce all graduate attributes achieving reports at program level. Class-5 ODS support the data integration needed to generate same reports at faculty level.

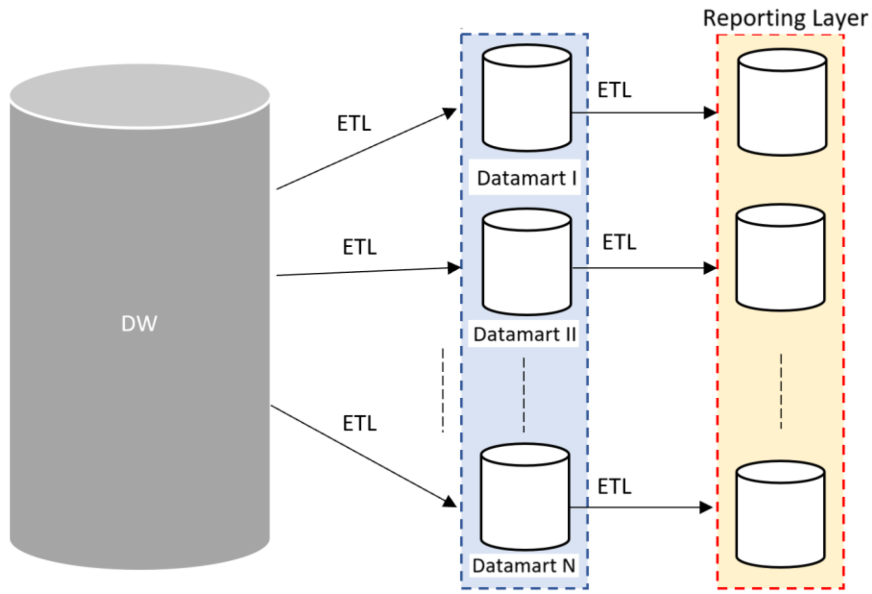


Figure 68. Inmon data warehouse design.

The two models shown in Figure 66 and Figure 68 respectively are combined (as shown on Figure 69) to illustrate the complete GAIA data warehouse architecture.

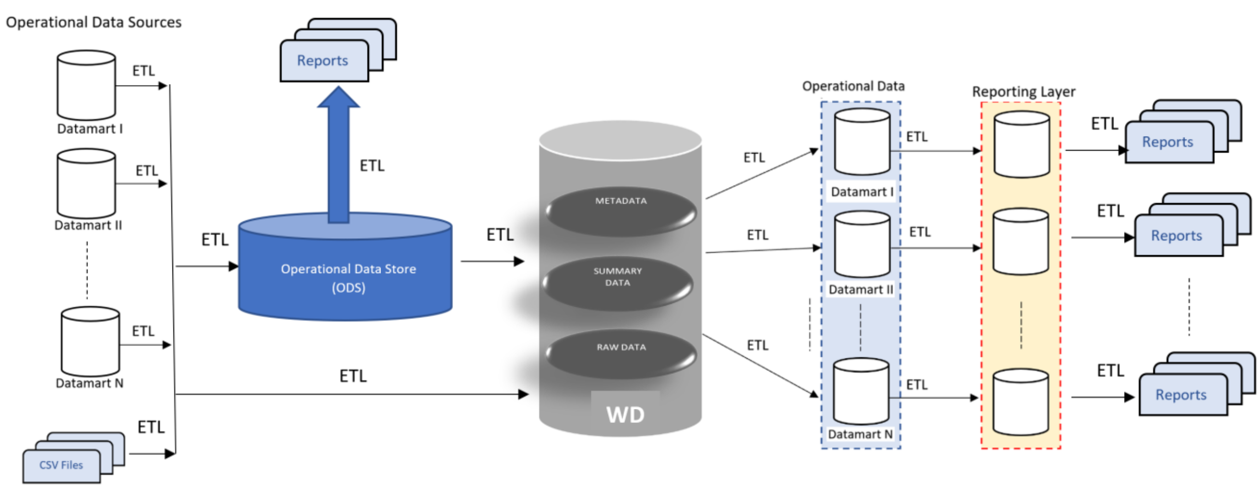


Figure 69. GAIA data warehouse architecture.

We are still looking for possible solutions to deal with missing data. Missing data occurs whenever a professor is unable to provide complete data for all indicators for all students for a section. It also occurs if the program decides to change which indicators are collected form which courses. We are currently in the process of testing a maximum likelihood method for filling in the missing data assuming normal data distribution, a method suggested by Cheema (Cheema, 2012). We ran a more successful goodness of fit tests by using mean substitution – a method that allows for substitution of missing data by the mean of the total sample. We are also exploring the conditional mean imputation, i.e. by using regression equations where the highest correlation is used as independent variable and the missing data as dependent variable.

From this well-structured data warehouse, cohort data management within GAIA is supported by a mathematical model, shown in Fig. 68, that modifies related data entered by users into n, $\tilde{x}$ (calculated using population mean) and SD (calculated using the standard deviation σ, as a measure of the spread/variability of the assessment scores per GA) form. The symbol 'μ' represents the population mean. The symbol 'ΣX_i' represents the sum of all scores present in the population (in this case) X_i, where $1 \leq I \leq N$. The symbol 'N' represents the total number of students in particular program population. The Data Transformation and Analysis Technique (DTAT) allows for generating informative reports per cohort showing clustery or dispersion of data per program measured against selected GA(s). Cohort data management DTAT illustrated on Figure 70 below demonstrates the use of selected GA data from three consecutive years in the same program.

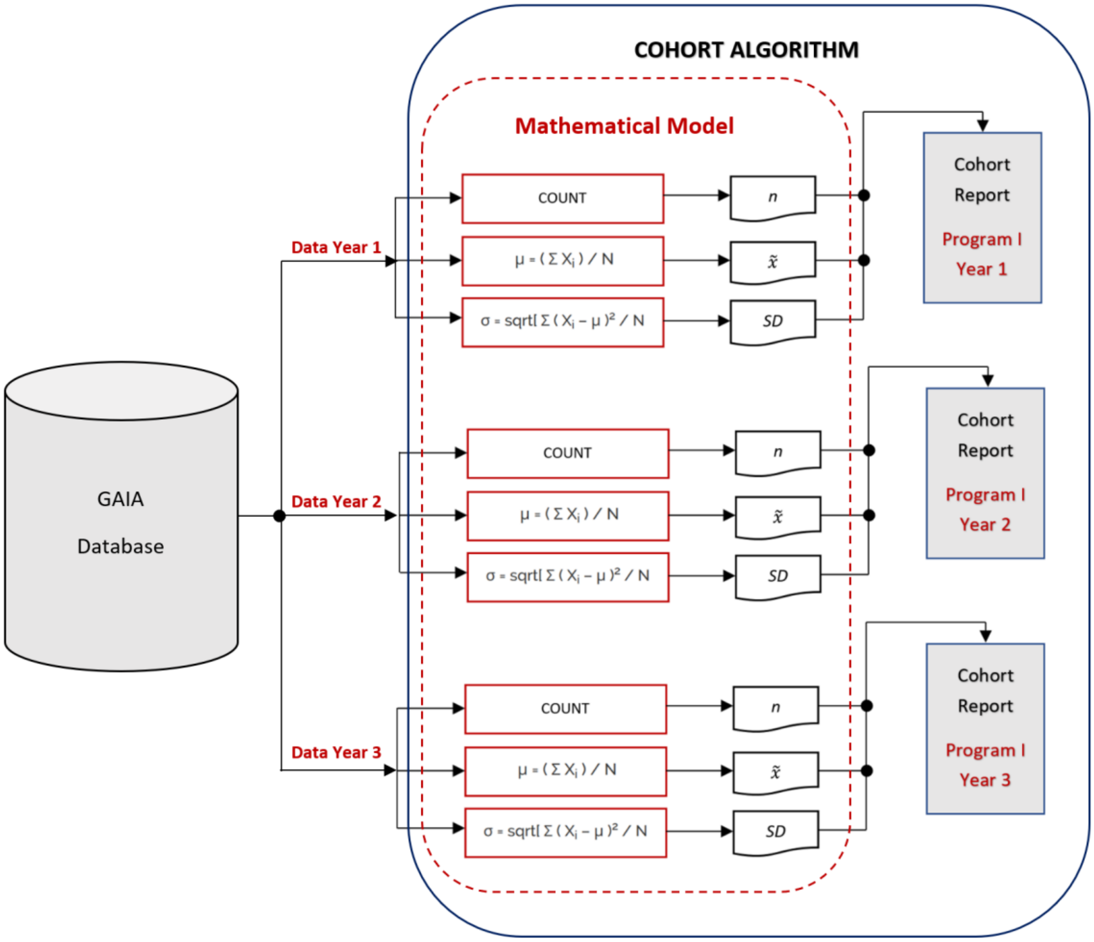


Figure 70. Cohort Data Transformation.

Chapter 6. Assessment of Tools Support for Performance Management of Engineering Education

6.1 Overview

Tool support is critical to performance management of engineering education, so it is critical that organizations be able to make a systematic assessment of how well the tools they are using are supporting their approach for performance management of their engineering programs. In particular, they need to ensure that each of the main users (actors) in performance management of engineering education perceive the tool support is efficient and effective in order to ensure their participation in the performance management process. In Section 6.2, we draw on the established literature with respect to user-centered technology adoption models (TAM) to establish a user-centered tool evaluation process (UCTEP) specifically for performance management of engineering education. Based on UCTEP, in Section 6.3 we present a tool assessment check list we developed that can be used to systematically evaluate tool support for performance management of engineering education. This checklist helped us do a systematic analysis of our GAIA prototype after each case study (Chapter 4) during each of the design science research iterations in our research methodology. Finally, in Section 6.4, we discuss the use of the tool assessment checklist by an expert grounded in our systematic approach versus the need for user surveys to measure feedback directly from users. In Chapter 7, Section 7.1, we follow up on this to discuss the construction of the User Survey that we built to gather feedback from users of the GAIA prototype.

Most of the variables in our checklist are based on previous work found in the literature review we performed. Furthermore, we include several custom created variables the need for which is identified as part of the gap analysis in Chapter 2. Based on our system architecture discussed in Chapter 3, Section 3.2, we also created differentiated criteria for the different types of user and machine interfaces for the different types of users.

6.2 User-Centered Tool Evaluation Process (UCTEP)

To ensure that a tool is useful, time must be spent identifying user needs first. Thus, the first step is to identify the exact need for the tool. Grading the extent to which a tool or system covers our needs reflects the usefulness aspect of adoption. At the same time, identifying gaps in the coverage of our needs can be used to set up the basic expectations for adapting a tool.

The second step is to evaluate the extent to which a tool is usable for different uses. Quantifying the weighted importance of the different uses gets an overall score for usability as second aspect of adoption. This will set additional expectations our model must satisfy.

We propose the use of two sets of variables – one set to be used for the Machine Interfaces of tool support and another set for User Interfaces. We evaluate the tool on the basis of usefulness, usability, and interoperability.

Figure 71 below shows a simplified graphical presentation of the user-centered tool evaluation process. It presents a cycle of machine-human interface (MHI) that incorporates university actors, GAA Database and final product quality evaluation subject to selected user-specific context.

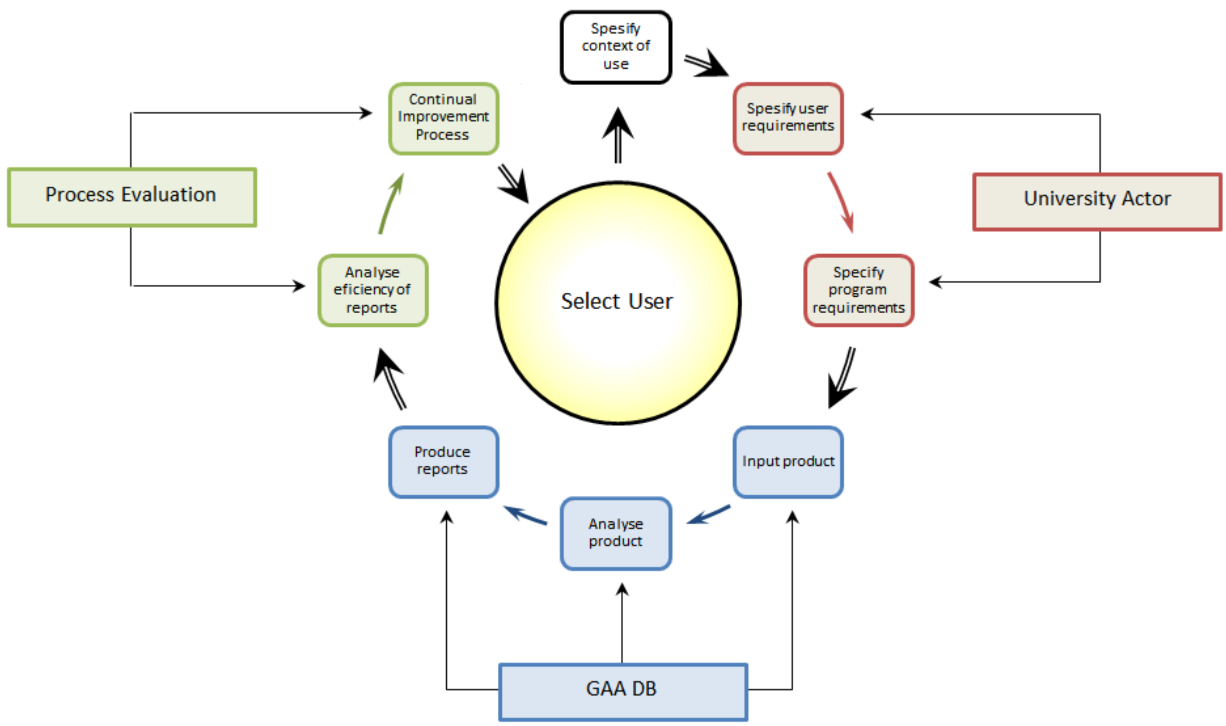


Figure 71. User-Centered Tool Evaluation Process (UCTEP)

This User-Centered Tool Evaluation Process is an integral part of our research as a series of loop iterations evolving consequently to our research methodology described in Chapter 1.4 as the GAIA prototype, we built evolved during each iteration of our design science research methodology. Figure 72 below illustrates the action research flow within the respective GAIA modification phase cycles.

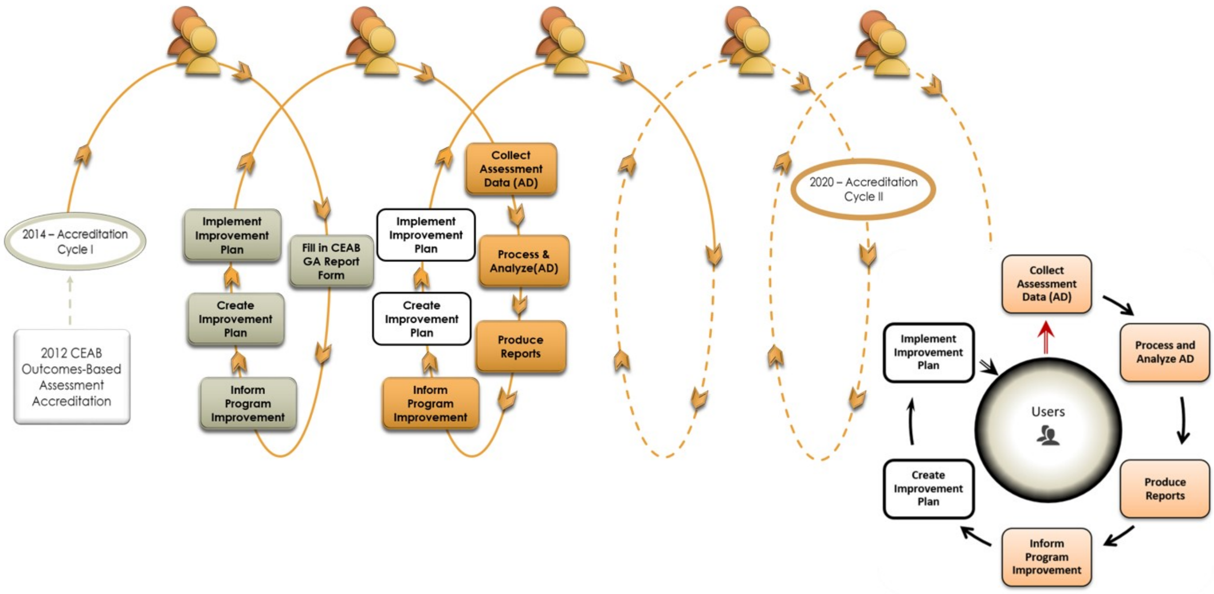


Figure 72. Program Evaluation and Improvement Cycle

The evaluation criteria we propose focuses on thirteen variables. Variables 1 through 5 are the typical TAM (Technology Adoption Model) variables from the literature. 6 and 7 are adopted from UTAUT models used in academia. We also involved custom variables specific to performance management of engineering education (8 through 13). Below we list all constructs and the meaning we are trying to convey by them. Variables are listed the way they are ordered in our Tool-Assessment Checklist (see Chapter 6.3, Table 15).

1. Perceived Ease of Use (PEOU)

This is a core variable, which measures the degree of belief that mastering the tool will not require any extra effort. In the TAM 2 model this construct is defined as a direct determinant of perceived usefulness (Venkatesh & Davis, 2000). Example for its use in academia is the study performed by Park in 2009 (Park, 2009).

2. Perceived Usefulness of the Tool (PU)

Perceived Usefulness is the degree to which a user believes the tool will help successfully complete the task and excel at their job performance. This is a core variable, closely related to Step 1 of our TAM development process described above. It has been used to measure adoption in academia assessing learning performance, academic productivity and supporting learning process (Park, 2009).

3. Attitude toward Using the Tool

The attitude toward use measures the user's feeling about performing the task using the tool. It shows the user's desire to actually use the tool, their positive or negative evaluation of performing the behavior. It measures the ability to perform the task faster, improve user performance when using the tool, using the tool is related to increase of productivity and effectiveness. As a core variable, it is a part of almost every TAM construct set. Samples for its use in academia can be found in the studies by Kim, Park and Tsai (Kim, Chun, & Song, 2009), (Park, 2009), (Tsai, 2012).

4. Behavior Intention to Use the Tool

It measures the strength of the user's intention to use the tool or the degree of one's willingness to use the tool. It is one of the best indicators of the real usage of the tool. In other words, the actual use depends on the user's intentions to apply effort. It is a combined measure of the wish to finish the task and planning its use in the future.

5. Perceived Usage of the Tool

This is the amount of time interacting with the tool and the frequency of its use. Measuring this variable has highest importance for Faculty Administrator (UI1) as manager interested in evaluating the impact of the tool as a whole.

6. Experience Using the Tool

Prior experience was identified as a determinant of behavior in 1980 by Ajzen and Fishbein long before Davis proposed the technology acceptance model (Ajzen & Fishbein, 1980). Measuring the variable is mentioned in several studies (Yang & Yoo, 2004), (Alharbi & Drew, 2014). According to the studies, experienced users show strong correlation to perceived usefulness of the tool and the behavioral intention to use the tool. Being related to the number of years using the tool, this construct provides valuable information in terms of university users being ready to deal with measuring graduate attributes an ongoing process in a long term.

7. Complexity of the Tool

The variable measures the extent to which the user expects to use the tool without any additional effort. It has to do with the tool being difficult to understand and use. Complexity is measured in terms of time taken for the task and integration of tool usage results into existing tool. Complexity is inversely proportional to perceived usefulness (PU) and perceived usage as aspects of adoption. It is also measured by the extent to which the user realizes the possibility of computer crash or data loss.

8. Mandatory versus Voluntary Use of Tool

This variable is measured by the extent to which adoption is perceived as a mandatory or non-mandatory task. It is positively related to the behavioral intention to use the tool. In our particular case, the use of the tool is mandatory (requirements enforced by CAEB), so definitely imposed on the Faculty Administrator (UI1) and the Program Coordinator (UI2). Participation is mandatory for UI1 and UI2. It becomes mandatory for UI3 if their course is included. At the same time, UI3 cannot easily be coerced for tenured professors so UI3 adoption is critical. Similarly, indirect UI for students, employers etc. cannot be coerced so adoption into process is also critical. The point of this is how to weight the importance of various aspects of the tool. The reporting to

CEAB is mandatory and critical so that UI adoption is both constrained and important, but adoption by the administrator and coordinator will be coerced and therefore not so critical.

9. Interoperability

This measure the tool compatibility with other systems or tools used simultaneously including LMS, COOP and student surveys.

10. Handling Assessment Data

This measure reflects on the tool's ability to serve as database and to enable the analysis and comparison of historic trends. The ability to use quantitative and qualitative data needs to be evaluated as well.

11. Reporting Ability

Reporting ability tests the tool against its ability to produce reports at course and program levels; reports per cohort including COOP progress report per cohort.

12. Reporting Quality

Quality of reports is measured in terms of their:

1. Visibility:

a) report form (tabular and/or graph),

b) color codes;

c) compatibility and consistency with sound statistical analysis

2. Ability to inform:

a) program improvement and

b) student achievement of graduate attributes

13. Alignment with CEAB accreditation requirements

This construct provides direct information on the user's belief that the work performed will serve the need it was intended for. Analysis of the results will have a wide range of application – from indication for improving the tool, to explanation about the user's attitude and perceived intentions.

6.3 Tool Assessment Checklist

The tool assessment checklist is something that an expert responsible for engineering performance evaluation could use to assess how well their systematic approach for performance management was supported by respective tools. The assessment checklist measures each construct by applying the 5-scale grading scheme used by Brooke (Brooke, 2013) in his evaluation model.

It provides grading in the boundaries of “Strongly Agree” to “Strongly Disagree” The scale was revised in the literature review section 2.2.3 and identified as “easy and reliable” by the author (Brooke, 2013).

Finally, because we have four users - UI1 (faculty administrator), UI2 (program coordinator), UI3 (program professor) and UI4 (system administrator), we devised the proposed criteria for each one of them. Table 15 below shows our Tool-Assessment Checklist.

Table 15. Tool-Assessment Checklist

Construct	Measurement Instrument (items used to measure the construct)	UI1	UI2	UI3	UI4
1. Perceived Ease of Use	1.A) I find the tool easy to use				
	1.B) Learning to use the tool is easy				
	1.C) It is easy to become skillful user of this tool				
2. Perceived Usefulness	2.A) Using the tool will improve my work performance				
	2.B) Using the tool will increase my productivity				
	2.C) Using the tool simplifies the process of GAA				
3. Attitude Toward Using the Tool	3.A) Using the tool is a great idea				
	3.B) Using the tool is a good idea				
	3.C) Using the tool is not a bad idea				
4. Behavior Intention to Use the Tool	4.A) I intent to use the tool				
	4.B) I am excited about using the tool				

	4.C) I enjoy using the tool				
5. Perceived Usage of the Tool	5.A) I use the tool regularly before the task is assigned				
	5.B) I use the tool every semester				
	5.C) I use the tool only if needed				
6. Experience Using the Tool	6.A) I have several years of experience using the tool				
	6.B) I started using the tool recently				
	6.C) Never used the tool before				
7. Complexity of the Tool	6.A) Using tool takes too much time				
	7.B) I find it difficult to transfer data from my records to the tool				
	7.C) I use all the options the tool provides and complete the task quickly				
8. Mandatory versus Voluntary Use of Tool	8.A) I use the tool voluntarily as long as the task is related to my work				
	8.B) I am not required to use the tool often and will wait for that specific time				
	8.C) I will never use the tool if not pressured to do so				
9. Interoperability	9.A) I can use the tool with the LMS in place at my institution				
	9.B) I can use the tool for entering survey data				
	9.C) The tool produces spreadsheets which are not compatible with my OS				
10. Handling Assessment Data	10.A) I think the tool efficiently stores the data and provides easy access to it				
	10.B) The tool uses quantitative and qualitative data				
	10.C) The tool supports historic trend data analysis				
11. Reporting Ability	11.A) The tool produces reports at program and course level				

	11.B) The tool generates GA reports and course progress reports per cohort				
	11.C) The toll generates COOP reports per cohort				
12. Reporting quality	12.A) The tool produces reports in graph and table form				
	12.B) Reports produced can be used to inform program improvement				
	12.C) Reports produced can be used to inform student achievement				
13. Aligned with CEAB accreditation process	13.A) The tool can be used for accreditation purposes				
	13.B) The tool produces enough GA assessment data analysis for common continuous improvement process				
	13.C) The tool can be used during accreditation visits to demonstrate the correct approach in GAA				

Users will be asked to show their level of agreement on a 5-point scale (*strongly disagree*, *disagree*, *agree*, *strongly agree* and *not applicable*) where 1 represents "strongly disagree", 4 represents "strongly agree" and 5 is to be selected if the criterion does not reflect user's needs. For example, UI4 (System Administrator) is not expected to evaluate criterion 8 (mandatory v/s voluntary use of the tool).

6.4 User Survey

Our tool assessment checklist is intended to be used by someone with a strong understanding of our approach for performance management of engineering education to do a systematic assessment of tools support. It is important to recognize that the Tool-Assessment Checklist proposed in Chapter 6.3 targets tools evaluation at its most general case. It does not take under consideration the specifications of particular tool or the characteristics of a particular domain where the tool is being applied. Thus a “blind” application of the checklist by unskilled users may easily produce skewed results and misleading data. A common practice when performing evaluation of such type is to use a well-designed user-friendly user survey to gather feedback from all users. The survey questions are being carefully developed based on the tool assessment checklist taking under consideration the specifics of the evaluated environment.

Chapter 7. Evaluation

The evaluation of our systematic approach for tool-supported performance management is based on the case studies described in chapter 4 as well as the tool-assessment checklist described in Chapter 6, Section 6.3. In Section 7.1, we collect and analyze feedback from all the users of GAIA who participated in the case studies described in Chapter 4. In Section 7.2 we compare our systematic approach for tool-supported performance management to the related works identified in Chapter 2, Section 2.3, based on our Gap Analysis in Chapter 2, Section 2.4, the components of our systematic approach described in Chapter 3, and the results of our case studies described in chapter 4. Finally, in Section 7.3 we discuss assumptions, limitations and threats to validity for our research.

7.1 GAIA User Survey

A user-friendly survey was constructed based on the 6.3 Tool Assessment Checklist to collect feedback from all the participants in performance management of engineering education from 2014 – 2018 at the School of Electrical Engineering and Computer Science at the University of Ottawa. There were three types of users – course professors, program coordinators and faculty level accreditation experts. They all used the GAIA prototype as their tool support for graduate attribute assessment (GAA) as part of a continuous improvement process for their programs as mandated by the Canadian Engineering Accreditation Board (CEAB).

7.1.1 Survey Design

We follow the guidelines outlined by Statistics Canada in Catalogue no. 12-587-X Survey Methods and Practices (Statistics, 2010). For developing our questionnaire, we considered two major points: (1) types of questions and (2) suitable scale in terms of (i) required dimensions, (ii) administration, and (iii) scoring.

Development and evaluation of the survey questions is based on the IBM technical report on application of psychometric methods that measure user satisfaction with system usability (Lewis, 1993). We take under consideration the options related to administration and scoring for the four different IBM questionnaires discussed in the technical report.

Our survey consists of 21 closed type statements (participants select their level of agreement with the statement on a rating scale of 1 to 5) and 1 optional open question (participants answer in their own words) inviting them to share suggestions/recommendations regarding future improvement of the tool. The questions are grouped into 4 categories:

Part I: Participation in Graduate Attribute Assessment

It consists of 5 check-box questions. They indicate participants' demographic characteristics related to their involvement in the Graduate Attribute Assessment process. Participants select all that apply.

Part II: Tool Assessment

This part consists of 10 questions to be answered on a rating scale from 1 to 5.

The questions assess user's experience with the GAIA tool.

Part III: Feedback

It consists of 2 questions to be answered on the rating scale from 1 to 5 and one free response question inviting them to share thoughts and ideas for improvement of the tool.

Part IV: Program Analysis

This part consists of 4 questions related to the affect the tool had in supporting the systematic approach. This part consists of 4 questions to be answered on a scale from 1 to 5.

The 5 - point Likert-type scale (Likert, 1932) used in our survey is generally considered to increase response rate and response quality along with reducing respondents' "frustration level" (Babakus & Mangold, 1992). A rating scale from 1 to 5 with 1=Strongly Agree, 2=Agree, 3=Not Sure, 4=Disagree and 5=Strongly Disagree is supplied with each statement. N/A=Not Applicable option is provided for participants to select if they believe that the statement provided does not reflect the type of interaction, they had with the GAIA system. An example of using the rating scale is illustrated on Figure 73 below.

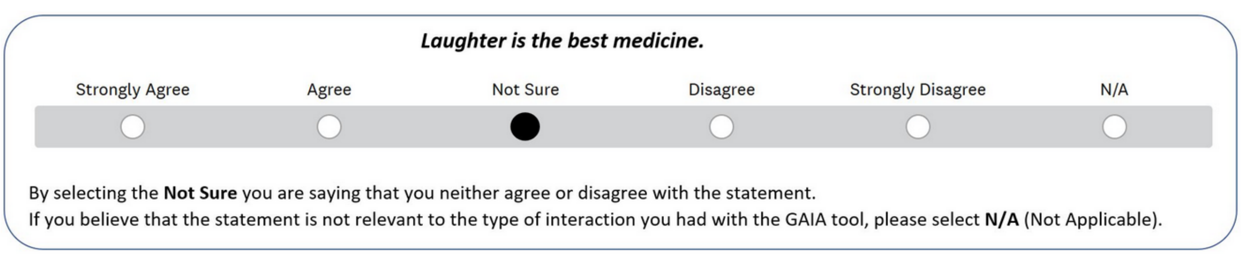


Figure 73. Example of using the GAIA User Survey rating scale.

7.1.2 Research Ethics Approval, Privacy and Confidentiality

The survey was approved by the Office of Research Ethics and Integrity at the University of Ottawa, Ethics File Number H-09-18-1107 (attached to this thesis as Appendix A), entitled "The Use and Effectiveness of Enterprise Architecture in Higher Education". The author is certified by the Panel on Research Ethics on the Ethical Conduct for Research Involving Humans. A Consent Form (attached to this thesis as Appendix B) was distributed to all participants as part of a recruitment email (attached to this thesis as Appendix C).

To protect participants' privacy, the survey was anonymous. No information that would directly identify a participant was collected. Possible identifiers such as name, email address, or user IP were not collected. Data confidentiality and security were assured by implementing physical and technical safeguards to protect data from unauthorized access, use, loss, disclosure or modification.

7.1.3 Purpose and Objectives

The survey collects feedback from EECS professors who have been using GAIA system for GAA as part of their engineering program's continuous improvement process as mandated for accreditation by CEAB. During the period 2014-2018 the program's continuous improvement process and the GAIA system were based directly on the systematic approach for tool-supported performance management proposed in this thesis. The survey provides objective quantitative data on how well users felt the GAIA system and continuous improvement process supported performance management as mandated by CEAB accreditation. As such, it provides, strong, albeit in-direct, evidence for the viability and validation of our systematic approach for tool-supported performance management.

The research questions addressed are:

1. Do the professors who have used GAIA find it (i) useful and (ii) easy to use for graduate attribute assessment?
2. Is the GAIA system an improvement over the standard set of Excel forms provided by the CEAB for GAA during the 2014 accreditation visit?
3. Is the Tool-Assessment Checklist useful and effective for evaluating tools used to support GAA?
4. Are there any areas where EECS could improve its tool support for GAA and continuous improvement process of its programs?

7.1.4 Execution of the Survey

The survey was executed using an online survey development cloud-based software as a service (SaaS) platform. A recruitment email was sent to 40 EECS professors who have taught courses for which GAA data was collected since 2014. Some of the professors no longer worked at the university at the time when the survey took place, so we were hoping to have around 25 participants.

To gather feedback, as well as statistics on actual usage and adoption for the purpose of analysis of survey results and reporting, participants were assigned to a particular user category.

The clustering is performed using participant's answers on the demographic questions from Part I of the survey. The following three user groups were formed:

- **Group I:** Part-time professors;
- **Group II:** Full-time professors with no program responsibilities;
- **Group III:** Full-time professors with program responsibilities. This is the most motivated group of users. It includes program coordinators, faculty executives and accreditation experts.

The survey was opened in December 2018 and closed in March 2019. It covered professors submitting GAA data since the CEAB accreditation visit in Fall 2014 till Fall 2018 (in preparation for the 2nd accreditation cycle in 2020). 27 responses from three different user categories were collected within this time frame.

7.1.5 Survey Data Analysis

To analyze the survey results for Part II, Part III and Part IV of the survey and use them to report on measured variables the following statistical tests were performed on the survey data:

1. General statistical approach was used to analyze the demographic data (Part I of the survey) and report on professors' comments (Part III, Question 18).
2. Analysis related to questions from Part II, Part III (without Question 18) and Part IV were performed using general statistics applied for reporting on total population

We use the survey results to compare the experience with the system and its implementation for GAA data for accreditation among users from different programs – ELG, CEG, SEG and COOP. Considering that GNG courses are common, the GNG survey data was imbedded within the programs data.

In the analysis section all survey questions are numbered from 1 to 22 as follows: questions 1-5 for Survey Part I; questions 6-15 for Survey Part II, questions 16-18 for Survey Part III, and questions 19-22 for Survey Part IV. The average time per user for completing the survey is 6 min 33 sec against the projected 10-15 minutes.

In sections 7.1.5(1) through 7.1.5(4) hereunder we describe the analytics that took place and elaborate on the results.

1. Part I: Demographics

Demographic analysis report on participation rate indicates (1) percentage of users experienced with different performance management forms, (2) informs on users' intentions and expectations, (3) detects correlation within and between sample sizes, and (4) tracks the frequency of the system usage. The information is gained from analyses performed on questions 1 through 5 from the survey using sample variance, standard deviation and confidence intervals.

Professors from three EECS engineering programs participated in the survey. Note that some EECS professors teach courses from more than one category (SEG, ELG, CEG, GNG, COOP). The participation rate from each program is as follows:

- Software Engineering Program (SEG): 48.15% (13 responses);

- Electrical Engineering Program (ELG): 55.56% (15 responses);
- Computer Engineering Program (CEG): 18.52% (5 response).

In addition to that professors teaching General Engineering courses (GNG) and professors reporting COOP work terms assessment data (including COOP placement) also took part in the survey. Their respective participation rate is:

- General Engineering courses (GNG): 3.7% (1 response);
- Work term data (COOP): 7.41% (2 responses).

Graphical presentation of the above statistics is illustrated in Appendix E. Figure 74 below depicts the percentage distribution per program, COOP and GNG included.

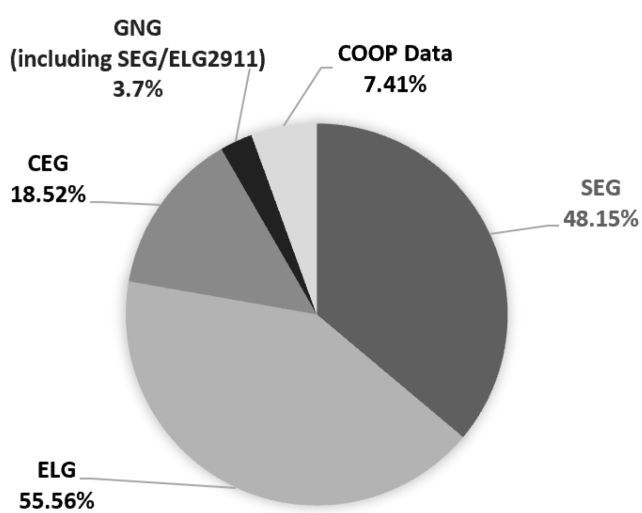


Figure 74. Demographic Data.

The graph indicate that the analysis is expected to be affected by the responses of the ELG and SEG professors (in terms of program relation), and by the opinions of the full-time professors with no administrative duties (in terms of responder type).

Based on users' responses to Question 2, pre-2014 experience of professors with CEAB accreditation was analyzed. The results are illustrated in Figure 75 in dark red colored bars. The graph shows that we have all COOP and majority of professors from SEG and CEG programs who used the original CEAB forms for GAA data collection before the GAIA prototype and our systematic approach for tool-supported performance management was introduced. This indicates that we are having valuable input in terms of measuring user satisfaction with the GAIA system and our systematic approach as compared to what was in use before we implemented the system. Furthermore, the significance of the SEG program professors' input in the overall analysis is increased by the fact that they represent about half (48.15%) of the total population.

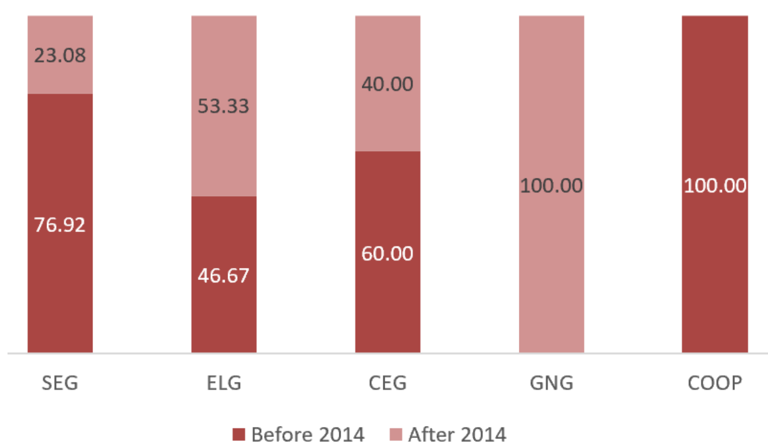


Figure 75. Percentage of participants with experience submitting GAA data for 2014 accreditation.

The various ways in which the GAIA system was used as part of the continuous improvement process for programs were also observed. As expected, the survey results on Question 5 indicate that a vast majority of the sample group (96.15%) used the system to provide GAA data for accreditation. An interesting finding is that half of the survey participants (50%

exactly) used the system to analyze one or more of their courses. We were able to extract the numbers of professors from each program who compiled these 50%. The results exhibit that most interested in this feature of the system were ELG professors (compiling 53.3% from the 50% overall), followed by the SEG professors (30.8%), and 20% of the CEG professors. This usage is not mandated by CEAB and would be completely voluntary for all participants. This is a strong indicator that the GAIA system is useful and easy-to-use, and that our systematic approach is effective in encouraging engagement in continuous improvement. The analyses performed above are displayed on Figure 76.

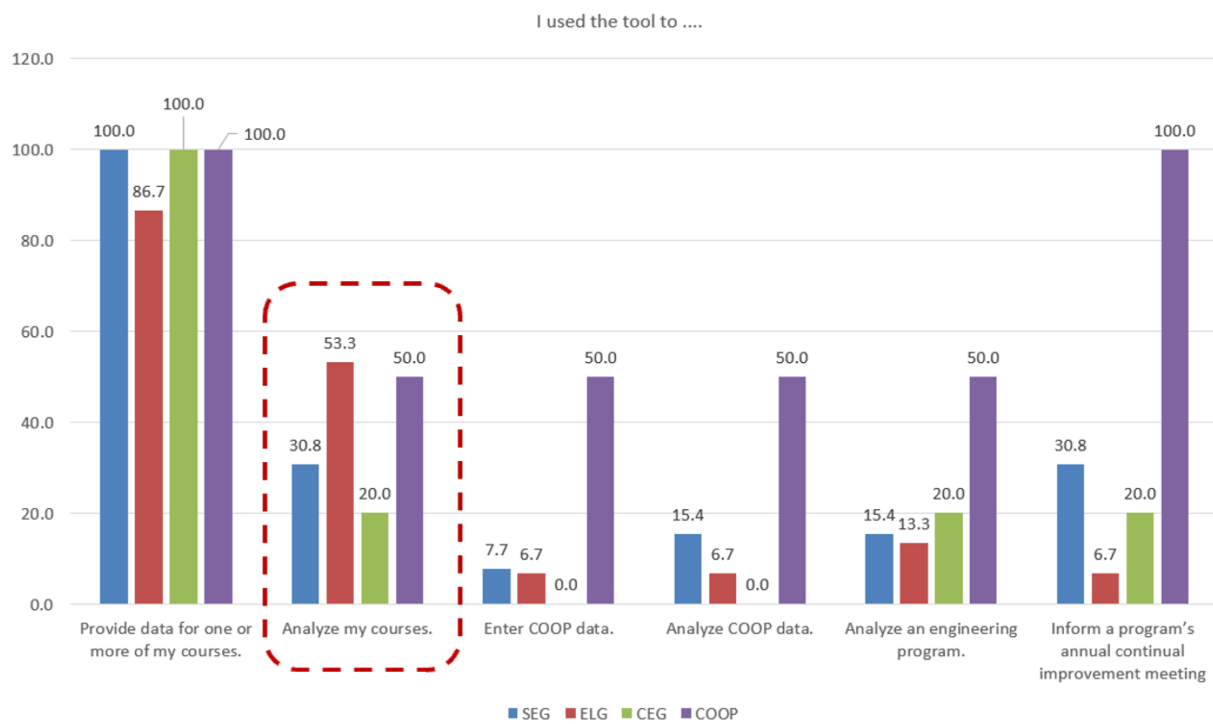


Figure 76. System Usage.

According to user's group distribution, 33.33% of the participants were part-time professors (Group I), 62.96% were full-time professors with no program responsibilities (Group

II), and 18.52% were program coordinators and faculty executives (Group III). The group distribution is illustrated in Figure 77. According to the combined results from Figure 80 and Figure 82, the full-time SEG professors are expected to influence the survey data. Since the GAIA system was firs tested and implemented in the SEG program, this will add to validity and consistency of the survey analysis.

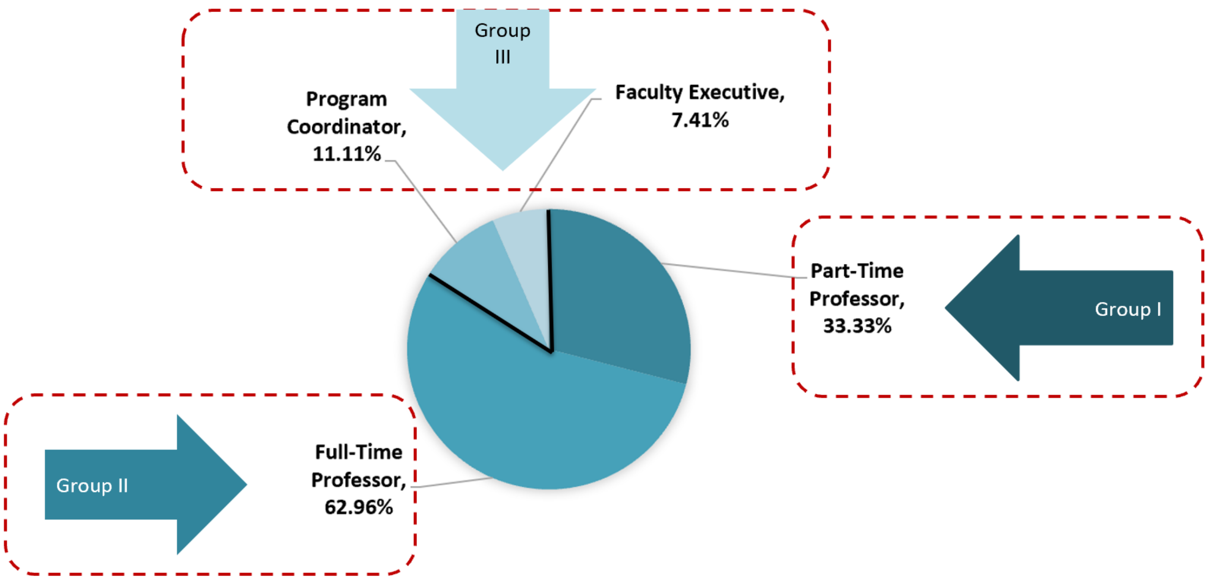


Figure 77. Participants' Group Distribution (data in %).

Users' overall responses to Question 2 indicate that majority of our sample group were professors who participated in the 2016-2017 GAA data collection (70.37%) and the smallest percentage of the survey participants were involved in the 2018-2019 GAA data collection (see Appendix E, Question 2). We need to point out that only Fall 2018 data would have been collected at the time of the survey in January 2019, thus the result is rather reasonable than opposing expectations. Furthermore, a percentage usage of the GAIA system was calculated per year. Figure

78 below shows a comparison between the programs and COOP professors in terms of their engagement in the process of GAA reporting.

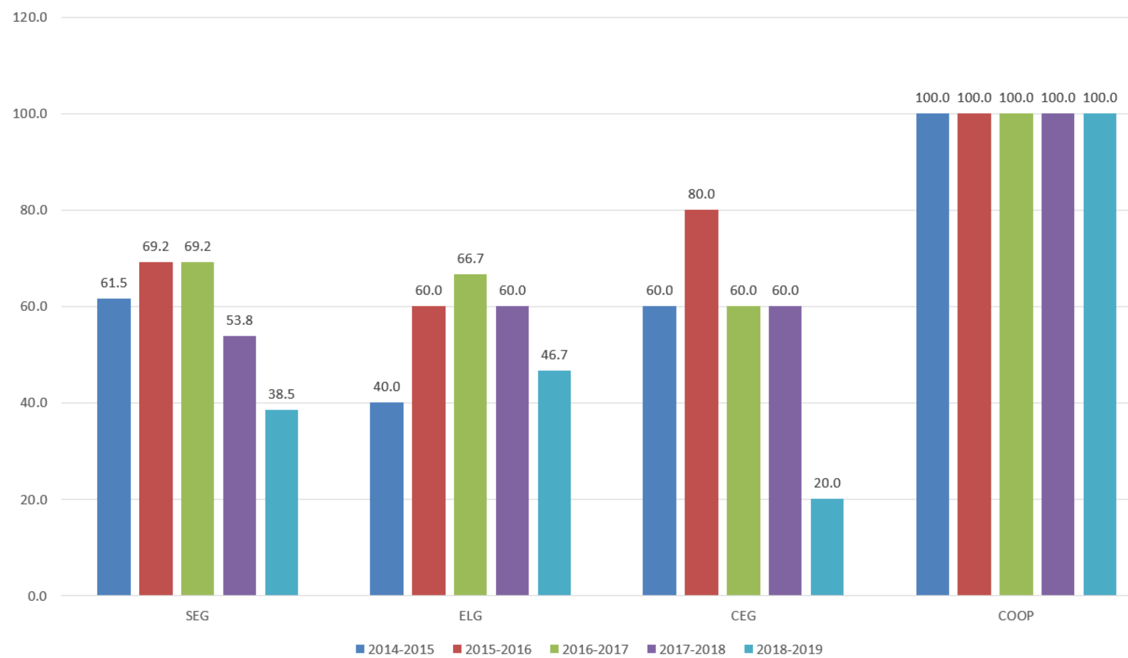


Figure 78. Percentage usage of GAIA per fiscal year.

The graph points out that after implementing GAIA, the percentage of professors involved with the GAA increased. This is a nice-looking result, but unfortunately due to the very small sample size especially for CEG and COOP, the graph may be misleading. To assure appropriate accuracy we calculate the confidence interval per each program.

	SEG	ELG	CEG	COOP
Mean	58.46154	54.66667	56	100
Standard Error	5.756396	4.898979	9.797959	0
Median	61.53846	60	60	100
Mode	69.23077	60	60	100
Standard Deviation	12.87169	10.95445	21.9089	0
Sample Variance	165.6805	120	480	0
Kurtosis	0.535714	-1.68724	2.916667	#DIV/0!
Skewness	-1.08851	-0.51842	-1.29323	#DIV/0!
Range	30.76923	26.66667	60	0
Minimum	38.46154	40	20	100
Maximum	69.23077	66.66667	80	100
Sum	292.3077	273.3333	280	500
Count	5	5	5	5
Confidence Level(95.0%)	15.98232	13.60175	27.2035	0
Lower	42.47922	41.06492	28.7965	100
Higher	74.44386	68.26841	83.2035	100

Figure 79. Percentage GAA Involvement per Program. Confidence Intervals.

The calculations denote that we can be 95% certain that the mean percentage participation in the GAA per program (COOP included) is within the values in the orange ovals on Figure 79 above. Because the confidence intervals for SEG and ELG almost overlap, the two programs cannot be significantly different. On the contrary, CEG is significantly different (with very little overlap), thus despite having the least participation rate for the last two years, the CEG professors show the highest interest in GAA. The COOP data is being 100% collected across the years, so in this particular case, we can call it an outlier.

2. Part II: GAA Data at Course Level

To report on the tool's support for GAA data at course level we use the data from user responses on questions 6 through 15 (responding to questions 1 through 10 in the actual survey in Appendix D). Analysis are performed using basic statistical methods for the overall data.

The analysis confirms that the GAIA system is useful and easy to use and our systematic approach is effective in encouraging engagement in implementing GAA to inform continuous improvement.

Overall Analysis Based on Total Population Data[2]

77.78% of professors believe GAIA is helpful (Appendix E, Question 7), its implementation for the purpose of GAA is a good idea is indicated by the 88.89% of the users (Appendix E, Question 8). And the intent to use GAIA when asked to do so is reported by the 85.18% of professors (Appendix E, Question 9). This is a strong indication of compliance with Construct 3 (attitude towards using the tool) and Construct 4 (perceived usage of the tool) from our Tool-Assessment Checklist (Table 11). The percentage distribution on this point is almost equally split between "agree" and "strongly agree" choices (Appendix E, Question 6). The use of the system is supported by 65.37% of professors who found it straightforward to copy-paste the assessment data into GAIA (Appendix E, Question 12). A success in meeting Construct 11 (reporting ability) is indicated by 66.67% of professors who believe that GAIA system generates all the reports they need to measure GAs (Appendix 11, Question 15).

The use of Excel Files for storing and moving data is found adequate as well with 84.62% of the professors agreeing that the Excel files are easy to use for storing and accessing data (Appendix E, Question 13). These numbers clearly indicate that we have successfully met the requirement of Construct 10 (handling assessment data). 81.48% of users agree that the system's platform is successful for generating historic trend analysis from year to year (Appendix E, Question 14). Furthermore, with majority of professors (62.96%) feeling that using the system for GAA reporting does not take much of their time (Appendix E, Question 11) we can conclude that

[2] The question numbers we use in the analysis refer to the order used in Appendix E, GAIA Survey Results.

our effort in terms of minimizing the system complexity in alignment with Construct 7 (complexity of the tool) from the Tool-Assessment Checklist (Table 11) was successful.

The fact that the system is useful and easy to use and our approach is effective in encouraging engagement in continuous improvement is also supported by 69.23% of the users who find the system useful for analyzing how the students perform in their classes and will use it even if it was not required for CEAB accreditation (Appendix E, Question 10).

A summary of professors' responses per question is provided in Table 16 below. The percentage listed in the table is a summative result of "strongly agree" and "agree" type of responses.

Table 16. GAIA Survey Responses to Part II Questions. Summary.

Question # *(numbers shown as listed in Appendix E)*	Q.6	Q.7	Q.8	Q.9	Q.10	Q.11	Q.12	Q.13	Q.14	Q.15
Highly affirming the statement *(data in %)*	77.78	77.78	88.89	85.11	69.23	62.96[3]	65.37	84.62	81.48	66.67

3. Part III: Feedback

Feedback provided by the participants through their responses on questions 16, 17 and 18 measure the system's perceived usefulness, perceived usage and compatibility with the CEAB accreditation process. Similar to the approach in Part II analysis, we first look at the overall population data for Questions 16 and 17. Professor responses on Question 18 give qualitative aspect of the survey analysis and they are interpreted separately.

Overall Analysis Based on Total Population Data

The report on 74.07% alignment with GAIA being an improvement over the official CEAB forms used for 2014 accreditation (Appendix E, Question 16) was expected result. Still, taking into account that GAIA is being developed and constantly improved to meet accreditation requirements in general and user expectations in particular, we would have expected a better result. Being almost within the last quartile relates mainly to issues pointed out in users' suggestions for system improvement.

12 professors responded to the optional Question 18 which asks for their suggestions for improving the system. Five of the survey participants express their satisfaction with the system and underline the ease of use and usefulness of the system. Four of the users point the integration with university's LMS as a major issue. Two of the professors although being happy with the system, are not comfortable with the GA description and number of indicators used. With the CKPIs in use in the near future part of the problem is going to be resolved. One of the respondents was only participating in GAA data collection in 2014, using the CEAB forms and was not able to provide an input to the tool's improvement. The analysis of professors' responds to Question 17 indicate that 77.77% of the participants find the GAIA system useful and informative.

4. Part IV: Program Analyses

This analysis is based on user responses to questions 19 through 22. It targets GAIA's ability to support continuous improvement at the program and faculty level. Users in the face of program coordinators and faculty executives, evaluate the tool's reporting ability, reporting quality and alignment with CEAB accreditation requirements. As specifically noted at the beginning of

Part IV of the survey, all users who are not program coordinators are asked to select N/A. These users are not being involved with evaluations at the faculty level, thus their responses (N/A) are not included in the analysis. We have also identified three part-time professors who responded to the questions, thus their respective percentage input in the overall data was eliminated as well. Proceeding with this analysis we applied the same approach as in Parts II and III of the survey. The same type of tests applies.

Overall Analysis Based on Total Population Data

Considering the restrictions enforced in this part of the survey, we have composed summary of responses shown in Table 200. The percentage data in the table accumulates "agree" and "strongly agree" responses from professors who identified as executives or program coordinators. Three program coordinators and two faculty executives are being recognized. The data indicates that all responses align with the statements in questions 19 through 22. The users' opinion is divided between "strongly agree" and "agree" as indicated on Table 17 below.

Table 17. GAIA Survey Responses to Part IV Questions. Summary.

Questions 19-22	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
SEG	66.67%	33.33%	0.00%	0.00%	0.00%
ELG	0.00%	100%	0.00%	0.00%	0.00%
CEG	50%	50%	0.00%	0.00%	0.00%
COOP	100%	0.00%	0.00%	0.00%	0.00%

7.2 Comparison to Related Works

Comparing the experience of users with GAIA to similar experiences and shared expertise, was a productive and constructive learning experience. The comparison to related works follows the historic trend of GAIA's development and is meant to highlight the positive input all related works had on the progression and gradual implementation of our systematic approach for tool-supported performance management.

In this section, we evaluate our systematic approach in comparison to the related works identified in chapter 2.3, based on three sets of criteria which are described in detail below. Criteria 1, 2, 3 and 4 are based on the main components of our systematic approach for tool-supported performance management. This helps identify whether or not the related works had similar components.

Criteria 5, 6, and 7 correspond to the three major gaps that were identified for the related works in the gap analysis of chapter 2.4. This helps identify to what degree our approach was able to address the gaps. Finally, criteria 8, perhaps the most critical element for ensuring use and adoption by engineering programs, is how well the systematic approach for tool-supported performance management aligns with accreditation requirements for performance management and a continuous improvement process.

Table 18 provides a color-coded snapshot of the comparison which is explained in detail after the table.

The following 4-level evaluation scale per criterion applies:

Criterion 1 (System Architecture):

- Green: UI (for GAA database), MI (for LMS, COOP Portal and/or other sources of data), HMI (human-machine interface), MMI (machine-machine layer), all must be present.
- Yellow: There are sufficient interfaces to (in theory) cover all types of data, but well-defined and usable machine interfaces are missing.
- Red: There are not sufficient interfaces to cover integration of all types of data from all types of sources and participants.
- White: N/A

Criterion 2 (Common CIP):

- Green: Systematic common CIP is implemented and informed across all programs (closing the loop).
- Yellow: There is an attempt to standardize CIP across programs, but it lacks compliance.
- Red: Systematic common CIP does not exist (each program is different or the process is not well defined).
- White: N/A

Criterion 3 (Common KPI):

- Green: Common/uniform across engineering programs KPIs are measured and reported.

- Yellow: There is an attempt to standardize KPIs across programs, but it lacks compliance (programs are in fact different making comparisons difficult).
- Red: There are no common KPIs (each program is measured in a different way with no attempt to compare).
- White: N/A

Criterion 4 (Performance Management Forms, PMF):

- Green:

    i. PMF at course, program and faculty level exist and they are used to inform CIP.

    ii. There must be a program report that shows historical trends (ideally by cohort).

    iii. There must be a program report that can include non-course data.

- Yellow: PMF at some level exist with historical trend analysis and they are used to inform CIP.
- Red: Failed to provide a PMF with historical trend analysis to inform the CIP.
- White: N/A

Criterion 5 (Information System Model):

- Green: IS supports CIP and ongoing changes of accreditation policies and procedures.

- Yellow: IS supports CIP, does not support ongoing changes of accreditation policies and procedures.
- Red: IS does not support accreditation.
- White: N/A

Criterion 6 (Tool Support Specifications):

- Green:

  i. Processes different types of data (qualitative and quantitative);
  ii. Supports data from different sources (LMS, CVS/Excel, COOP Portal, System DB etc.);
  iii. Fully integrated with existing tools and processes;
  iv. Supports historic trend analyses and generates various types of reports at different levels.

- Yellow: partial compliance with the requirements listed above;
- Red: complies with at most two of the requirements;
- White: N/A.

Criterion 7 (Tool Adoption):

- Green: Full engagement that can be measured by constructs 1 through 8 inclusive from the Tool-Assessment Checklist proposed in Section 6.3;
- Yellow: Partial engagement with the requirements listed above;

- Red: Tool adoption issues are not properly addressed;
- White: N/A.

Criterion 8 (Tool Alignment with Accreditation Process):

- Green: Fully aligns with accreditation process;
- Yellow: Partially aligns with accreditation process;
- Red: Does not align with accreditation process;
- White: N/A.

Table 18. Comparison of Related Work

Accreditation Board	Related Tools and Apps	Concept Map							
		Methodology				Gap Analyses			Engineering Accreditation
		Chapter 3.2	Chapter 3.3	Chapter 3.4	Chapter 3.5	Chapter 2.4.1	Chapter 2.4.2	Chapter 2.4.3	
		Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8
		System Architecture	Common CIP	Common KPI	Performance Management Forms	Information System Model	Tool Support Specifications	Tool Adoption	Tool Alignment with accreditation process
ABET	ACAT: ABET Course Assessment Tool	Yellow	Yellow	Red	N/A	Red	Yellow	Yellow	Green
ABET	ABET Compliance Tracking System (ACTS)	Yellow	Yellow	N/A	N/A	Yellow	Yellow	Red	Green
ABET	ABET Accreditation Manager	Yellow	N/A	N/A	Green	Green	N/A	Yellow	Green
CEAB	AMS at the University of Alberta	Yellow	Red	Red	N/A	Green	Yellow	Green	Green
CEAB	GA Assessment and CPI at McGill University	Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Green
CEAB	OBACIS, University of Regina	Green	Red	Red	Yellow	Red	N/A	Yellow	Green
N/A	'Best of Breed' Off-the-shelf Tools	N/A	Red	Red	N/A	Red	Red	Red	Yellow
CEAB	GAIA, University of Ottawa	Green	Green	Green	Green	Green	Yellow	Green	Green

7.2.1 ABET Related Experience

1. ACAT, ABET Course Assessment Tool (Essa, 2010)

Essa reports that the overall evaluation of the ACAT tool performed at the faculty level indicates 100% user satisfaction with the product and compatibility with ABET accreditation requirements over two ready products previously in use (Essa, 2010). ACAT accommodates data from surveys, job placement statistics with data being averaged per course outcome. Although the system generates standardized reports that support accreditation, the tool requires changes to existing evaluation methods to assure data compliance needed for the tool to process it. Furthermore, there is no evidence for compatibility with other systems and the tools in place. ACAT requires data to be entered directly by the user and does not support historic trend analysis, GA analysis per cohort or COOP employment statistics and employer evaluation reports for mandatory COOP programs. It has no option reflecting on student work term performance as well. Reports generated can be used to inform common CIP, but no mechanism for informing CIP is evident in the tool description. The system does not use common KPIs. (Essa, Dittrich, Dascalu, & Harris Jr., 2010).

2. ABET Compliance Tracking System, ACTS (Zahorian, Summerville, & Craver, 2012)

The ABET Compliance Tracking System (ACTS) is a web-hosted database system, very similar to ACAT in terms of system architecture and performance. It has clearly defined process for informing CIP. The system is used by two programs – Electrical Engineering and Computer Engineering but no common KPI or common CIP are described to be used. On the contrary, the paper reports that 54 Performance Criteria are being used for the electrical engineering program and 53 for the computer engineering program. The tool uses qualitative and quantitative data, but not all assessment forms and data sources are being fully incorporated. The authors describe dealing with the tool complexity and creating a user-friendly interface design as the "largest challenge". (Zahorian S. , Summerville, Craver, & Elmore, 2011). No use of COOP or employer evaluation data is evident. The paper does not specify if any GA reports per cohort are being generated.

3. ABET Accreditation Manager (Shankar, Dickson, & Mazoleny, 2013)

Similarities between the ABET Accreditation Manager tool and GAIA are identified in terms of system architecture HUI. ABET Accreditation Manager accounts for UI in a similar to GAIA fashion. The tools' players identified as ABET coordinator, faculty members and graduation coordinator map to GAIA's UI1, UI3 and UI2 respectively. Tasks are assigned in accordance with specifically oriented IS. An automatic reminder is sent to all faculty members due to enter data for a particular semester. The tool offers user friendly interface which similar to GAIA positively affects the subjective norm behavior. The tool is a web-based solution that supports only meta-format of CSV files. This requires all assessment data collected and recorded by the professors to be uploaded in .csv format. The tool serves one engineering program so common CIP and common KPI s are not applicable. A major difference compared to GAIA is the fact that there are no MMIs involved in the process. Furthermore, the tool uses only three levels criteria entered by the course instructor per student – *satisfactory*, *unsatisfactory* or *not applicable* as opposed to GAIA's fine granularity of raw assessment data which is processes and clustered automatically within a 4-level scale. The Accreditation Manager does not support employers' evaluation data of any form and cannot be used for COOP term reporting.

In addition, we performed a comparison based on reports by several Canadian universities using self-developed tools. A common preference towards Excel based or Excel compatible tools is evident throughout different related publications we've explored.

7.2.2 CEAB Related Experience

1. An Engineering AMS (Dew, Lavoie, & Snelgrove, 2011)

The Engineering Accreditation Management System (AMS) developed at the University of Alberta fully supports criteria 5, 7 and 8. The Web-based system architecture provides access to different UI based on users' roles – it clusters users by privileges to improve data security and restrict access. In contrast, security in GAIA is provided by implementing different forms to assigne user privileges (i.e. differentiated access is achieved through implementation of different reporting forms). As a result, GAIA generated reports can address particular users' needs. Generalizing the access using respective password instead is still to be developed, tested and implemented in GAIA. This research provides good background for respective future work. Although not fully integrated with existing tools or systems, AMS is well received by the users. The system generates a large list of CEAB tables and an Attribute Map which shows the degree of development for each GA at a course level. Although faculty level administrator and department admin users are being part of the system's UIs, no common KPI or common CIP are being described in the paper. There is no evidence of MMI. The authors do not report on the use of different types of data as well. (Dew, Lavoie, & Snelgrove, 2011). This is a major difference between the AMS tool and GAIA.

2. GA Assessment and CPI at McGill University (Saunders & Mydlarski, 2015)

In addition to the lack of systematically generated historic trend analysis, COOP data and cohort reports, none of the related work mentioned above addresses the use of common performance indicators at the program level or implementing and informing common continuous improvement process across several programs. The development of processes to meet CEAB GA and CIP criteria reported by the Faculty of Engineering at McGill University is the only relevant experience mapping our Common CIP and Common KPI criteria. Similar to our Phase Zero of GAIA development, data collection and analysis are performed using existing Excel spreadsheets. Another similarity is noted in the way GA evaluation is being addressed. Like in the case with GAIA, the approach is to measure GAs by selecting relevant performance indicators, rather than directly. Adopting already existing processes which are being identified as flexible enough to respond to reporting requirements changes gives this work a complete compliance with Criterion 1, 2 and 3 from the comparison table above. Lack of evidence for the use of different data source platforms and the fact that GA assessment is performed based on sampling of student give this work a partial compliance with Criterion 5, 5 and 7.3.

3. OBACIS (Ismail, 2016)

Similar to GAIA, OBACIS implemented by the University of Regina, is based on bottom-up mapping course activities to graduate attributes, indicators and course LO (Ismail, 2016). The tool generates analysis per category (assignments, labs, mid-term, final exam, project), per LOs and graduate attributes thus maps our Criteria 4. The reports generated are in a box-plot format, a type of graph not supported by GAIA. The process however, remains largely very similar to GAIA's. Course projects, term papers, case studies, capstone projects and essays are most matching activities to GA indicator matrix thus the system described concentrates largely on their use for accreditation. In contrast to GAIA, historical records per student can be tracked over their course of study, but no data on GA achievement per cohort is generated. The tool provides analysis per category (assignments, labs, mid-term, final exam, project), which is not supported in GAIA. The use of apps is a potential area for GAIA development. We are not able to identify any ability of the tool to report on work-place performance or include alumni surveys or employers' evaluation. In terms of tool support specifications, no variety of data storage/source is identified and no implementation of qualitative data is evident.

7.2.3 Off-the-shelf Software Tools Supporting Outcomes-Based Continuous Improvement process

Performing theoretical and empirical evaluation of selected "of-the-shelf" tools, Kaupp and Frank report on compatibility with different aspects of the GAA but stress that off the shelf tools currently are only viable for secondary support of performance management for accreditation (Kaupp & Frank, 2014), (Kaupp & Frank, 2015). Because they are not designed specifically for accreditation, they fall short for Criteria 2, 3, 5, 6, and 7.

7.2.4 A systematic approach for tool-supported performance management (GAIA)

The criteria used above deliver a summary of characteristics that allow to estimate the extent to which a systematic approach for tool-supported performance management would succeed. Aligning the Graduate Attribute and Information Analysis system (GAIA) against Criteria 1, 2, 3, 4, 5, 7 and 8, gave us a complete match with the highest expectations simply because these components are rooted within our own systematic approach.

Criterion 7 is measured by the constructs 1 through 8 form the Tool-Assessment Checklist and the green oval allocated is strongly supported by 76% of the GAIA users according to their responses to Part II questions of the GAIA survey.

We did manage to use ODBC for extracting data from the COOP Portal, but failed to find a suitable solution for exporting data form the LMS we have in place at the University of Ottawa. Due to this partial compliance, our systematic approach is assigned a “yellow” oval for Criterion 6.

And last, but not least, we would like to share the positive influence we experienced by exploring related works and publications. We learned as much from others’ successes, as we did from the obstacles they faced. Based on the analysis Essa performed (Essa, 2010), we were able to identify the similarity in the development process sequence between ACAT and our own GAIA. Furthermore, we explored the relation between implementing each additional feature of the ACAT tool and the level of tool complexity (LTC), technology adoption issues (TAI) and user attitude (UA). We use those findings to predict, manipulate and in many cases, avoid potential difficulties in implementing modification to GAIA. The respective relations between GAIA development stages and LTC, TAI and UA are shown on Fig. 80 below.

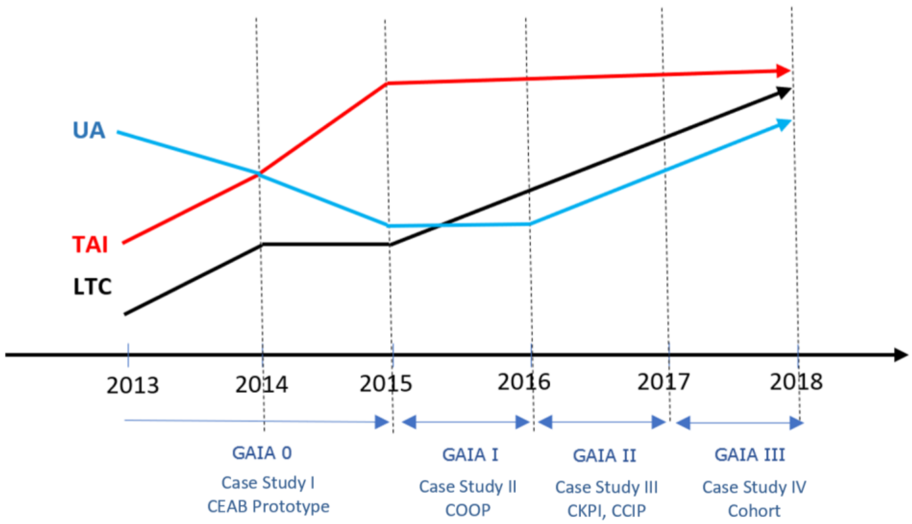


Figure 80. Relation between GAIA evolution and LTC, TAI and UA

The graphical presentation of the LTC (black line), TAI (red line) and UA (blue line) as functions of time clearly indicate that any GAIA modifications implemented after 2015 (when we actually started GAIA Phase I) did not possess increase in terms of technology adoption issues (the red line on Figure 91). In fact, the rapid increase we had when we started implementing the initial CEAB forms in 2013-2014 was followed by a secondary flow in the rate caused by the need for professors to spend more time on the GAA tasks to fill in the clustered GAA data into the data collection form added by the department. Since 2015 when the first GAIA performance management forms were implemented a steady rate is reported (i.e. no increase of technology adoption issues). This positively affected the UA behavior line (illustrated in blue in Fig. 91). A certain one-year aloof period followed until users realized that all additional reports GAIA started generating affected positively their performance and ability to track GAA of the students without the need for them to apply any additional time or effort. Thus, a positive jump in the user attitude rate followed and the negativity towards accreditation related tasks started to slowly disappear.

7.3 Assumptions, Limitations and Threats to Validity

7.3.1 Assumptions

We have assumed, as do most accreditation organizations world-wide, that all engineering programs are similar enough, thus it is possible to specify a common process for performance management, with a common set of graduate attributes and indicators. In effect, we have assumed that all engineering programs are comparable, i.e. we are assuming that different branches of engineering are comparable in terms of the performance management of engineering education.

7.3.2 Limitations

1. The thesis is strictly focused on performance management of engineering programs based on graduate attribute assessment. There are other approaches that could be used for performance management of engineering programs. Accreditation often specifies the minimum number of courses, and minimum number of hours of instruction in key topics and requires a minimum number of hours of instruction from certified professional engineers. Similarly, other disciplines (such as medicine) describe specific indicators, and specific tools and guidelines for evaluating and measuring.

2. Effective performance management is dependent on the skill and experience of the program professors/administrators in determining the right courses or sources of data to measure

graduate attributes. The use of our systematic approach for tool-supported performance management does not guarantee in any way that a program is a good program or that its students are good ones. It merely enables the measurement of performance by programs in a systematic manner based on the indicators, courses and sources of data that they have decided to measure and ensures that a continuous improvement process for the program is informed by that measurement.

7.3.3 Threats to Validity

Design science research is "early" research that seeks to provide initial evidence that the theory has the potential to close the gaps that have been observed with respect to a specific research problem. In that respect, we have been successful in showing how our systematic approach for tool-supported performance management has the potential to address the current gaps in performance management of engineering education based on graduate attribute assessment (GAA). The GAIA User Survey clearly shows the success of the prototype GAIA-supported systematic approach for performance management of the software, electrical and computer engineering programs over the last four years in the School of Electrical Engineering and Computer Science at the University of Ottawa. More studies are needed however to validate that other researchers can duplicate the results in other organizations with other engineering programs.

Chapter 8. Conclusions and Future Work

8.1 Conclusions

Preliminary results indicate the viability of our systematic approach to tool-supported performance management of engineering education, as evidenced by the success of the GAIA prototype used at the University of Ottawa from 2014 to the present. Both the GAIA user survey and the comparison with related works provide evidence that our approach can improve upon current approaches to performance management of engineering education.

The most critical elements of our work are the system architecture, CKPIs, and tool assessment checklist. Establishing a system architecture is important for understanding and managing the complexity of performance management of engineering education, and understanding where tool support is required in terms of user interfaces and reports for different actors.

Establishing a common set of key performance indicators across programs is critical for simplifying and standardizing the mapping from detailed course level outcomes, to program level indicators that measure attainment of graduate attributes. Without this mapping, institutions get over-focused on detailed common course learning outcomes, and collect too much data that is not directly related to overall program objectives. With a common set of indicators, it makes it easier to compare different programs within a single university, and it makes it easier to compare a single type of program across several universities. This is essential for accreditation to achieve consistency and standardization of graduate attributes for engineers, across programs and universities.

The theory and approach to the development of a tool assessment checklist contributes a strong foundation to guide anyone responsible for engineering programs at an educational institution on how to evaluate the quality of any tool or tools used to support a systematic approach to performance management of engineering education. This includes guidance on the development of user surveys to elicit feedback from users, as was illustrated with the GAIA user survey.

CCIP and performance management forms are also important contributions. The definition of a common continuous improvement process with a set of clearly defined and scheduled deliverables and associated templates, reduces the management burden and ensures a level of consistency and completeness. Performance management forms and the associated data transformation and analysis techniques help identify the key elements for data collection and reporting that are useful in performance management including historical trend analysis (in order to spot trends and verify improvements over a multi-year cycle of continuous improvement); coop reporting (to include data from employers); and cohort reporting (in order to understand the performance of one group of students across all four years of their program).

8.2 Future Work

To improve the tool specifications and ability to seamless integrate data from any LMS or any external source of data for measuring graduate attributes. The current tool interfaces are an improvement over current practice and sufficient for the task, but they can still be improved to ensure adoption.

A more thorough validation of our tool evaluation checklist should be done using structural equation modeling (SEM) with disturbances. Considering the wide variety of SEM-enable software (Mplus, R, LISREL, EQS, Amos, Calis, Mx, SEPATH, Tetrad, STATA etc.) a comprehensive secondary systematic review needs to be performed to assure correct empirical assessment of the theoretical model. In addition to that, a further exploration of the concept of random errors and especially the different statistical effect they have on independent and dependent variables needs to take place.

Another potential area for improvement is to optimize GAIA's online interface to better accommodate external user data.

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APPENDIX A: Certificate of Ethics Approval

30/10/2018

Université d'Ottawa
Bureau d'éthique et d'intégrité de la recherche

University of Ottawa
Office of Research Ethics and Integrity

CERTIFICAT D'APPROBATION ÉTHIQUE | CERTIFICATE OF ETHICS APPROVAL

Numéro du dossier / Ethics File Number	H-09-18-1107
Titre du projet / Project Title	Graduate Attribute Assessment Tool (GAIA) Survey
Type de projet / Project Type	Thèse de doctorat / Doctoral thesis
Statut du projet / Project Status	Approuvé / Approved
Date d'approbation (jj/mm/aaaa) / Approval Date (dd/mm/yyyy)	30/10/2018
Date d'expiration (jj/mm/aaaa) / Expiry Date (dd/mm/yyyy)	29/10/2019

Équipe de recherche / Research Team

Chercheur / Researcher	Affiliation	Role
Aneta TRAIKOVA	École de science informatique et de génie électrique / School of Electrical Engineering and Computer Science	Chercheur Principal / Principal Investigator
Liam PEYTON	École de science informatique et de génie électrique / School of Electrical Engineering and Computer Science	Superviseur / Supervisor

Conditions spéciales ou commentaires / Special conditions or comments

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www.recherche.uottawa.ca/deontologie | www.recherche.uottawa.ca/ethics

30/10/2018

Université d'Ottawa

Bureau d'éthique et d'intégrité de la recherche

University of Ottawa

Office of Research Ethics and Integrity

Le Comité d'éthique de la recherche (CÉR) de l'Université d'Ottawa, opérant conformément à l'*Énoncé de politique des Trois conseils* (2014) et toutes autres lois et tous règlements applicables, a examiné et approuvé la demande d'éthique du projet de recherche ci-nommé.

L'approbation est valide pour la durée indiquée plus haut et est sujette aux conditions énumérées dans la section intitulée "Conditions Spéciales ou Commentaires". Le formulaire « Renouvellement ou Fermeture de Projet » doit être complété quatre semaines avant la date d'échéance indiquée ci-haut afin de demander un renouvellement de cette approbation éthique ou afin de fermer le dossier.

Toutes modifications apportées au projet doivent être approuvées par le CÉR avant leur mise en place, sauf si le participant doit être retiré en raison d'un danger immédiat ou s'il s'agit d'un changement ayant trait à des éléments administratifs ou logistiques du projet. Les chercheurs doivent aviser le CÉR dans les plus brefs délais de tout changement pouvant augmenter le niveau de risque aux participants ou pouvant affecter considérablement le déroulement du projet, rapporter tout évènement imprévu ou indésirable et soumettre toute nouvelle information pouvant nuire à la conduite du projet ou à la sécurité des participants.

The University of Ottawa Research Ethics Board, which operates in accordance with the *Tri-Council Policy Statement* (2014) and other applicable laws and regulations, has examined and approved the ethics application for the above-named research project.

Ethics approval is valid for the period indicated above and is subject to the conditions listed in the section entitled "Special Conditions or Comments". The "Renewal/Project Closure" form must be completedfour weeks before the above-referenced expiry date to request a renewal of this ethics approval or closure of the file.

Any changes made to the project must be approved by the REB before being implemented, except when necessary to remove participants from immediate endangerment or when the modification(s) only pertain to administrative or logistical components of the project. Investigators must also promptly alert the REB of any changes that increase the risk to participant(s), any changes that considerably affect the conduct of the project, all unanticipated and harmful events that occur, and new information that may negatively affect the conduct of the project or the safety of the participant(s).

Germain ZONGO
Responsable d'éthique en recherche / Protocol Officer
Pour/For **Daniel LAGAREC** Président(e) du/ Chair of the **Comité d'éthique de la recherche en sciences sociales et humanités** / **Social Sciences and Humanities Research Ethics Board**

550, rue Cumberland, pièce 154 550 Cumberland Street, Room 154
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APPENDIX B: Consent Form

Consent Form

Please read the following and if you consent click on the link at the bottom of this form to proceed to the survey.

Principal Investigator: Aneta Traikova
Thesis Supervisor: Liam Peyton

If you have any queries regarding the survey, please contact Liam Peyton or Aneta Traikova. If you have any questions with regards to the ethical conduct of this study, contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5, tel.: (613) 562-5387 or ethics@uottawa.ca.

This survey is being done independently of the School of Electrical Engineering and Computer Science. It is part of the research for Aneta Traikova's PhD thesis supervised by Prof. Liam Peyton.

Invitation to Participate: You are invited to this survey, because on one or more occasions in the last 3 years (2015-2018) you taught an EECS course and provided data from that course using the GAIA Tool (Enhanced Excel Spreadsheet) for graduate attribute assessment. You may have also participated in the 2014 accreditation visit by the Canadian Engineering Accreditation Board (CEAB) where graduate attribute assessment data was collected and presented WITHOUT the use of the GAIA tool.

Participation: Participation in this survey is voluntary. If you wish to participate in this study, please answer the online questions and click submit when you are finished. The survey should take you approximately 10-15 minutes to complete. You do not have to answer any questions that you do not want to answer. You can choose not to click submit if you do not want your answers used and simply exit the browser. If you click submit, your answers will be completely anonymous. As such, it will not be possible to remove your answers from the survey once they have been submitted.

Purpose of the Study: The aim of this survey is to gather feedback on your experiences using the GAIA tool. The survey is for the PhD thesis of Aneta Traikova ("A Tool-Supported Methodology for Performance Management of Engineering Education"). We wish to evaluate the GAIA tool to see if it provides better tool support for graduate attribute data collection, analysis and reporting as required by CEAB. We also wish to identify opportunities to improve the GAIA tool and the processes implemented at uOttawa to comply with CEAB's requirement for ongoing graduate attribute assessment.

Potential Benefits: The aggregate results of the survey will be included in Aneta Traikova's PhD thesis and possibly other academic publications. Aggregate results will also be shared with the EECS Director and program coordinators for electrical, computer and software engineering.

Potential Risks: Like many professors, you many not enjoy collecting and analyzing assessment data as required by CEAB, and you may feel that this survey is a burdensome administrative task that you do not enjoy. Just remember that your responses, including whether you participate or not, are voluntary and anonymous. You do not need to answer all questions. You can decide not to submit your answers.

Confidentiality and Anonymity: The information that you will share will remain strictly confidential and will be used solely for the purposes of this research. The only people who will have access to the research data are Aneta Traikova and Liam Peyton. Your answers to open-ended questions may be used verbatim in presentations and publications but you will not be identified. In order to minimize the risk of security breaches and to help ensure your confidentiality we recommend that you use standard safety measures such as closing your browser when you have completed the study. Results will be published in pooled (aggregate) format. Anonymity is guaranteed since you are not being asked to provide your name or any personal information. Individual responses will be kept strictly private and protected.

Conservation of data: The surveys will be kept in a locked filing cabinet in the office of Liam Peyton at the University of Ottawa for a period of 5 years after Aneta Traikova's PhD defense. After that time, they will be destroyed.

Background: The CEAB visits every Canadian engineering program at least once every 6 years to review the program and renew its accreditation. The CEAB requires that each program collects data from its courses to assess how well students in the program are achieving key graduate attributes - engineering knowledge, problem analysis, investigation, design, use of engineering tools, individual and team work, communication skills, professionalism, impact of engineering on society and environment, ethics and equity, economics and project management, life-long learning[1].

Survey: This survey consists of questions grouped into 4 categories:

> **Part I: Participation in Graduate Attribute Assessment** consists of 5 check-box questions to indicate how you have participated. Please select all that apply.
>
> **Part II: Tool Assessment – Graduate Attribute Data** consists of 10 questions to be answered on a scale from 1 to 5 to assess your experience in using the GAIA tool.
>
> **Part III: Feedback** consists of 3 questions - 2 questions to be answered on a scale from 1 to 5 and 1 optional question where you can provide suggestions for improving the GAIA tool.
>
> **Part IV: Tool Assessment – Program Analysis** consists of 4 questions to be answered on a scale from 1 to 5 to assess your experience using the GAIA tool for program analysis (ELG, CEG, SEG).

All questions EXCEPT the last optional question in Part III need to be answered.

Estimated time for completing the survey is 10 - 15 minutes.

If you have any queries regarding the survey, please contact Aneta Traikova or Liam Peyton.

If you consent please click on the link below to fill out the Graduate Attribute Assessment Tool (GAIA) Survey:
https://www.surveymonkey.ca/r/GXCWLHW

[1] CEAB (2015(a), p.13). *Accreditation Criteria Procedures 2015, Engineers Canada.* https://www.engineerscanada.ca/sites/default/files/accreditation_criteria_procedures_2015.pdf.

APPENDIX C: Recruitment Email

We would appreciate it if you could fill out a short survey to provide feedback with respect to the GAIA tool (Enhanced Excel File) that you have used to provide graduate attribute assessment data for one or more courses during the period 2015-2018. You should only participate in the survey if you have used the GAIA tool during that period for graduate assessment for a course or a program in the School of Electrical Engineering and Computer Science.

Please read the attached consent form. Located at the end of the form, you will find a link to the survey. Please note that by filling out and submitting your responses to the survey you indicate your consent.

Participation in this survey is voluntary. You can decide not to participate at any time, even after starting or submitting your responses (your responses will be removed from the study and deleted).

This survey is being done independently of the School of Electrical Engineering and Computer Science. It is part of the research for Aneta Traikova's PhD thesis supervised by Prof. Liam Peyton.

Your responses will be aggregated and analysed to help inform positive improvements to how EECS conducts graduate attribute assessment and provides tool support. Aggregated survey results and analysis will be included in Aneta Traikova's PhD thesis and possibly other academic publications. Individual surveys will contain no identifying information, and will be stored secured so only the aggregating tool has access.

If you have any queries regarding the survey, please contact Liam or Aneta.

Thank you in advance for your participation!

APPENDIX D: Graduate Attribute Assessment Tool (GAIA) Survey

Title of the Survey: **Graduate Attribute Assessment Tool (GAIA) Survey**

Principal Investigator: Aneta Traikova
Thesis Supervisor: Liam Peyton

If you have any queries regarding the survey, please contact Liam Peyton or Aneta Traikova. If you have any questions with regards to the ethical conduct of this study, contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5, tel.: (613) 562-5387 or ethics@uottawa.ca.

This survey is being done independently of the School of Electrical Engineering and Computer Science. It is part of the research for Aneta Traikova's PhD thesis supervised by Prof. Liam Peyton.

Invitation to Participate: You are invited to this survey, because on one or more occasions in the last 3 years (2015-2018) you taught an EECS course and provided data from that course using the GAIA Tool (Enhanced Excel Spreadsheet) for graduate attribute assessment. You may have also participated in the 2014 accreditation visit by the Canadian Engineering Accreditation Board (CEAB) where graduate attribute assessment data was collected and presented WITHOUT the use of the GAIA tool.

Participation: Participation in this survey is voluntary. If you wish to participate in this study, please answer the online questions and click submit when you are finished. The survey should take you approximately 10-15 minutes to complete. You do not have to answer any questions that you do not want to answer. You can choose not to click submit if you do not want your answers used and simply exit the browser. If you click submit, your answers will be completely anonymous. As such, it will not be possible to remove your answers from the survey once they have been submitted.

Purpose of the Study: The aim of this survey is to gather feedback on your experiences using the GAIA tool. The survey is for the PhD thesis of Aneta Traikova ("A Tool-Supported Methodology for Performance Management of Engineering Education"). We wish to evaluate the GAIA tool to see if it provides better tool support for graduate attribute data collection, analysis and reporting as required by CEAB. We also wish to identify opportunities to improve the GAIA tool and the processes implemented at uOttawa to comply with CEAB's requirement for ongoing graduate attribute assessment.

Potential Benefits: The aggregate results of the survey will be included in Aneta Traikova's PhD thesis and possibly other academic publications. Aggregate results will also be shared with the EECS Director and program coordinators for electrical, computer and software engineering.

Potential Risks: Like many professors, you many not enjoy collecting and analyzing assessment data as required by CEAB, and you may feel that this survey is a burdensome administrative task that you do not enjoy. Just remember that your responses, including whether you participate or not, are voluntary and anonymous. You do not need to answer all questions. You can decide not to submit your answers.

Confidentiality and Anonymity: The information that you will share will remain strictly confidential and will be used solely for the purposes of this research. The only people who will have access to the research data are Aneta Traikova and Liam Peyton. Your answers to open-ended questions may be used verbatim in presentations and publications but you will not be identified. In order to minimize the risk of security breaches and to help ensure your confidentiality we recommend that you use standard safety measures such as closing your browser when you have completed the study. Results will be published in pooled (aggregate) format. Anonymity is guaranteed since you are not being asked to provide your name or any personal information. Individual responses will be kept strictly private and protected.

Conservation of data: The surveys will be kept in a locked filing cabinet in the office of Liam Peyton at the University of Ottawa for a period of 5 years after Aneta Traikova's PhD defense. After that time, they will be destroyed.

Background: The CEAB visits every Canadian engineering program at least once every 6 years to review the program and renew its accreditation. The CEAB requires that each program collects data from its courses to assess how well students in the program are achieving key graduate attributes - engineering knowledge, problem analysis, investigation, design, use of engineering tools, individual and team work, communication skills, professionalism, impact of engineering on society and environment, ethics and equity, economics and project management, life-long learning[1].

Survey: This survey consists of questions grouped into 4 categories:

Part I: Participation in Graduate Attribute Assessment consists of 5 check-box questions to indicate how you have participated. Please select all that apply.

Part II: Tool Assessment – Graduate Attribute Data consists of 10 questions to be answered on a scale from 1 to 5 to assess your experience in using the GAIA tool.

Part III: Feedback consists of 3 questions - 2 questions to be answered on a scale from 1 to 5 and 1 optional question where you can provide suggestions for improving the GAIA tool.

Part IV: Tool Assessment – Program Analysis consists of 4 questions to be answered on a scale from 1 to 5 to assess your experience using the GAIA tool for program analysis (ELG, CEG, SEG).

All questions EXCEPT the last optional question in Part III need to be answered.

Estimated time for completing the survey is 10 - 15 minutes.

[1] CEAB (2015(a), p.13). *Accreditation Criteria Procedures 2015, Engineers Canada.* https://www.engineerscanada.ca/sites/default/files/accreditation_criteria_procedures_2015.pdf.

APPENDIX D: Graduate Attribute Assessment Tool (GAIA) Survey

Part I: **Participation in Graduate Attribute Assessment**

1. Did you provide data for your course(s) that was used for the 2014 Accreditation visit for your program?
   - Yes
   - No

2. In which academic years did you use the GAIA tool to report the data for your course(s). Select all that apply.
   - 2014-2015
   - 2015-2016
   - 2016-2017
   - 2017-2018
   - 2018-2019

3. For which types of courses have you submitted graduate attribute assessment data? Check all the course prefixes below that apply.
   - SEG
   - ELG
   - CEG
   - GNG (including SEG/ELG 2911)
   - COOP Data (not a course)

4. Check the categories that apply to you.
   - Part-Time Professor
   - Full-Time Professor
   - Program Coordinator
   - Faculty Executive

5. Check all that apply:
   - I used the tool to provide data for one or more of my courses.
   - I used the tool to analyze one or more of my courses.
   - I used the tool to enter COOP data.
   - I used the tool to analyze COOP data.
   - I used the tool to analyze an engineering program.
   - I used the tool to inform a program's annual continual improvement meeting.

APPENDIX D: Graduate Attribute Assessment Tool (GAIA) Survey

Part II: Tool Assessment – Graduate Attribute Data

Estimate your level of agreement with each of the following statements using a scale from 1 to 5 with 1=Strongly Agree, 2=Agree, 3=Not Sure, 4=Disagree and 5=Strongly Disagree.

Example of using the rating scale:

Laughter is the best medicine.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	●	○	○	○

By selecting the 3 (Not Sure) you are saying that you neither agree or disagree with the statement.

If you believe that the statement is not relevant to the type of interaction you had with the GAIA tool, please select N/A (Not Applicable).

1. I find it easy to enter data for my course(s) graduate attribute assessment using the GAIA tool.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

2. The GAIA tool is helpful for providing graduate attribute assessment data as required by CEAB.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

3. Using a data analysis and collection tool like GAIA to support graduate attribute assessment is a good idea.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

4. I intend to use the GAIA tool in the future, when asked to do so by my program or the faculty.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

APPENDIX D: Graduate Attribute Assessment Tool (GAIA) Survey

5. The GAIA tool is useful for analyzing how students perform in my courses and I would use it even if it was not required for CEAB accreditation.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

6. Due to its complexity, using the tool takes too much of my time.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

7. It is straightforward for me to copy-paste my course data into the GAIA tool.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

8. I am satisfied with how the GAIA tool uses Excel files to store the data and provide easy access.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

9. I am satisfied with how the GAIA tool manages graduate assessment data to provide historic trend data analysis from year to year.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

10. The GAIA tool generates all the reports I need to measure graduate attributes.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

Part III: **Feedback**

Estimate your level of agreement with each of the following statements using a scale from 1 to 5 with 1=Strongly Agree, 2=Agree, 3=Not Sure, 4=Disagree and 5=Strongly Disagree.

Example of using the rating scale:

Laughter is the best medicine.

Strongly Agree	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**	
1	2	3	4	5	N/A
○	○	●	○	○	○

By selecting the 3 (Not Sure) you are saying that you neither agree or disagree with the statement.

If you believe that the statement is not relevant to the type of interaction you had with the GAIA tool, please select N/A (Not Applicable).

1. Using the GAIA tool for graduate attribute assessment is an improvement over just using the official CEAB forms that were used for the 2014 Accreditation visit.

Strongly Agree				**Strongly Disagree**	
1	2	3	4	5	N/A
○	○	○	○	○	○

2. Given that my faculty and CEAB require that graduate attribute assessment must be done each semester, I find GAIA tool useful and informative.

Strongly Agree				**Strongly Disagree**	
1	2	3	4	5	N/A
○	○	○	○	○	○

3. How can we improve? Please list any suggestions you may have regarding future development of the GAIA tool.
Note: *Filling in the comment box below is optional.*

The remaining questions cover analysing graduate attributes across an entire program (ELG, CEG, SEG) using the GAIA tool. This is only relevant to program coordinators. Feel free to indicate 'N/A' for the remaining questions, if you did not do this.

Part IV: Tool Assessment – Program Analysis

Estimate your level of agreement with each of the following statements using a scale from 1 to 5 with 1=Strongly Agree, 2=Agree, 3=Not Sure, 4=Disagree and 5=Strongly Disagree.

Example of using the rating scale:

Laughter is the best medicine.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	●	○	○	○

By selecting the 3 (Not Sure) you are saying that you neither agree or disagree with the statement.

If you believe that the statement is not relevant to the type of interaction you had with the GAIA tool, please select N/A (Not Applicable).

1. I am comfortable analyzing the graduate attribute assessment data for my program using the GAIA tool.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

2. The GAIA tool is helpful for analyzing graduate attribute assessment data for an entire engineering program as mandated by CEAB.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

3. It is straightforward for me to use GAIA reports when providing documentation for a CEAB accreditation visit.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

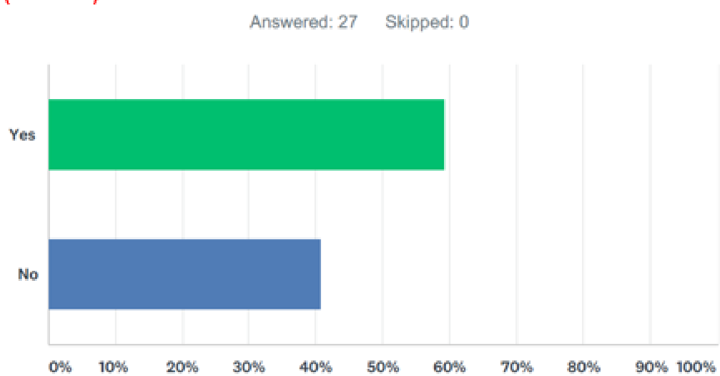
4. The GAIA tool aligns well with the graduate attribute assessment process that the faculty has put in place to meet CEAB requirements for accreditation.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
1	2	3	4	5	N/A
○	○	○	○	○	○

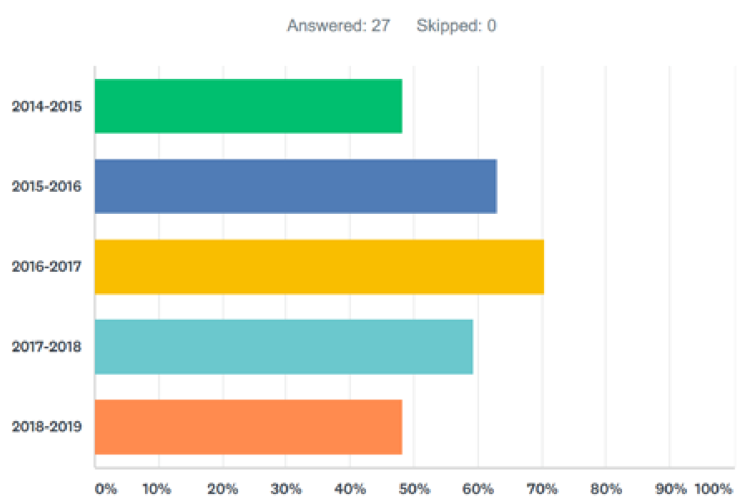
APPENDIX E: GAIA Survey Results

Part I: **Participation in Graduate Attribute Assessment**

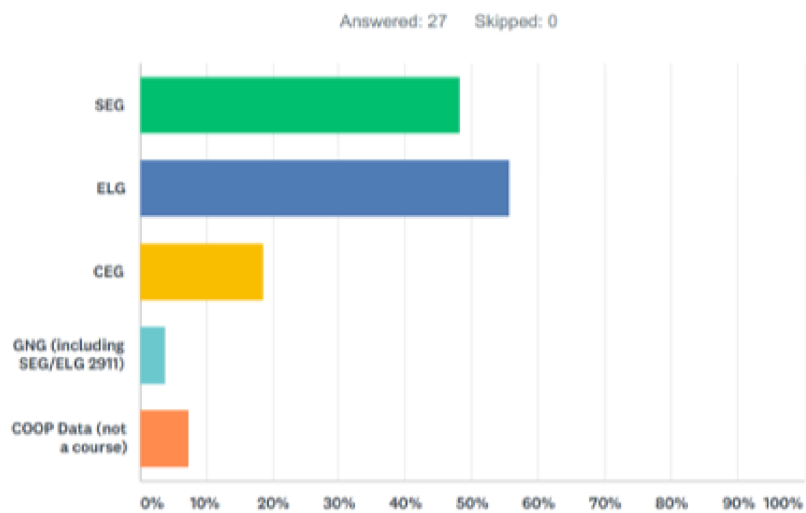
1. Did you provide data for your course(s) that was used for the 2014 Accreditation visit for your program?
   - Yes (59.26%)
   - No (40.74%)



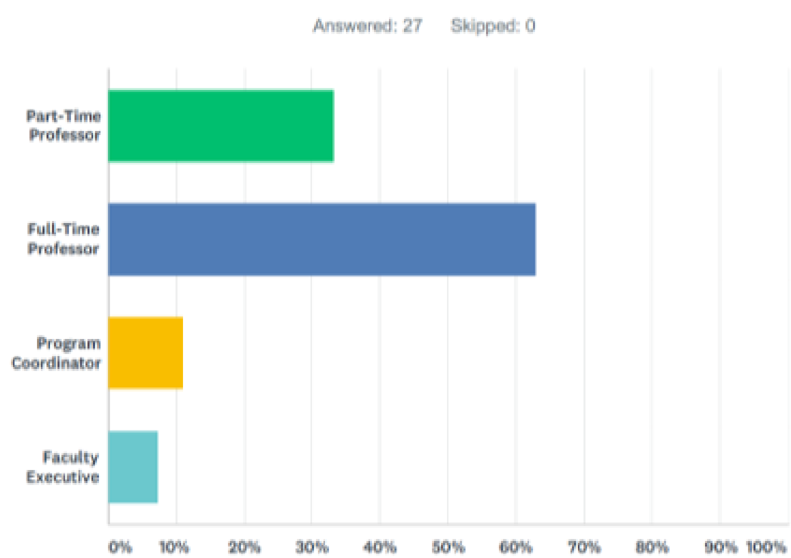
2. In which academic years did you use the GAIA tool to report the data for your course(s). Select all that apply.
   - 2014-2015 (48.15%)
   - 2015-2016 (62.96%)
   - 2016-2017 (70.37%)
   - 2017-2018 (59.26%)
   - 2018-2019 (48.15%)



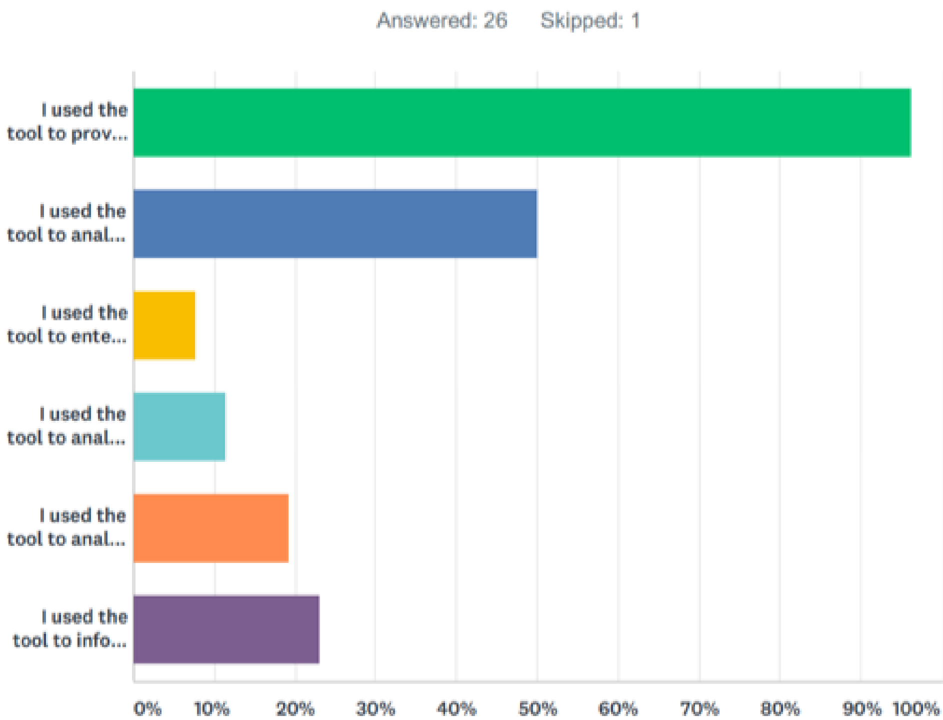
3. For which types of courses have you submitted graduate attribute assessment data? Check all the course prefixes below that apply.
   - SEG (48.15%)
   - ELG (55.56%)
   - CEG (18.52%)
   - GNG (including SEG/ELG 2911) (3.70%)
   - COOP Data (not a course) (7.41%)



4. Check the categories that apply to you.
   - Part-Time Professor (33.3%)
   - Full-Time Professor (62.96%)
   - Program Coordinator (14.8%)
   - Faculty Executive (7.41%)



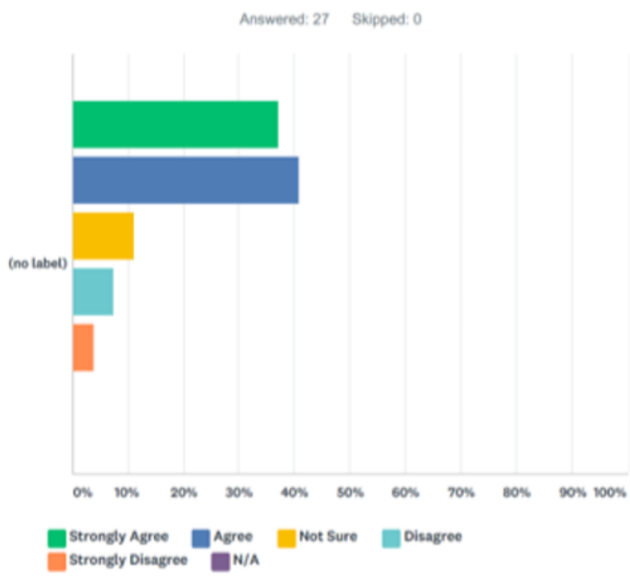
5. Check all that apply:
    - I used the tool to provide data for one or more of my courses. (96.15%)
    - I used the tool to analyze one or more of my courses. (50%)
    - I used the tool to enter COOP data. (7.69%)
    - I used the tool to analyze COOP data. (11.5%)
    - I used the tool to analyze an engineering program. (19.23%)
    - I used the tool to inform a program's annual continual improvement meeting. (23.08%)



Part II: Tool Assessment – Graduate Attribute Data

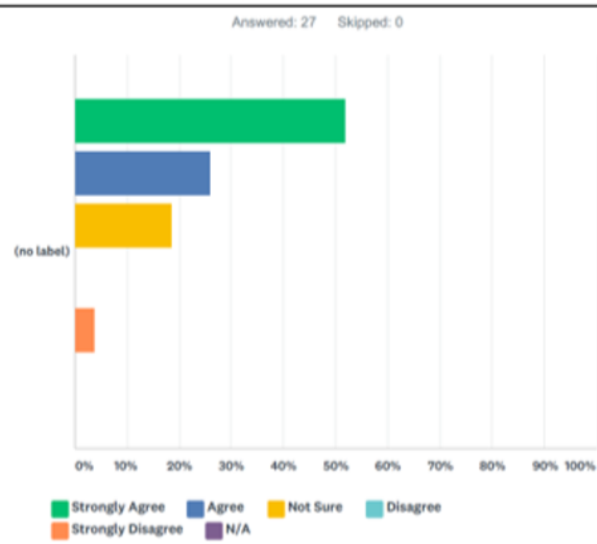
6. I find it easy to enter data for my course(s) graduate attribute assessment using the GAIA tool.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
37.04%	40.74%	11.11%	7.41%	3.70%	0.00%



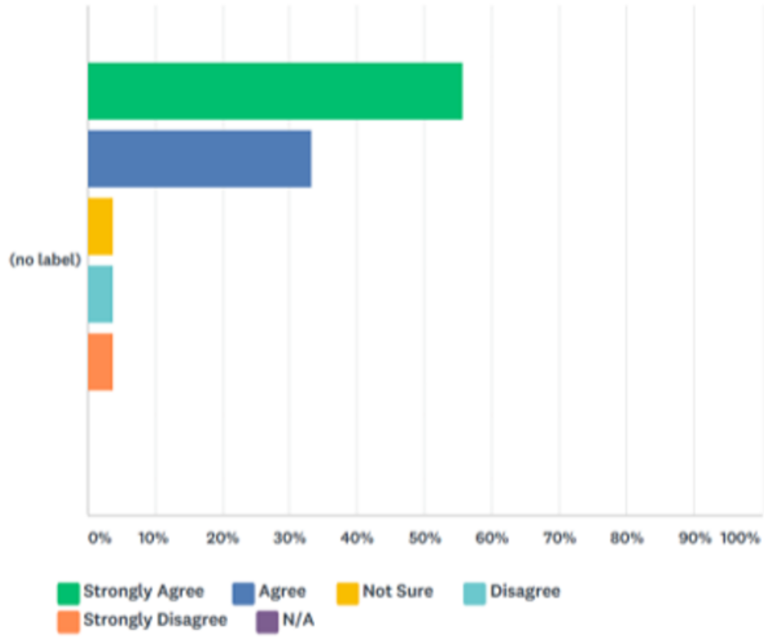
7. The GAIA tool is helpful for providing graduate attribute assessment data as required by CEAB.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
51.85%	25.93%	18.52%	0.00%	3.70%	0.00%



8. Using a data analysis and collection tool like GAIA to support graduate attribute assessment is a good idea.

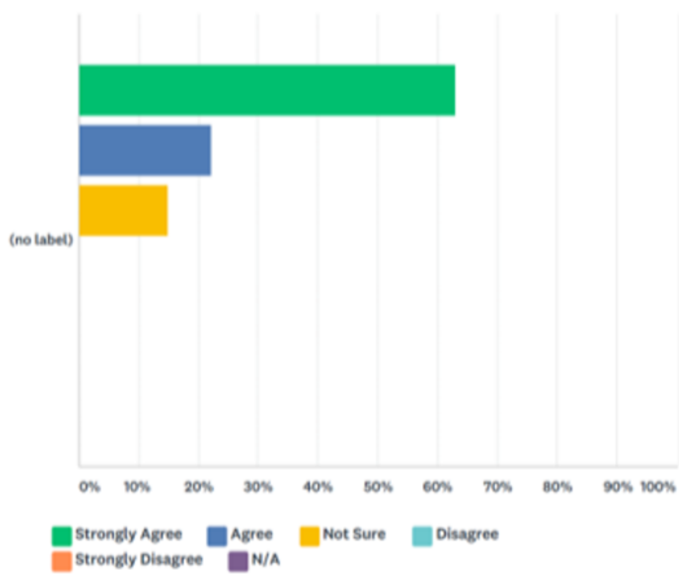
Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
55.56%	33.33%	3.70%	3.70%	3.70%	0.00%



9. I intend to use the GAIA tool in the future, when asked to do so by my program or the faculty.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
62.96%	22.22%	14.81%	0.00%	0.00%	0.00%

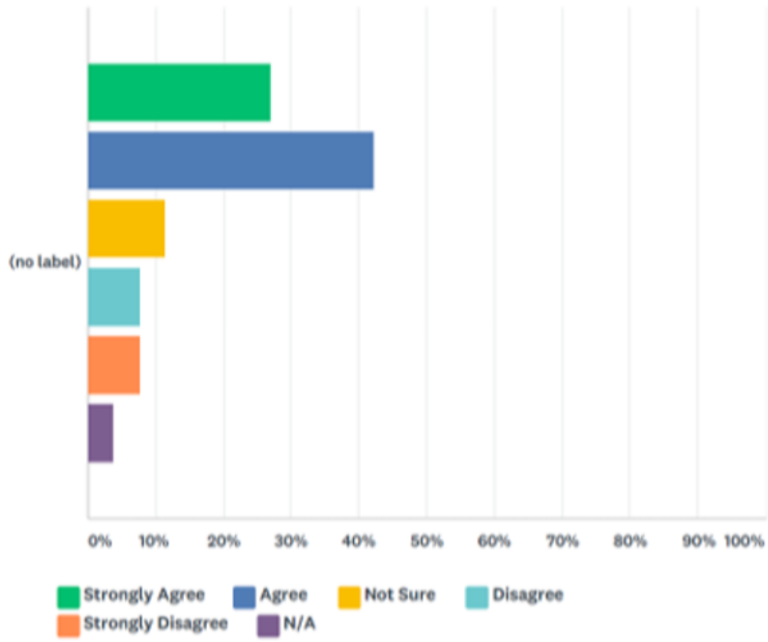
Answered: 27 Skipped: 0



10. The GAIA tool is useful for analyzing how students perform in my courses and I would use it even if it was not required for CEAB accreditation.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
26.92%	42.31%	11.54%	7.69%	7.69%	3.85%

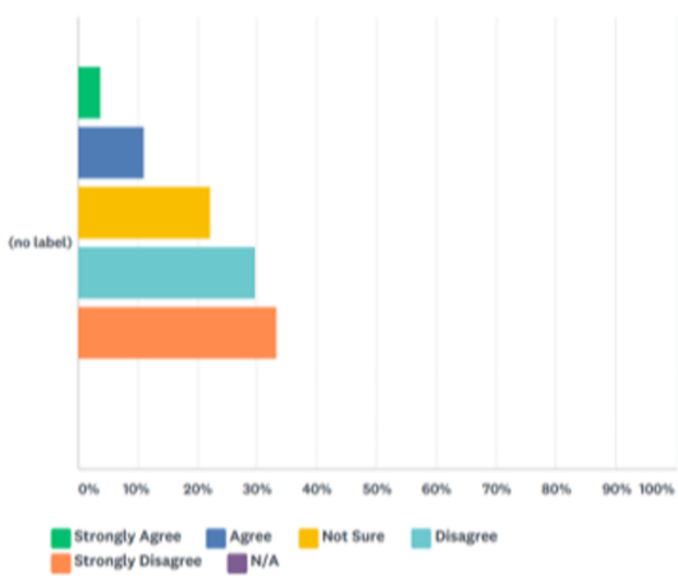
Answered: 26 Skipped: 1



11. Due to its complexity, using the tool takes too much of my time.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
3.70%	11.11%	22.22%	29.63%	33.33%	0.00%

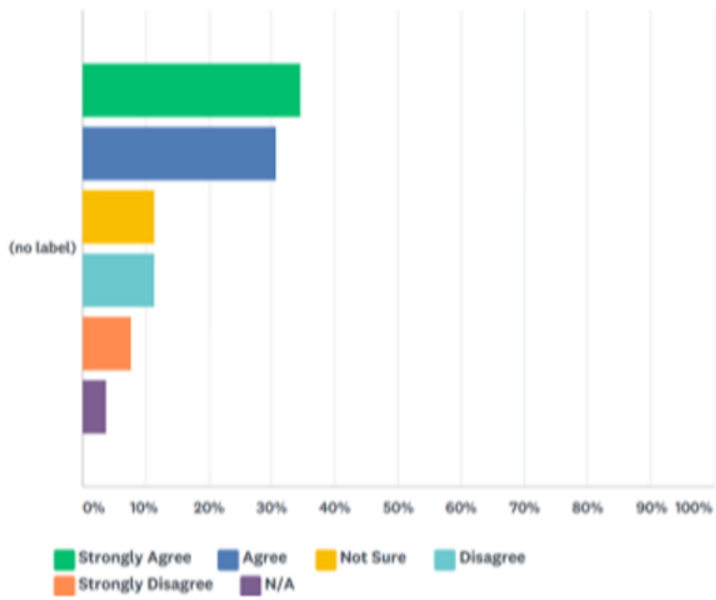
Answered: 27 Skipped: 0



12. It is straightforward for me to copy-paste my course data into the GAIA tool.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
34.62%	30.77%	11.54%	11.54%	7.69%	3.85%

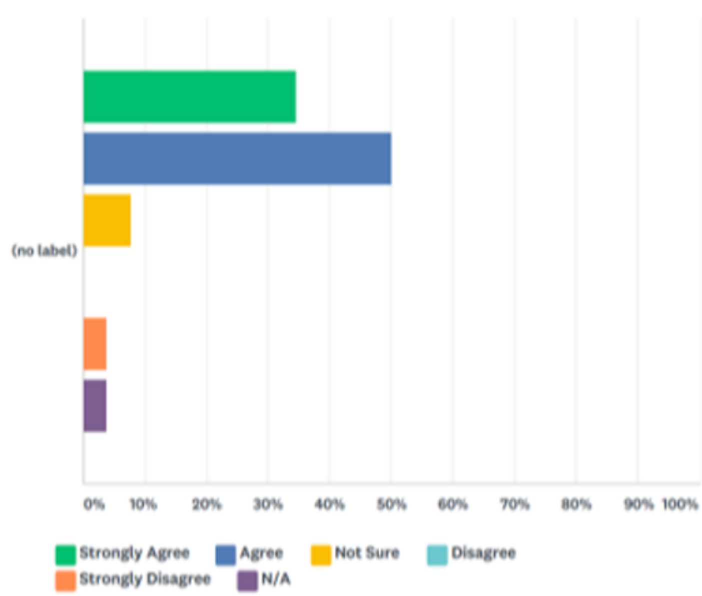
Answered: 26 Skipped: 1



13. I am satisfied with how the GAIA tool uses Excel files to store the data and provide easy access.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
34.62%	50.00%	7.69%	0.00%	3.85%	3.85%

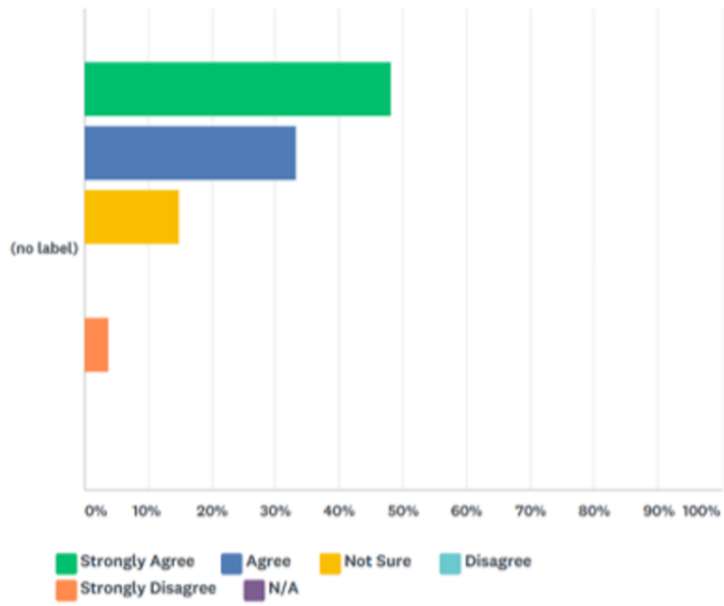
Answered: 26 Skipped: 1



14. I am satisfied with how the GAIA tool manages graduate assessment data to provide historic trend data analysis from year to year.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
48.15%	33.33%	14.81%	0.00%	3.70%	0.00%

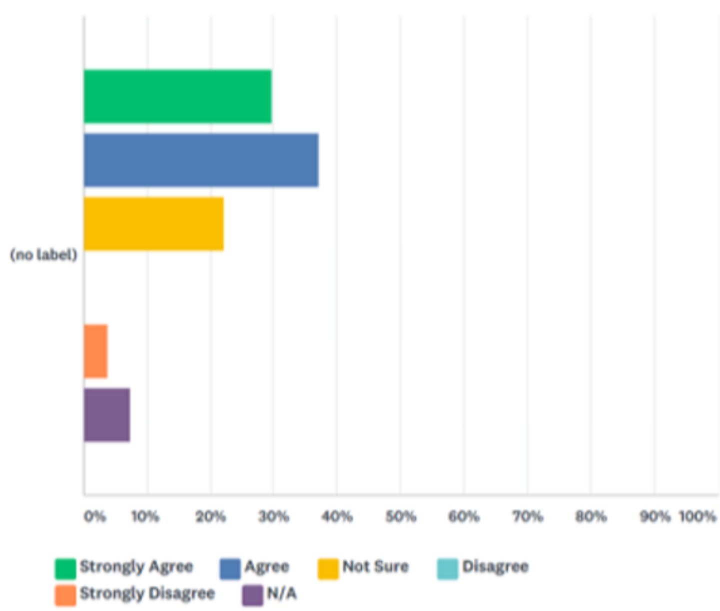
Answered: 27 Skipped: 0



15. The GAIA tool generates all the reports I need to measure graduate attributes.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
29.63%	37.04%	22.22%	0.00%	3.70%	7.41%

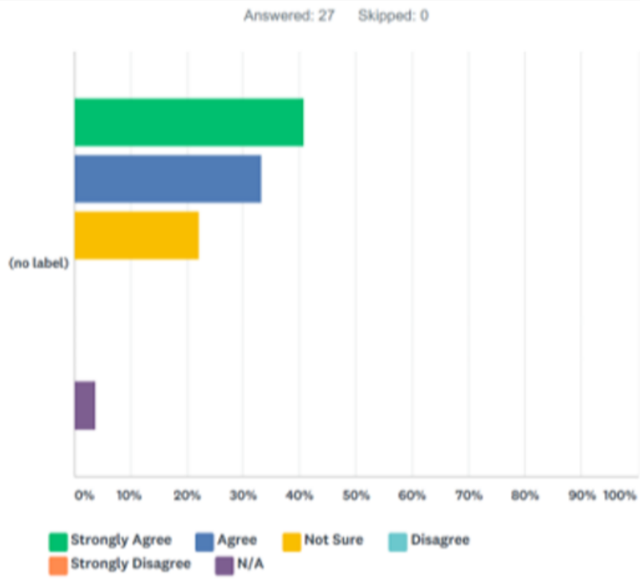
Answered: 27 Skipped: 0



Part III: **Feedback**

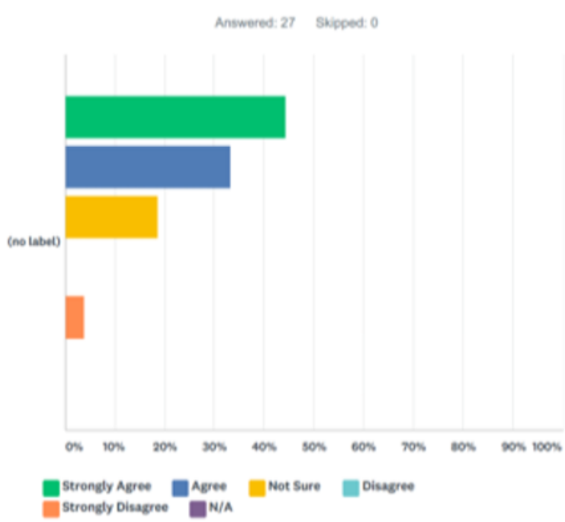
16. Using the GAIA tool for graduate attribute assessment is an improvement over just using the official CEAB forms that were used for the 2014 Accreditation visit.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
40.74%	33.33%	22.22%	0.00%	0.00%	3.70%



17. Given that my faculty and CEAB require that graduate attribute assessment must be done each semester, I find GAIA tool useful and informative.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
44.44%	33.33%	18.52%	0.00%	3.70%	0.00%



18. How can we improve? Please list any suggestions you may have regarding future development of the GAIA tool.

Summary of comments is provided below:

#	RESPONSES
1	Thank you
2	The tool is very easy to use. Thank you for developing this.
3	The tool is very useful. The reports and analysis it generates are very helpful. Thank you!
4	I guess my main issue is not so much the tool itself (which is fine from what I see) but with the complexity of the indicators I defined for my courses (too many links to graduate attributes, and too many sources of information from individual exam questions and fractions of assignments). I guess a big warning should be provided to users who might find themselves in a similar situation... My lesson is keep the indicators simple and aligned with the granularity used in the collection of partial grades in the course (e.f., a specific assignment or a specific test). This might bias some of the results however.
5	Integration with Brightspace. That is, mapping grade columns in Brightspace with graduate attributes so the report is automatically generated. Remote plugins in Brightspace, I think, could be used for this purpose. Other than this, the current tool is really easy to use.
6	A better automated system to collect and enter data. More specific attributes would be appreciated. The current ones are "elastic". One can fit pretty much anything in certain attributes.
7	I have participated with the CEAB board during 2014 in a capacity of part time professor , and that course was my first course (ELG4178) taught at Uottawa . I provided my course material for evaluation . however I personally do not recall using the GAIA tool .
8	It would be nice if the tool could interface with Brightspace to simplify the mapping of grades to KPI, the collection of data, and the transfer of KPI information to the GAIA tool.
9	Thank you
10	I would like to see some results from the tool (not sure that I have seen any yet) and a tie-in with the rubrics for my courses
11	Integrate the tool with a Learning Management System (LMS), such as Brightspace, so that data from the LMS can be loaded into the GAIA tool automatically.
12	Support the ability to import/upload data directly from an excel file (similar to how grade submission currently works for courses).

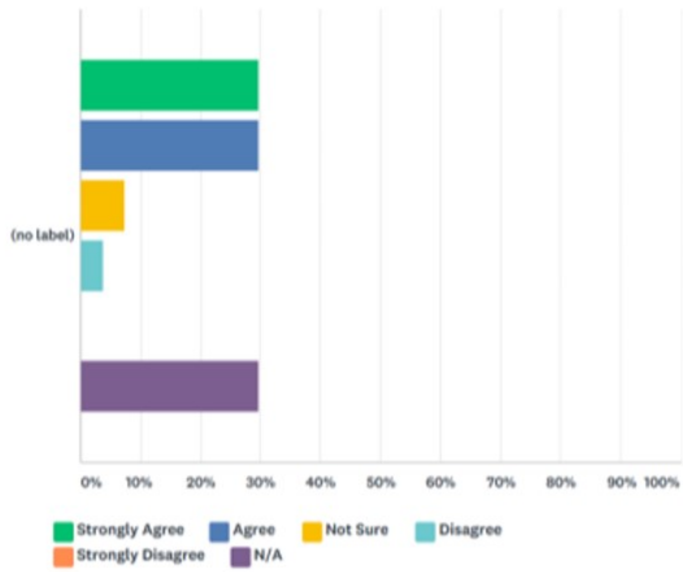
The remaining questions cover analysing graduate attributes across an entire program (ELG, CEG, SEG) using the GAIA tool. This is only relevant to program coordinators. Feel free to indicate 'N/A' for the remaining questions, if you did not do this.

Part IV: Tool Assessment – Program Analysis

19. I am comfortable analyzing the graduate attribute assessment data for my program using the GAIA tool.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
29.63%	29.63%	7.41%	3.70%	0.00%	29.63%

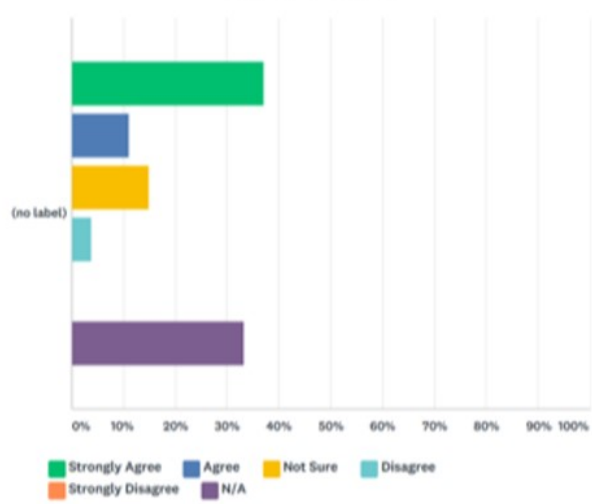
Answered: 27 Skipped: 0



20. The GAIA tool is helpful for analyzing graduate attribute assessment data for an entire engineering program as mandated by CEAB.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
37.04%	11.11%	14.81%	3.70%	0.00%	33.33%

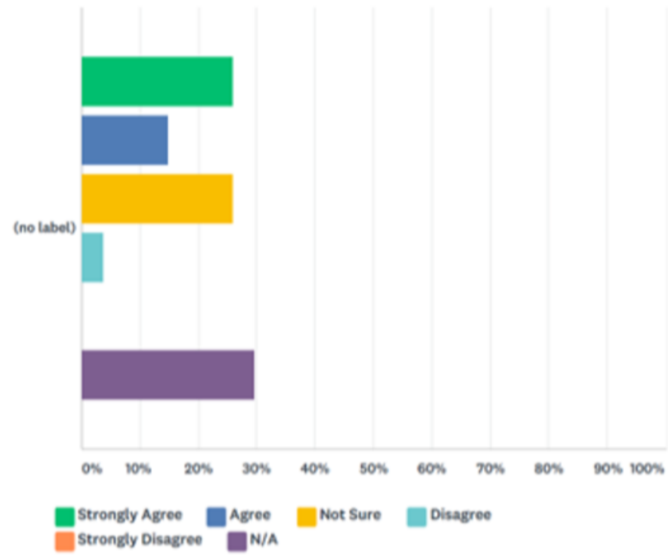
Answered: 27 Skipped: 0



21. It is straightforward for me to use GAIA reports when providing documentation for a CEAB accreditation visit.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
25.93%	14.81%	25.93%	3.70%	0.00%	29.63%

Answered: 27 Skipped: 0



22. The GAIA tool aligns well with the graduate attribute assessment process that the faculty has put in place to meet CEAB requirements for accreditation.

Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	N/A
40.74%	18.52%	18.52%	0.00%	0.00%	22.22%

Answered: 27 Skipped: 0