TEACHING AND LEARNING ACTIVITIES LEADING TO ENGINEERING GRADUATE ATTRIBUTE DEVELOPMENT

Robyn Paul, Stephanie Hladik, Ronald J Hugo

Schulich School of Engineering, University of Calgary

ABSTRACT

Engineering graduate attributes guide educational institutions in the design and development of engineering curricula. However, engineering educators are provided with limited guidance on which teaching, learning, and assessment activities should be used to most effectively develop these graduate attributes. A systematic literature review explored the various teaching and learning activities being used to teach and assess graduate attributes. This literature review encompasses the last five years of data from engineering education journals and conference proceedings. The results provide a breakdown of the most prevalent graduate attributes and the teaching and learning strategies currently employed to foster the growth of those attributes in students. Some graduate attributes, such as teamwork and communication, are highly correlated and many activities are able to teach them simultaneously. Some teaching and learning activities, such as project-based and service-based learning, are able to teach a wide variety of graduate attributes. Certain graduate attributes had very few teaching and learning activities associated with them, and this opens an area for future research. Finally, the strategies to assess graduate attributes consisted mainly of non-validated surveys or analysis of student grades. This highlights that, while assessment is being performed, further work can be done to improve and validate assessment methods.

KEYWORDS

Learning Outcomes, Graduate Attributes, Accreditation, Assessment, Standards 2, 3, 7, & 11.

INTRODUCTION

The work of engineers has a direct impact on many diverse social, economic, and environmental systems. For this reason, the education of engineers and the regulation of the engineering profession are two critical components for safe and efficient societal operation. To this end, many countries have implemented accreditation systems which include a list of desired attributes that graduating engineers should possess. These include the knowledge, skills, and, attitudes that are required for conduct as a practicing engineer in modern-day society. Previous studies have provided insight into the similarities and differences between graduate attributes worldwide (Paul, Hugo, & Falls, 2015; Abdulwahed, Balid, Hasna, & Pokharel, 2013). Consistency among these graduate attributes provides a mechanism for international collaboration, global mobility, and improved unity in the increasingly diverse workplace.

Although engineering attributes are well defined, many institutions continue to explore teaching & learning activities (TLAs) that effectively and efficiently develop these attributes. Additionally, once TLAs have been defined and implemented, the process of assessing these attributes in students remains an area of development. Through a comprehensive and systematic literature review, this paper provides a summary of the most common TLAs and assessment methods used in the development of engineering graduate attributes.

BACKGROUND

Graduate Attributes

Accreditation processes used for the evaluation of engineering programs have been in place for decades, and these processes were traditionally based on accounting methods that quantified the number of instructional contact hours in areas that included math and science, engineering science, and design. Although this accounting-based approach ensured content coverage, it did not include consideration for the actual performance requirements of an engineering graduate in professional practice. In 1996 the document “Desired Attributes of an Engineer” (Boeing, 1996) effectively summarized the needs of industry, demonstrating that the performance requirements of a professional engineer extended well beyond technical knowledge.

Starting in 2000 with ABET’s EC2000, engineering accreditation bodies worldwide have been shifting their focus from input measures to output measures, expecting graduates from engineering programs to have a specific set of skills indicative of an appropriate level of practice (IEA, 2014), referred to as graduate attributes. Graduate attributes (GAs) are also called competency guidelines or programme outcomes. These attributes are mandated, regulated, and updated by national accreditation bodies, and they direct institutions towards the expected outcomes for their respective engineering curricula.

Outcomes-based education has been a strong catalyst for curricular change and improvement in engineering education (Maranville, Neill, & Plumb, 2012). GAs provide learning outcomes that communicate the goals of engineering programs to both the students and the instructors (Crawley, Malmqvist, Östlund, & Brodeur, 2014). The structure provided by the GAs facilitates the curricular continuous improvement process and provides a systematic method for the design, development, and assessment of curriculum.

A 2015 study analyzed the GAs of 17 countries within the Washington Accord as part of the International Engineering Alliance (Paul et al., 2015). Using a content analysis methodology, Paul et al. (2015) summarized and grouped the main themes and categories of GAs observed across the 17 countries. Figure 1 below shows the category proportional frequencies of the attributes.

Teaching and Learning Activities

Given the complexities of the global economy, students need more than technical knowledge to solve multi-dimensional problems. Engineers need to be skilled in understanding the contexts in which their knowledge is useful (Litzinger et al., 2011) . Traditionally, engineering education focused on the presentation of knowledge. Instead, , the contextual application focuses on the “concept of integration of knowledge” (Mohammad Yusof, Aliah Phang, Hamzah, Ismail, & Isa, 2012). Conceptual knowledge not only increases student motivation, but it also provides students with application-oriented topics, integration of diverse knowledge, and skills to solve real-world problems.

The majority of engineering researchers and educators have limited experience with theories and practices from education (Borrego & Henderson, 2014; Borrego & Bernhard, 2011). Therefore, the practical implementation of graduates attributes in classrooms is often ineffective, and there is a gap between research and practice (Finelli, Daly, & Richardson, 2014). Instructors worldwide use a variety teaching and learning activities (TLAs); however, it is unclear which TLAs effectively foster the desired attributes. This paper seeks to determine which teaching and learning activities are most commonly used to foster each of the engineering graduate attributes, and as will be mentioned next, how these TLAs are assessed to measure to effectiveness.

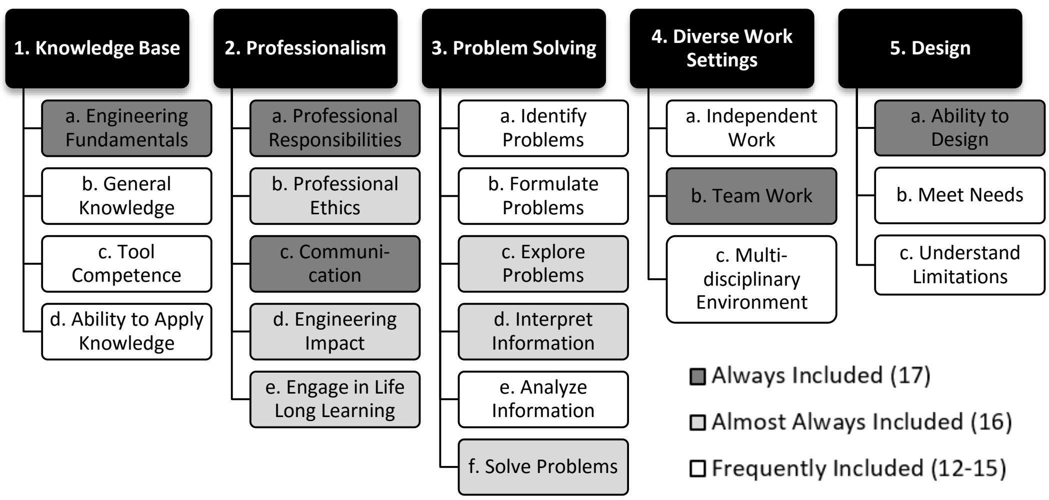

Figure 1. Attribute Category Proportional Frequencies (the number of countries in which the category appeared) (Paul et al., 2015)

Assessment Methods

Alongside the challenge of determining effective TLAs for graduate attributes, instructors are faced with the challenge of assessment. Shuman, Besterfield-Sacre, and McGourty (2005) discuss three hurdles that educators face in assessing how students have learned and understood the professional outcomes. Firstly, there exists a lack of consensus on definitions for graduate attributes. Secondly, there is difficulty in assessment with scope (Shuman et al., 2005). While technical information can be learned through lectures and assignments, professional outcomes are typically learned in settings that extend beyond traditional coursework. Finally, the nature of the professional outcomes increases the difficulty of their assessment (Shuman et al., 2005). Many attributes are concerned with students' awareness and being able to demonstrate the use of a particular attribute, which affects their aims, attitudes, and values (Shuman et al., 2005). While there have been efforts in the engineering education community to discover better assessment methods, there is still much work to be done.

LITERATURE REVIEW METHOD

A systematic literature review was undertaken (Lopes, Fialho, Cunha, & Niveiros, 2013) to determine which TLAS are used to teach graduate attributes. The search spanned five years, and included two databases as the field of Engineering Education is interdisciplinary and does not perfectly fit into one field. Table 1 lists a summary of the search criteria and search terms.

Table 1. Summary of the Literature Search Terms and Databases

Database	Date	Title	Subject/Title/Abstract	# of Results
Compendex *(engineering village.com)*	2011-current	Capability OR attribute OR skill OR competence	[develop OR development OR "teaching and learning"] AND [“graduate attribute" OR CDIO OR abet]	85
Scopus *(scopus.com)*	2011-current	Engineering	[capability OR attribute OR skill OR competence OR develop OR development OR "teaching and learning"] AND ["graduate attribute" OR CDIO OR abet]	136 *(27 duplicates of Compendex search)*

Selection Criteria and Process

The following criteria were used to determine which articles would be included in the review: 1) accessible from the databases available at the University of Calgary; 2) published in English; 3) in reference to undergraduate engineering; 4) within the Scholarship of Application (Boyer, 1990); and 5) focused on the development of one to four specific attribute(s), including a discussion on the associated teaching and learning activities.

Criteria 1-3 allowed for quick acceptance or rejection of articles outside of scope. In total, 51 articles were rejected, mostly due to references to other groups, such as non-engineering students, graduate students, or professionals.

Boyer’s Model of Scholarship (1990) refers to four main categories of scholarship, and this was used for criterion 4. The *Scholarship of Discovery* refers to the building of new knowledge and is typically associated with ‘traditional’ research (Boyer, 1990). *Scholarship of Integration* takes this new knowledge and interprets it in an interdisciplinary way to bring new insight (Boyer, 1990). *Scholarship of Application* is defined as “service activities [which] must be tied directly to one’s special field of knowledge and relate to, and flow directly out of, this professional activity.” (Boyer, 1990, p. 22) Finally, *Scholarship of Teaching* uses teaching models and new practices to improve learning (Boyer, 1990).

This literature review considers the application of teaching and learning activities in classrooms to teach graduate attributes, which aligns most closely with the *Scholarship of Application*. There were 32 articles rejected based on criterion 4.

Lastly, 31 articles were rejected based on criterion 5. Most of these articles included a teaching and learning activity which was fostering “ABET” or “CDIO” attributes. Although these provided interesting insight, they discussed several attributes and did not focus on a select few. In total, 35 papers were accepted for the detailed analysis.

Selection of Attributes

The terminology used to describe graduate attributes varies across countries, institutions, and even across departments within institutions. Recently, a special report in the *Journal of Engineering Education* highlighted this challenge and the need for a common language in engineering education research (Finelli, Borrego, & Rasoulifar, 2015). For the purpose of this study, it was necessary to choose the graduate attributes that would serve as a framework for grouping the papers.

An analysis and discussion of engineering graduate attributes was completed in a previous paper titled *International Expectations of Engineering Graduate Attributes* (Paul et al., 2015). The graduate attributes guidelines were obtained from 17 engineering regulatory bodies worldwide and analyzed using content analysis. The result was five overall themes and 21 categories (Paul et al., 2015), with the category frequency shown above in Figure 1. Of the 21 categories identified, the 11 categories that were always, or almost always, included serve as the framework for this literature review.

Attribute Mapping

After the attributes were freely identified for each paper, they were mapped to the 11 attributes. Attributes which could not be mapped directly were grouped with an attribute that covered a similar idea. This was completed as a collaborative process involving more than one person to ensure validation during the mapping process.

Global issues, global perspectives, contemporary issues, and sustainability and environmental issues were all mapped to *Engineering Impact*. Creativity was observed in two papers with a focus on divergent thinking; therefore, these papers were grouped into *Explore Problems.* Project management and agile development were mentioned in a few papers; however, they were not the main attribute and therefore these attributes were discarded. There were also three attributes which were the main topic of papers however, they did not map within the 11 specified categories. Therefore, it was agreed these would be included independently. These three attributes were as follows: tools, entrepreneurship, and leadership.

RESULTS

The following section discusses specific examples of TLAs in the context of teaching each attribute. Figure 2 shows a visual summary of the frequency of TLAs which were associated with each graduate attribute. From this figure, it is evident that Project Based Learning and Inquiry Based Learning were observed across the majority of the attributes, often with a high frequency. Service Learning was also a popular TLA, observed being used to teach 50% of the attributes.

Looking at the distribution across the graduate attributes in Figure 2, it is evident as to which graduate attributes were discussed most frequently in the literature (communication, teamwork, ability to design) and which were discussed the least (tools and solve problems). Entrepreneurship and leadership were also observed infrequently, however these were additional attributes added.

The teaching and learning activities (TLAs) observed for each graduate attribute are summarized in Table 2 below, along with any observations and specific examples for each attribute. Information on assessment methods used is also included, with particular mention of any validated assessment tools used.

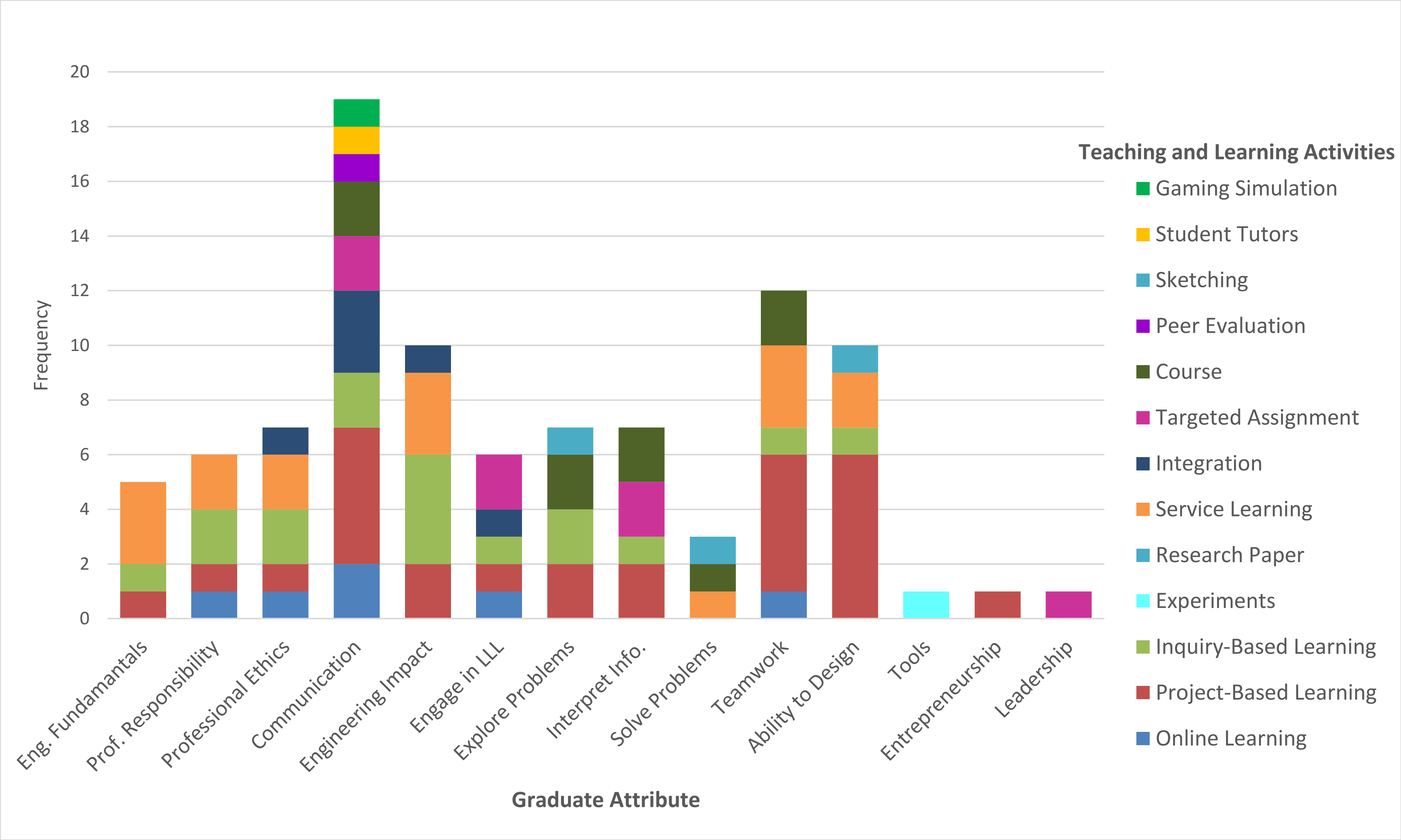

Figure 2. Frequency of attribute mapping to teaching and learning activities.

Table 2. Summary of findings for TLAs related to each graduate attribute.

Graduate Attribute	General Observations	Specific Examples	Assessment Methods
Engineering Fundamentals	- Few papers specifically mentioned engineering fundamentals - Service learning to increase confidence in technical abilities	- Service learning project within leadership module increased confidence of women in engineering skills[1] - Service learning project increased student interest and recognition and relevance within specific technical engineering[2]	- Grades, exams
Professional Responsibilities	- Multiple TLAs - Service learning, project-based learning, model-eliciting activities, multi-modal assignments, online modules - Similar to those for professional ethics	- Service learning projects with social and environmental impact[3] or projects abroad[4] - PjBL with discussion of technical content and professional responsibilities and ethics[5] - Research, case studies, and presentations on professional responsibility topics[6] - Online modules with professional responsibility in context of professionalism, economics, and project management[7]	- Student surveys - Grades
Professional Ethics	- Often main or secondary attribute in a paper - TLAs varied - Similar to those for professional ethics - Model-eliciting activities, PjBL, online modules, textbook companion	- Project including ethics and sustainability[8] - Capstone projects involving service learning and sustainability[3] - 5 of 19 online modules specifically targeting ethics[7] - Textbook companion to explore ethics in relation to thermodynamics topics[9]	- Student surveys - Grades
Communication	- Main TLA was PjBL - Taught directly in courses - Digital media initiatives - Student tutors - 65% of papers fostering teamwork also mentioned communication	- Entrepreneurship projects or capstone projects[10] - K-12 outreach activities[11] - Online modules during co-op work terms[7] - Gaming simulation to explore communication behavior of cultures[12] - Tutors from non-engineering majors[13]	- Student feedback surveys - Grades - Faculty assessment - Industry expert assessment[10]

[1](Wang, Patten, Shelby, Ansari, & Pruitt, 2012)
[2](Sevier, Callahan, Schrader, Chyung, & Schrader, 2012)
[3](Lathem, Neumann, & Hayden, 2011)
[4](Budny & Gradoville, 2011)
[5](Bursic, Shuman, & Besterfield-Sacre, 2011)
[6](St. Clair, Riley, Thaemert, & Lindgren, 2011)
[7](Barakat & Plouff, 2014)
[8](Jollands & Parthasarathy, 2013)
[9](Riley, 2011)
[10](Kiefer & Kuchnicki, 2013)
[11](Pruitt, 2011)
[12](Ekaterina, Anastasya, & Ksenya, 2015)
[13](Weissbach & Pflueger, 2013)

Table 2 (continued). Summary of findings for TLAs related to each graduate attribute.

Graduate Attribute	General Observations	Specific Examples	Assessment Methods
Engineering Impact	-Most common TLA was open-ended problem solving -Three papers that used service learning -Includes multi-modal assignments[6], model-eliciting activities[5], and problem-based learning[14]	-Water supply system project in Ecuador[4] -One-on-one interviews with professionals in the field, both private and public[6]	-Validated: Concept inventories to measure the gain[5] -Validated: Student Attitude survey[3]
Engage in Life-Long Learning	-Only main focus of one paper -TLAs includes research projects, independent study, and case studies	-Open-ended problems in a fluid mechanics course[15] -Information literacy projects requiring students to conduct research, design projects, and write reports[16]	-Measured enthusiasm, perception of skills for life-long learning[15] -Self-assessment of activity impact on ability to “learn how to learn”[15]
Explore Problems	-Seven papers overall -Three discussed PjBL -Discussion of structure of overall courses	-Article that had students use sketching to encourage them to engage more deeply in problem exploration and idea generation[17]	-Self-developed surveys -Observations -Student grades
Interpret Information	-Two papers specifically discussed information literacy -Four used PjBL	-Information literacy, which is the ability to identify a need for information and effectively apply that information to a problem[16]	-Skill assessment - SAILS[16] -Surveys -Peer evaluations -Grades
Solve Problems	-Observed least frequently of all specified 11 attributes -Never primary topic -Main theme of problem solving is divided into: explore problems, interpret information, solve problems -Papers primarily focused on process rather than solution	-Using sketching to help students explore product design and practice a visual method of the problem solving process[17] -Capstone design projects focused on team-based engineering problems to be solved[18]	-Recommendation Reports -Self-assessment

[3](Lathem et al., 2011)
[4](Budny & Gradoville, 2011)
[5](Bursic et al., 2011)
[6](St. Clair et al., 2011)
[14](Pierce et al., 2014)
[15](Vasko et al., 2011)
[16](Naz & Casto, 2013)
[17](De Vere, Melles, & Kapoor, 2012)
[18](Mohammed & Dimmitt, 2012)

Table 2 (continued). Summary of findings for TLAs related to each graduate attribute.

Graduate Attribute	General Observations	Specific Examples	Assessment Methods
Teamwork	-Discussed in 14 of the 35 papers -Main TLAs were PjBL (6 papers) and service learning (3 papers) -Mainly taught in classroom, but also online	-Entire courses on teamwork and communication[18,19] -Aeronautical engineering student teams to build an Unmanned Aerial System[20] -Student teams to design tabletop devices to extract juice from apples[10] -Water project in Ecuador[4] -Development of a K-12 project with a local science centre[1] -Web-based collaboration[21]	-Student self-assessments -Peer assessments -Small number of papers considered grades
Ability to Design	-Discussed in 11 papers, of which 5 papers included as main attribute -Main TLA was PjBL (6 papers)	-Air pollution study with experiments, design considerations, and report[11] -Real world projects from industry[10]	-Peer feedback -Faculty & industry judges[10]
Tools	-One paper -Extensively discussed graduates' abilities to use techniques, skills, and modern engineering tools	-Use of smartphones as mobile computing devices, using their position, velocity, and acceleration sensors to calculate acceleration values and learn how to handle noisy experimental data[22]	-Student survey
Entrepreneurship	-One paper -PjBL	-Students came up with an entrepreneurial project idea and pitched it to their classmates[23]	-Student survey to measure student interest in the design projects
Leadership	-Service learning project	-Students use engineering knowledge to develop science and engineering activities for K-12 students at a local science centre[11]	-Survey -Self-assessment

[1](Wang et al., 2012)
[4](Budny & Gradoville, 2011)
[10](Kiefer & Kuchnicki, 2013)
[11](Pruitt, 2011)
[17](De Vere et al., 2012)
[18](Mohammed & Dimmitt, 2012)
[19](Dimmitt, Mohammed, & Moore, 2012)
[20](Holgado-Vicente, Gandia-Aguera, Barcala-Montejano, & Rodriguez-Sevillano, 2012)
[21](Lingard & Barkataki, 2011)
[22](Bevill & Bevill, 2015)
[23](Dahm & Riddell, 2011)

DISCUSSION

Graduate Attributes

All eleven graduate attributes were observed in the literature review. This suggests that research and implementation of TLAs is being done to promote the need for defining attributes required to be a successful engineer.

Teamwork was observed to have a high correlation with communication, approximately 65% of the papers with TLAs which fostered teamwork also mentioning communication. This is not surprising, as working in a team involves a high level of communication between team members. Team projects also typically have communication-focussed deliverables such as written reports and oral presentations. Although teamwork is dependent on communication, communication was observed to exist separately from teamwork in the form of individual assignments such as independent research projects and resume building.

There were five papers which discussed TLAs for both professional responsibilities and professional ethics. These two attributes were also intertwined. It could be argued that professional responsibilities include ethics, yet the terminology was not consistent across the literature. Therefore, it was difficult to distinguish which attribute authors were discussing.

Problem Solving

In Figure 1, it can be seen that “Problem Solving” is an overall theme that included the following attributes: explore problems, interpret information, and solve problems. Within the original study (Paul et al., 2015), the attribute *explore problems* included experimentation, investigation, and the ability to conduct research. *Interpret information* included synthesis of information and the ability to interpret data. Whereas the attribute *solve problems* was in reference to the ability to solve engineering problems by selecting the appropriate analysis to reach valid conclusions. The distinction can be seen in that the emphasis of *explore problems* and *interpret information* is not on solving the problem but rather going through the problem solving process.

The results of the literature review show the attribute *solve problems* was observed the least, with no paper focusing on this topic. Edström & Kolmos (2014) define problem-based learning as “a broad philosophy of teaching and learning focusing exclusively on the *learning process*, that is, *how* students should learn, and not on *what* they should learn.” Consequently, it follows that the papers and TLAs tended to focus on attributes on the process of problem solving (explore problems and interpret information) rather than the end result (solve problems).

Problem solving is covered throughout the conceive-design-implement-operate framework. Using TLAs which support this approach helps students to first engage in the process, and then understand how to apply the technical theory to the problem solving and engineering practice (Crawley et al., 2014). While all elements of problem solving are important, “learning to learn” is an illustration of the idea of improving engineering problem solving skills rather than simply providing students with a technical base of knowledge (Crawley et al., 2014). Within the education system, it is more important that students are exposed to undefined problems that involve new ways of combining problems, rather than they reach a predetermined solution.

Teaching and Learning Activities

Although not always directly mentioned, active learning (any instructional method that engages students in the learning process) was an overarching theme observed and is central to TLAs such as project-based learning, model-eliciting activities, and service learning. Evidence has shown that active learning strategies support an effective learning environment (Prince, 2004), and therefore evidence of its implementation is encouraging. However, it is important to clarify a successful implementation of a TLA does not imply that any single experience can lead to the complete development of an attribute. Instead, the aim is that each experience contributes as much as possible towards student growth (Litzinger et al., 2011).

Project-Based Learning

Project-based learning (PjBL) was the most commonly observed TLAs in the literature. More specific types of PjBL included experiments, team-based learning, cooperative learning, product archeology, inquiry-based learning, problem-based learning, multi-modal assignments, and open-ended problems. All of these were grouped within the TLA of “project-based learning;” however, it is evident that a more consistent terminology is required to distinguish between these activities (Finelli et al., 2015).

All but one of the attribute categories were associated with PjBL teaching and learning activities (see Table 2). These results suggest that PjBL is a TLA which is very common in engineering education, as well being effective at providing students with the variety of necessary engineering skills and attitudes. The most common attributes associated with the use of PjBL were *teamwork*, *communication,* and the *ability to design*.

Within CDIO, the use of PjBL is central, where the learning experiences are “based on pedagogical theories of how students, especially engineering students, learn and develop cognitive skills” (Crawley et al., 2014, p.157) . Although PjBL is rated to be highly successful by instructors, one limitation of this TLA is that inexperienced instructors find the transition to a project-based course to be extremely challenging and demanding.

Service Learning

The central purpose of engineering is to provide solutions (products, processes, and systems) that directly or indirectly serve society. Therefore, within CDIO there is an emphasis on the skills and the attitudes conveying that conceiving-designing-implementing-operating is the role of engineers in their service to society (Crawley et al., 2014). Service learning could be considered a subset of PjBL, where the project is specifically targeted towards the service of others. However, as its own independent TLA it was still the second most commonly observed. Service learning was also associated with many attributes: 7 of the 11 categories used in this analysis. The main focus was typically to provide students with an understanding of the professional responsibilities, ethics, and the impact of engineering on society. Overall, these projects help to widen students’ perspectives.

Assessment Methods

The main assessment method was surveys written by the instructors and completed by students. While many surveys asked similar questions, very few validated their instruments or used an already validated tool. This raises questions of whether or not these instructors can academically prove the success of their chosen TLA in teaching a particular attribute. Another popular assessment method was looking at students' grades and comparing these to previous years. This method can point out that the students had a similar level of understanding for a particular attribute, but it fails to capture any qualitative differences in that understanding. This shortcoming was addressed in many papers by also including the opportunity for students to give feedback on the activities and assess their own work, their peers' work, and occasionally that of their instructors. Less common assessment methods included observations and anecdotal feedback from professors.

CONCLUSION

Engineering education institutions worldwide are adopting new teaching and learning activities that promote the variety of attributes and skills engineers require to succeed in the 21st century. A systematic literature review explored the various teaching and learning activities being used to teach and assess graduate attributes.

Communication and *teamwork* were the most commonly discussed attributes, and these were often discussed together. The differences between *professional responsibilities* and *professional ethics* were not always identified. *Solve problems* was the least commonly discussed attribute perhaps given that it is a process including the attributes *explore problems* and *interpret information.* The most common TLA was project-based learning activities such as open-ended problems, team-based learning, and service learning which were used to simultaneously develop a number of graduate attributes in engineering students. Other unique approaches included sketching, student tutors, and gaming simulations.

One limitation of the implementation of all of the TLAs was the assessment methods used to measure their success in fostering the intended attribute. Most investigations used student grades, qualitative observations, and self-developed surveys, of which few authors provided their validation methods. Future work could include a literature review with search terms targeted towards assessment methods.

REFERENCES

Abdulwahed, M., Balid, W., Hasna, M. O., & Pokharel, S. (2013). Skills of engineers in knowledge based economies: A comprehensive literature review, and model development. *IEEE International Conference on Teaching, Assessment and Learning for Engineering, TALE 2013*, 759–765.

Barakat, N., & Plouff, C. (2014). A model for on-line education of ABET-required professional aspects of engineering. *IEEE Global Engineering Education Conference, EDUCON*, (April), 507–514.

Bevill, S., & Bevill, K. (2015). Smartphone-Based Measurement of Acceleration : Development of a Smart- phone Application for Use in an Engineering Dynamics Course. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Boeing. (1996). Desired Attributes of an Engineer. Retrieved from http://www.boeing.com.

Borrego, M., & Bernhard, J. (2011). The Emergence of Engineering Education Research as an Internationally Connected Field of Inquiry. *Journal of Engineering Education*, *100*(1), 14–47.

Borrego, M., & Henderson, C. (2014). Increasing the use of evidence-based teaching in STEM higher education:A comparison of eight change strategies.*Journal of Engineering Education*,*103*(2), 220–252

Boyer, E. L. (1990). *Scholarship Resonsidered, Priorities of the Professoriate*. http://doi.org/10.1002/tl.51

Budny, D., & Gradoville, R. T. (2011). International Service Learning design projects: Educating tomorrow's engineers, serving the global community, and helping to meet ABET criterion. *International Journal for Service Learning in Engineering*, *6*(2), 98–117.

Bursic, K. M., Shuman, L. J., & Besterfield-Sacre, M. (2011). Improving Student Attainment of ABET Outcomes Using Model- Eliciting Activities (MEAs). *ASEE Annual Conference and Exposition.*

Crawley, E. F., Malmqvist, J., Östlund, S., & Brodeur, D. R. (2014). *Rethinking Engineering Education*.

Dahm, K., & Riddell, W. (2011). Students learn fundamentals of engineering design while pursuing their own entrepreneurial ideas. *ASEE Annual Conference and Exposition, Conference Proceedings*.

De Vere, I., Melles, G., & Kapoor, A. (2012). Sketchfest: Emphasising Sketching Skills in Engineering Learning. *International Conference on Engineering and Product Design Education.*

Dimmitt, N. J., Mohammed, J., & Moore, D. (2012). Strategies for improving technical communication effectiveness skills in a middle east engineering program. *ASEE Annual Conference and Exposition.*

Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education*, *3797*(June 2015), 1–17.

Ekaterina, G., Anastasya, B., & Ksenya, G. (2015). Sociocultural Competence Training in Higher Engineering Education: The Role of Gaming Simulation. *Social and Behavioral Sciences*, 339–343.

Finelli, C. J., Borrego, M., & Rasoulifar, G. (2015). Development of a Taxonomy of Keywords for Engineering Education Research. *Journal of Engineering Education*, *104*(4), 365–387.

Finelli, C. J., Daly, S. R., & Richardson, K. M. (2014). Bridging the research-to-practice gap: designing an institutional change plan using local evidence. *Journal of Engineering Education*, *103*(2), 331–361.

Holgado-Vicente, J. M., Gandia-Aguera, F., Barcala-Montejano, M. A., & Rodriguez-Sevillano, A. A. (2012). Project Based Learning activities as a means of adapting conventional curricula to the demands of the 21st century aeronautical engineer. *Global Engineering Education Conference (EDUCON), 2012 IEEE*.

IEA. (2014). The Washington Accord. Retrieved January 10, 2015, from http://www.ieagreements.org/Washington-Accord/

Jollands, M., & Parthasarathy, R. (2013). Developing engineering students' understanding of sustainability using project based learning. *Sustainability (Switzerland)*, *5*(12), 5052–5066.

Kiefer, S. F., & Kuchnicki, S. N. (2013). Project-Based Learning : Teaching Engineering Design Not Tinkering. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Lathem, S. A., Neumann, M. D., & Hayden, N. (2011). The Socially Responsible Engineer: Assessing Student Attitudes of Roles and Responsibilities. *Journal of Engineering Education*, *100*(3), 444–474.

Lingard, R., & Barkataki, S. (2011). Teaching teamwork in engineering and computer science. *Frontiers in Education Conference (FIE), 2011*.

Litzinger, T. A. . b, Lattuca, L. R. ., Hadgraft, R. G. ., Newstetter, W. C. ., Alley, M. ., Atman, C. ., … Yasuhara, K. . (2011). Engineering education and the development of expertise. *Journal of Engineering Education*, *100*(1), 123–150.

Lopes, M. C., Fialho, F. a. P., Cunha, C. J. C. a., & Niveiros, S. I. (2013). Business Games for Leadership Development: A Systematic Review. *Simulation & Gaming*, *44*, 523–543.

Maranville, D., Neill, K. O., & Plumb, C. (2012). Lessons for Legal Education from the Engineering Profession's Experience with Outcomes-based Accreditation, *38*(3), 1017–1093.

Mohammad Yusof, Y., Aliah Phang, F., Hamzah, R., Ismail, S., & Isa, K. M. (2012). Epistemology of Knowledge for Technical and Engineering Education. *Procedia - Social and Behavioral Sciences*, *56*(Ictlhe), 108–116.

Mohammed, J., & Dimmitt, N. J. (2012). A COURSEWORK PLAN FOR IMPROVING SKILLS NECESSARY FOR SUCCESSFUL CAPSTONE PROJECTS. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Naz, A., & Casto, M. (2013). Bring best of two worlds in a software engineering class, student outcomes of Accreditation Board of Engineering and Technology (ABET) and information literacy standards of Association of College & Research Libraries (ACRL). *Proceedings - Frontiers in Education Conference, FIE*, 80–86.

Paul, R., Hugo, R. J., & Falls, L. C. (2015). International Expectations of Engineering Graduate Attributes. *Proceedings of the 11th International CDIO Conference*.

Pierce, C. E., Caicedo, J. M., Flora, J. R. V, Berge, N. D., Madarshahian, R., & Timmerman, B. (2014). Integrating Professional and Technical Engineering Skills with the EFFECTs Pedagogical Framework. *International Journal of Engineering Education*, *30*(6), 1579–1589.

Prince, M. (2004). Does Active Learning Work ? A Review of the Research. *Journal of Engineering Education*, *93*(3), 223–231.

Pruitt, L. A. (2011). INTRODUCTION TO ENGINEERING DESIGN FOR FRESH- MAN : IMPLEMENTATION OF LEADERSHIP AND SERVICE LEARN- ING FOR BROADENING ENGINEERING INGENUITY. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Riley, D. (2011). Engineering Thermodynamics and 21st Century Energy Problems: A Textbook Companion for Student Engagement. *Synthesis Lectures on Engineering*, *6*(3), 1–97.

Sevier, C., Callahan, J., Schrader, C., Chyung, S. Y., & Schrader, C. B. (2012). What Value Does Service Learning Have on Introductory Engineering Students ' Motivation and ABET Program Outcomes ? What Value Does Service Learning Have on Introductory Engineering Students ' Motivation and ABET Program Outcomes ?

Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET “Professional Skills” - Can They Be Taught? Can They Be Assessed? *Journal of Engineering Education*, *94*(1), 41–55.

St. Clair, S., Riley, C. E., Thaemert, D. K., & Lindgren, R. (2011). Using Positive Interdependence and Multi- Modal Assignments To Enhance Student Understanding. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Vasko, T. J., Vasko, T. J., Al-masoud, N., Systems, C., Section, H., & Baumann, P. F. (2011). AC 2011-1173 : ASSESSMENT OF SOFT-SKILLS-PROGRAM LEARNING Assessment of Soft-Skills for Student Outcomes.

Wang, J., Patten, E., Shelby, R., Ansari, F., & Pruitt, L. A. (2012). LEADERSHIP AND SERVICE LEARNING IMPROVES CONDIFENCE OF ENGINEERING SKILLS IN WOMEN. *ASEE Annual Conference and Exposition, Conference Proceedings*.

Weissbach, R., & Pflueger, R. C. (2013). Use of Student Tutors to Improve Engineering Technology Student Written Communication Skills. *ASEE Annual Conference and Exposition, Conference Proceedings*.

BIOGRAPHICAL INFORMATION

Robyn Paul is a Masters' of Science candidate in Civil Engineering in the Schulich School of Engineering at the University of Calgary. Her research focuses on the impact that teaching engineers leadership skills has on their early career success. She is also a sessional instructor and is involved with initiatives to collaborate across the University to increase the conversation around engineering education.

Stephanie Hladik is a M.Sc student in Electrical and Computer Engineering at the University of Calgary. Through her research she is exploring topics related to the integration of engineering into K-12 curricula. In particular, she is interested in bringing electrical engineering, programming, and the engineering design process into K-12 education. Aside from her research, Stephanie also participates regularly in outreach programs to promote STEM topics in classrooms and beyond.

Ronald J. Hugo is Professor of Mechanical and Manufacturing Engineering and Associate Dean (Teaching & Learning) at the University of Calgary. He is also the holder of the Engineering Education Innovation Chair in the Schulich School of Engineering. His research interests are in the areas of experimental fluid dynamics, energy systems, and engineering education.

Corresponding author

Robyn Paul
Department of Civil Engineering
Schulich School of Engineering
University of Calgary
2500 University Drive NW
Calgary, Alberta, Canada, T2N 1N4
1-403-220-4816
rmpaul@ucalgary.ca