Challenges and Opportunities Observed in the Implementation of a New Architectural Engineering Undergraduate Academic Program

Prof. Scott Walbridge P.E., University of Waterloo

Scott Walbridge has been a professor in the University of Waterloo's Department of Civil and Environmental Engineering since 2006. Prior to that, he completed his doctoral studies at the Ecole Polytechnique Federale de Lausanne (EPFL), and his bachelor's and master's degrees at the University of Alberta. Between his master's and doctoral studies, he worked as a structural engineering consultant for 2.5 years in Edmonton, Canada. His current research focuses on the design of steel and aluminum structures, with a focus on connection behaviour. He is currently serving as an Associate Editor for the ASCE Journal of Bridge Engineering. He also serves on a number of CSA design code committees, including those for the design of bridges, design of aluminum structures, and design of structural welds. He currently serves as Director for the University of Waterloo's new Architectural Engineering program.

Dr. Rania Al-Hammoud P.Eng., University of Waterloo

Dr. Al-Hammoud is a Faculty lecturer (Graduate Attributes) in the department of civil and environmental engineering at the University of Waterloo. Dr. Al-Hammoud has a passion for teaching where she continuously seeks new technologies to involve students in their learning process. She is actively involved in the Ideas Clinic, a major experiential learning initiative at the University of Waterloo. She is also responsible for developing a process and assessing graduate attributes at the department to target areas for improvement in the curriculum. This resulted in several publications in this educational research areas. Dr. Al-Hammoud won the "Ameet and Meena Chakma award for exceptional teaching by a student" in 2014 and the "Engineering Society Teaching Award" in 2016 and the "Outstanding Performance Award" in 2018 from University of Waterloo. Her students regard her as an innovative teacher who continuously introduces new ideas to the classroom that increases their engagement.

Challenges and Opportunities Observed in the Implementation of a New Architectural Engineering Undergraduate Academic Program

Abstract

In the fall of 2018, a new, first-of-its-kind in Canada architectural engineering undergraduate program was launched. The program features 24 months of compulsory / inclusive coop work experience, along with a series of core studio courses in each of the eight academic terms. Each of these courses will involve the planning and execution of a series of design projects that integrate and put into practice concepts covered in the other courses the students will be taking. For the entire third year of the program, the students will study at an off campus architecture school, where they will work on building design projects alongside architecture students. The curriculum for this new program has an emphasis on "communication, collaboration, and design". This paper presents an overview of the program curriculum and discusses challenges encountered and lessons learned in the program development and implementation to date. Highlights of the challenges faced include issues such as: attracting students to a new program where there are relatively few current examples to point to (in Canada) of well-established career paths, marketing lower year students of this new program to prospective coop employers, and developing and implementing an academic program that will meet the Canadian professional engineering accreditation requirements while at the same time exposing the students in a sufficient depth to related fields not classically considered to be engineering. While there is limited information available to quantify the success of the program to date, the paper does discuss a promising qualitative assessment of the abilities of the students in this program to be successful in teamwork oriented projects and to deal in creative ways with challenging, open-ended problems. Future plans to address the need to obtain quantifiable measures of success in terms of achieving the desired program outcomes will also be outlined.

1.0 Introduction

In the fall of 2018, a new, first-of-its-kind in Canada architectural engineering undergraduate academic program was launched. It is believed that the students graduating from this program will address a pressing societal need. With buildings accounting for 40% of Canada's energy consumption and 50% of its primary resource consumption, as well as 30% of global greenhouse gas emissions globally, the urbanized world faces a demand for engineers technically skilled in the whole scope of building design, construction, assessment, repair, and refurbishment. The trends of global population growth and urbanization suggest that the issues of climate change mitigation and improvement impacting buildings, as well as the need for infrastructure renewal, will only continue to grow in importance in the coming years. Architectural engineering as a discipline is – of course – not a new idea. For example, in 2006 there were 15 ABET-accredited programs in the US according to (Estrada, 2006), and this number rose to 21 in 2018 according to (Phillips, 2018). This program is relatively unique in Canada, however, with arguably only two comparable undergraduate university programs in "building engineering" and "architectural conservation and sustainability" existing to address similar needs.

The program features 24 months of compulsory / inclusive coop work experience, along with a

series of core studio courses in each of the eight academic terms. Each of these studio courses will involve the planning and execution of a series of design projects that integrate and put into practice concepts covered in the other courses the students will be taking. The curriculum for this new program has been designed with built-in flexibility, enabling a number of possible future career paths. In particular, the students in this program will be able to specialize with their upper year elective courses, either in “building science” or “building structures” or they may choose to take a mixture of elective courses including both of these topics and others.

The students graduating from this program will have learned enough about the architectural design process and the engineering of building and structural systems to be able to communicate effectively with the various specialists who currently perform these tasks. We therefor envision that they will be capable of playing a leadership role in future building projects. We believe that – in combination – the various elements of this new program (compulsory four-month coop work terms distributed throughout the five-year program, studio courses in each of the eight academic terms) make it unique in Canada and possibly North America.

This paper presents an overview of the curriculum of this new program and discusses challenges encountered and lessons learned in the program development and implementation to date. Highlights of the challenges faced include issues such as: attracting students to a new program where there are relatively few current examples to point to (in Canada) of well-established career paths, marketing lower year students of this new program to prospective coop employers, and developing and implementing an academic program that will meet the Canadian professional engineering accreditation requirements while at the same time exposing the students in a sufficient depth to related fields not classically considered to be engineering. While there is limited information available at this time to quantify the success of the program, the paper does discuss a promising qualitative assessment of the abilities of the students in this program to be successful in teamwork oriented projects and to deal in creative ways with challenging, open-ended problems. Future plans to address the need to obtain quantifiable measures of success in terms of achieving the desired program outcomes will also be outlined.

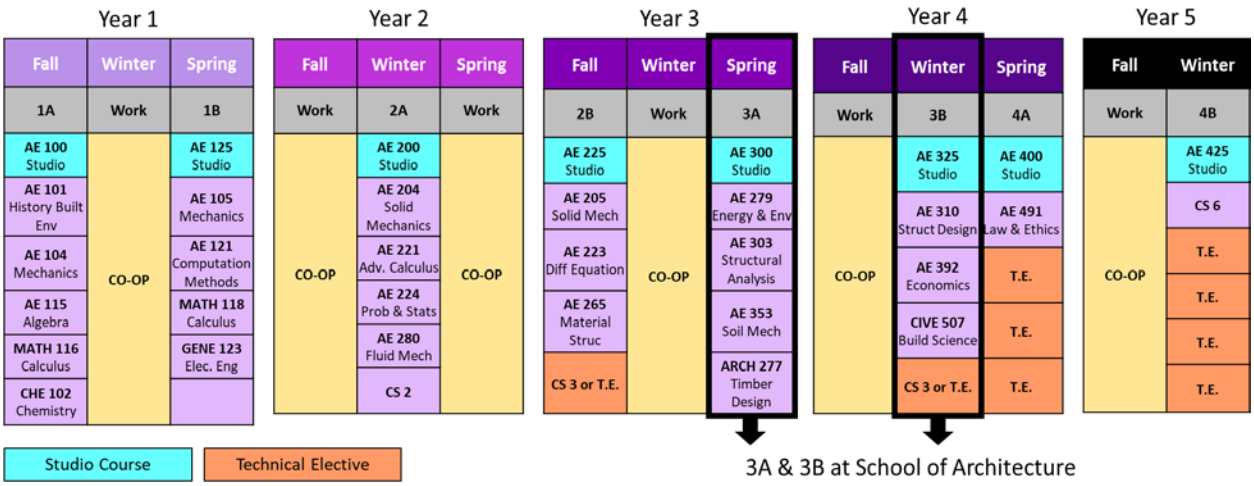
2.0 Curriculum Overview

Figure 1 presents an overview of the new architectural engineering program. Highlights of this program include the following: 1) the students alternate between academic and coop work terms, with the exception of having two back-to-back academic terms in their fourth year; 2) each term features a studio course – as mentioned earlier, each of these courses will involve the planning and execution of a series of design projects that integrate and put into practice concepts covered in the other courses the students will be taking; 3) the core courses in the first two years are built on the established civil, environmental, and geological engineering programs at the same institution, and include basic building blocks that appear in the lower years of most engineering programs; 4) in the upper years, the students take electives, which allow them to specialize in one of several areas within the broader field of architectural engineering.

The upper year academic terms align with the civil and mechanical engineering programs at the same institution, which means the architectural engineering students will have access to a variety

of established electives in areas including structural engineering and design of HVAC systems. In addition, new electives are being created, in areas including building enclosure systems, building service systems, and building performance measurement. While the architectural engineering students will not take courses with architecture students, they will undertake their entire 3A and 3B academic terms at the school of architecture.

In general, the program can be said to include innovative elements, while building on strengths of the established programs at the same institution. As the program evolves, it may eventually diverge further over time from these existing programs. However, this will be done in a sensible manner, based on evidence of benefits, input from industry stakeholders, etc.



[Figure 1] Overview of curriculum for new architectural engineering program.

Graphical, oral, and written communication skill development will be emphasized throughout the program. In the 2A academic term, complementary studies course CS 2 is a writing and communications course. The motivation for this required course is an identified need to produce engineers who are not only technically competent but also effective communicators. This need is articulated in (Betz, 2005), and the developed CS 2 course incorporates a number of aspects recommended in this reference, including small class sizes (25 students).

The content and focus of the various existing architectural engineering programs across North America varies widely. In (Estrada, 2006), ranges are given for the existing US programs of course hours in various “bins”, including: architecture, math and science, general, engineering, and technical electives. In the development of the current program, academic units (AUs) were counted, in a similar set of bins, as required by the Canadian Engineering Accreditation Board (CEAB) accreditation process. However, a single course can partially fill AU requirements for more than one bin. Looking at these AUs, 21% of the total (based on a critical path analysis) are attributed to math and science, compared with a range of 20-29% and an average of 25% found by (Estrada, 2006) for the existing four year undergraduate programs in the US. 45% of the AUs are in engineering, in comparison with a range of 40-50% and an average of 45% reported in (Estrada, 2006). The students in this program will take eight technical electives, accounting for 19% of their total course count, in comparison with a range of 5-14% and an average of 8.8%

reported in (Estrada, 2006). Quantifying the architecture content for this program is less straight forward. The AE 101 History of the Build Environment course is taught by an architecture professor, and each of the eight studio courses will be co-taught by one architecture and one engineering professor. Thus, if each studio course is considered 50% of an architecture course, then the architecture courses account for 11.9% of the total course count, in comparison with a range of 6-16% and an average of 11.6% reported in (Estrada, 2006). Thus, it can be seen that at a high level, the program is by no means abnormal in its overall distribution of course content, in comparison with other North American architectural engineering programs.

Regarding the content and focus of the program-specific courses, (Mitchell, 2009) explains that architectural engineering programs generally cover the following sub-disciplines to varying degrees: architecture, structure, HVAC, electrical, and construction management. Of these, the suite of core courses and technical electives for this new program place a heavy emphasis on architecture and structure. Building systems (HVAC) are also covered in several courses, but not to the same extent (it is believed) as other, more HVAC-focused programs. Building envelope and building science in general will also be major focus areas of study.

3.0 Implementation Challenges

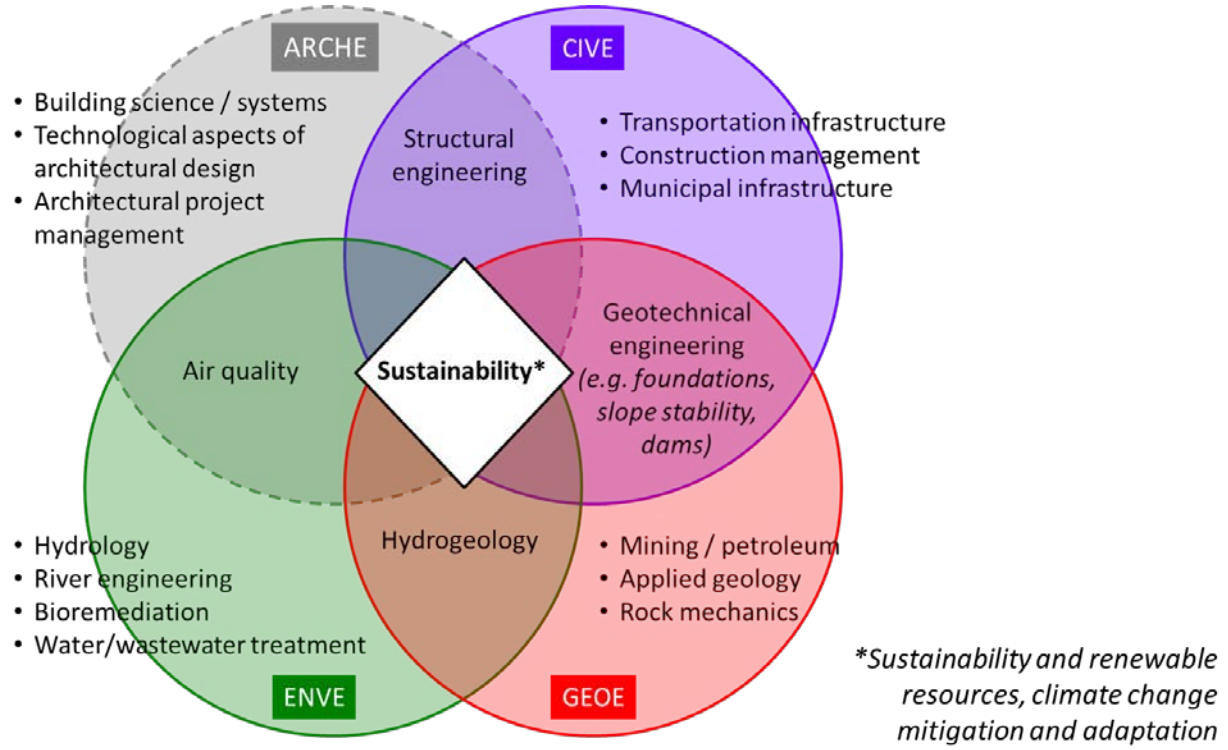
The first two classes of this new program began their studies in the fall of 2018 and 2019. With intakes of ~90 and ~85 students in the first two years, it is expected that this program will be one of the larger ones in North America, should the two current student cohorts (and those that follow) continue on to complete their studies successfully. Only Pennsylvania State University has a similarly-sized annual graduating cohort, according to (Phillips, 2018).

In the development and implementation of this new academic program, a number of challenges are worth noting and may be of interest to other institutions interested in modifying existing programs or developing new ones to address similar societal / industry needs.

As an example, while the program is proving to be very attractive to students with diverse backgrounds and interests (e.g. in the creative arts, as well as in math and the sciences), prospective students are very interested in knowing what kinds of jobs await them when they graduate. This can be a challenge in a country such as Canada, where the architectural engineering profession is virtually non-existent. While the program was developed based on careful solicitation of input from industry and a clearly identified expertise gap, answering these questions can be a challenge. While some students seem to revel in the possibility that they are pioneers and will be the ones building and eventually becoming leaders in this new (to Canada) field, others may be put off by the uncertainty that comes with this prospect. Discussion of the overlap and commonly encountered movements between the various existing engineering professions can be helpful in addressing these kinds of questions. Figure 2 is an example of a graphic that has been developed to explain how architectural engineering (Arch E) relates to a number of similar fields, including civil, environmental, and geological engineering.

Other challenges faced in the mounting of a new program such as this include the marketing of students to prospective coop employers. This can be particularly challenging in the lower years,

where the students are only starting to develop employable skills in their prospective engineering disciplines. Thankfully, to date, the coop placement statistics for students in this new program have been reasonably strong. Placement statistics for the first three coop terms were reported to be 90% (Class of 2023 after 1A term), 100% (Class of 2023 after 1B term), and 95% (Class of 2024 after 1A term). These numbers are in line with the established programs at the same institution, and generally expected to go up as the students progress through the program. The companies hiring students cover a broad range of sectors, including architectural and engineering consulting firms, construction firms, and owners of building infrastructure.



[Figure 2] Relationship between Arch E and several related engineering professions.

In implementing the program, it was quickly realized that giving the students employable skills, starting right from the first (1A) academic term, was going to be critical for ensuring that the students find coop placements. While other institutions address this issue by delaying the first coop term until several years into the program (or even until the end of the program in some cases), it is believed at the host institution of this new program that there is considerable pedagogical value in spreading the coop terms continuously through the degree program. Steps taken to ensure employability of the lower year students in view of the decision to employ this approach have including building basic drafting (e.g. hand and AutoCAD) skills into studio projects and activities in the very first academic term, and building on these skills methodically (e.g. integrating 3D modelling and BIM software) in successive academic terms. Soliciting input from industry is also critical, while at the same time recognizing that the purpose of a university degree is to build a strong foundation on which employers should expect they will have to do some work with young coop students and graduates to add task-specific training.

4.0 Assessment of Teamwork and Creative Problem Solving Skills

In the following section, an example of a first effort to qualitatively assess the impact(s) of unique elements of the Arch E curriculum delivery is described. In order to facilitate this effort, a qualitative comparison was conducted of the Arch E student performance and the performance of students in other engineering programs in completing a similar task. One of the first year mechanics courses common to all programs was used for this comparison. The same instructor taught the first year mechanics course for the four different programs, namely: architectural (Arch E), civil (Civ E), environmental (Env E), and geological (Geo E) engineering programs for two consecutive years. It should be noted that there was no noticeable difference in the average grade between the four programs across the two years. The class averages varied in both years between 77% and 82%. Noticeable differences were seen, however, during the course project – especially with the elements that required creativity and teamwork.

In this course, two teamwork workshops were conducted for all four programs on understanding conflict and conflict resolution (R. Al-Hammoud, M. Barichello, et al., 2020). During these workshops, it was clear from the observations of the instructor in class and the reflection reports written by the students that the Arch E students were working in teams more effectively than the students in the other programs. As reported in their reflection reports, the Arch E already knew how to work well together and resolve conflicts, as they have been doing this since Day 1 with their studio course and the Arch E Design Days event they all undertake in the first week of class (Mui et al., 2019). Teamwork being one of the twelve outcomes that need to be addressed for accreditation of an engineering program according to the Canadian engineering accreditation board (CEAB, 2018), it is important to identify that this outcome is being addressed in the program. As the first years of all four programs are similar, the difference in performance vis-à-vis this outcome suggest a positive impact resulting from the elements that are unique to the Arch E program – namely the first semester studio course and Design Days event. It is worth noting that studio and studio-like courses are increasingly becoming a model that other programs are looking into including as part of their curriculum and curriculum improvement.

In addition to the observations made regarding the teamwork aspect of this first year mechanics course, observable trends were also noted in the problem analysis and creativity aspects. One of the course tasks for all four programs was to prepare and deliver a project where students had to explain engineering concepts to middle school students (R. Al-Hammoud, Z. A. Khossa and M. Roclawski, 2020). Some of these engineering concept included elements such as arches, gothic cathedrals, retaining walls, culverts, and suspension bridges (see Figure 3 – left).

Students in all four programs were given the same deliverables and the project encouraged them to be creative in terms of delivery and assessment of the middle school kids. It was clear to the instructor during the observation and the execution of this project that the difference in creativity level between the Arch E students and the students from the other three programs was considerable. The Arch E students duplicated the feel of the forces in these structures in a way allowing the middle school kids to feel these forces in their body. One example is trying to explain the effect of buttresses in gothic cathedrals. The students brought a broomstick and asked two kids to hold it facing each other. They then asked two other kids to act as buttresses by pushing on the backs of the two kids holding the broomstick. They then asked a fifth kid to hang

from the broomstick. In this way, the kids were able to carry the weight no problem. As soon as the buttresses (i.e. the kids pushing on the back) were removed, the other kids were not able to carry the weight anymore (Figure 3 – right). It was interesting to see how feeling the forces allowed the kids to better understand the effect of the buttresses. This is just one example of many where the Arch E students were particularly creative in how they explained the different structures in a way that allowed the school kids to develop an intuition for how they work. It is expected that in the coming years, tasks such as this will not only develop the creativity and team work skills of the Arch E students, but also enable them to become effective in communicating complex technical ideas to non-expert clients and stakeholders.

[Figure 3] Building a suspension bridge (left) and demonstrating the effect of gothic cathedral buttresses (right).

5.0 Summary and Conclusions

As the presented new architectural engineering program is only in its second year, much of the story of the development of this program remains to be told. Systematic methods for measuring outcomes will be needed, both to ensure the program quality and to meet the requirements of the national engineering accreditation authority. Given that this is a new kind of engineering program – in Canada, at least – communicating the importance of the content that has been incorporated in this program in areas such as communication, exposure to the architectural design process, and building science and systems will be critical for ensuring that the program is successful in the long term. Early indications suggest that the implementation of the program is going well, and that the students currently participating in the program are developing a unique skill set, which should set them apart from other engineering graduates in a good way. We fully expect that they will be future leaders in the buildings sector, with the potential to substantially improve the quality of our buildings and the effectiveness of this industry to the benefit of society and all of the various stakeholders involved in building design.

References

Al-Hammoud, R., Barichello, M., Rennick, C., Jobidon, E., and Li, R., (2020) “Two Student Workshops on Identifying and Resolving Teamwork Conflict”, 2020 ASEE Annual Conference & Exposition.

Al-Hammoud, R., Khossa, Z.A., and Roclawski, M. (2020) “Constructing Community Learning Opportunities to Reduce Attrition Against Women in Engineering” in Canadian Engineering Education Conference.

Betz, J.A. (2005). “Writing in the Discipline: A case study for architectural engineering”, 2005 ASEE Annual Conference & Exposition.

Canadian Engineering Accreditation Board, revised Nov. 2018 “2018 Accreditation Criteria and Procedures”, retrieved from https://engineerscanada.ca, February, 2020.

Estrada, H. (2006). “A survey of the American architectural engineering curriculum”, 2006 ASEE Annual Conference & Exposition.

Mitchell, J. (2009). “Defining architectural engineering design”, 2009 ASEE Annual Conference & Exposition.

Mui, R.H., Woo, S.J., Arbuckle, S., Al-Hammoud, R., and Walbridge S., (2019) “Architectural Engineering Start with Design from Day 1”, 2019 ASEE Annual Conference & Exposition.

Phillips, J.J. (2018). “Current trends in architectural engineering education”, 2018 ASEE Annual Conference & Exposition.