UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Core Curriculum Review Task Force
Final Report – December 2014

Presented to Chairs and Directors – December 11, 2014
Presented to the Executive Committee of Faculty Council – January 20, 2015
Presented to Faculty Council – February 10, 2015

Table of Contents

EXECUTIVE SUMMARY

For the first time in over 12 years, the Faculty of Applied Science & Engineering has set out to formally review the content and delivery of its first-year (core) curriculum for the Core 8 and General First Year (TrackOne) programs. Since March 2013, a decanal Task Force has been working to:

1) Review the current Core 8 and TrackOne core curriculum,
2) Solicit the student, departmental, and instructors' views of the current core curriculum,
3) Assess the on-going and future needs of the departments, students, and the Faculty for the core curriculum,
4) Survey current and best practices within other North American engineering institutions,
5) Consider the possibility of moving to a common first-year curriculum,
6) Explore opportunities for the integration of the Core 8, TrackOne, and Engineering Science cohorts, and
7) Develop a set of recommended actions and a proposed implementation plan that benefits our students and departments, the Faculty, and the engineering profession, while maintaining the TrackOne program and the opportunity for program transfer at the end of first year.

We have found that the current core program has many positive aspects, including its strength and breadth of foundational material, interesting and challenging courses, focus on engineering design, communications, and teamwork, engaged faculty, and talented and hard-working group of students.

However, the students, the departments, the first-year instructors, and the Task Force have identified some specific areas in which the core curriculum needs to be improved, while building upon these core strengths. Students identified as the most critical areas for improvement the need for:

- More effective and cohesive delivery of the first-year lectures, tutorials, and assessments,
- Improved consistency of instruction and grading in Engineering Strategies and Practice,
- Inclusion of numeric computation,
- More discipline-specific introduction to the engineering profession,
- Improved relevance of the core courses to engineering applications and upper-year courses,
- Enhanced preparation for job opportunities and career development,
- Improved blending of curricular and co-curricular activities,
- Greater opportunity for hands-on experiences,
- Intentional transition to the university academic environment,
- An approach to better manage the discrepancies in background preparation in mathematics and computer programming,
- Improved relevance of the programming language to the particular discipline, and
- Introduction to important software such as Excel, MATLAB, and AutoCAD.

Faculty suggested the curriculum needs to support students to:

- Develop stronger skills to work with advanced mathematics in an engineering setting,
- Develop core engineering skills such as estimation, unit analysis, thinking across length and size scales, and solving problems through numeric computation,
- Focus more specifically on logical and computational thinking,
- Develop the ability to work in three dimensions (e.g., Cartesian, cylindrical, and spherical systems) and a greater capacity for spatial visualization,
- Understand the complexity of "real" engineering problems,

- Work to improve the retention of concepts and material into the second year and regularly assess this retention,
- Specifically develop their problem-solving skills.

In relation to other Canadian and American engineering programs, there is quite a bit of variability in the content of the first-year curricula. It was found that all Canadian programs studied had the traditional three mathematics course in first year (Calculus I, II, and Linear Algebra), while most programs in the United States had only Calculus I and II. About half the Canadian programs reviewed had three physics courses, while the other half had only two, as did most US schools. Most programs had an introductory chemistry course for all departments with some following up with either a second chemistry course and/or a materials science course in the first or second year for relevant departments. In terms of computer programming, courses structured around C, C++, Python, MATLAB, and C and MATLAB, were all observed. Finally, most programs had some introduction to the engineering profession, design methodology, teamwork and communications, but approach these differently: some had a two-term sequence with a significant client-based or hands-on project, while others offer a simpler lecture or seminar-based course.

A number of innovative programs were identified, including McMaster's EPIC lab (Experiential Playground and Innovation Classroom) for first-year students, Northwestern's Engineering First integrated program, which combine linear algebra, statics, dynamics, computer programming, and differential equations into four courses, Illinois' Engineering First-Year Experience (IEFX) interdisciplinary program for all first-year students in which "students' aspirations are respected, supported, fostered within the programmatic initiatives that lay a solid foundation for their collegiate career," [1] and MIT's Flexible Engineering Program that "responds to the evolving desires of our undergraduate students, and emerging changes in the engineering professions, while remaining true to the School of Engineering's tradition of rigorous technical education." [2] While none of these are directly applicable to our Faculty, they are good examples of how engineering schools have approached the changing needs of engineering students and graduates.

A number of important conclusions were also drawn from the related engineering education literature and recent reports on the future of the engineering profession. There is a broad call through reports within Canada, US, and the UK to ensure that engineering schools are supporting the development of the "whole engineer." Canadian employers report lower satisfaction levels with the non-technical skills as compared to the technical skills of recent engineering graduates. The Engineer of 2020 report highlights the importance of strong analytic skills, practical ingenuity, creativity, communication, leadership, professionalism, resilience and flexibility, and lifelong learning skills as the key attributes of the future engineer. In the UK, a report from May 2014 discussed how engineering schools in that country are increasing the use of "problem/project-based learning with real-world projects, active learning that fosters systems thinking, peer learning fostering collaboration, or Conceive Design Implement Operate (CDIO) fostering integration across the engineering curriculum."[3] The research literature on "first-year integrated curricula" shows that such approaches improve the development of some of these key attributes, while also improving

[1] http://www.iefx.engineering.illinois.edu/#!iefx-electives/c1xqq
[2] http://engineering.mit.edu/programs/flexible
[3] From *Thinking Like an Engineer: Implications for the Education System*, Royal Academy of Engineering, 2014, pg. 39.

disciplinary learning, material retention, and performance in subsequent courses. However, such programs have been difficult to sustain given the significant resource and administrative requirements needed to implement the "communities of learning," faculty team teaching, and coordination and integration of the core courses.

This report synthesizes the findings of the Task Force through a set of ten recommendations for change both in terms of curriculum content and delivery. These recommendations are:

Recommendation #1:
Improve the Relevance and Integration of the Foundational Courses
The current separations between courses need to be removed through intentional coordination and course collaboration, while maintaining a similar administrative approach to the individual course delivery. Through this improved integration and concept contextualization, enhanced learning and concept retention can be facilitated. Student workload must be reimagined through a review of the essential content for each course and a more critical and holistic view on assessment. To accomplish this, it is recommended that a new teaching-stream faculty position within the Faculty and the First Year Office be created which would be responsible for identifying opportunities for course integration, both in terms of content and delivery; working in collaboration with the teaching staff from all participating departments to facilitate this integration; developing curricular materials and resources to facilitate course integration; teaching into the design curriculum of the first-year program; and coordinating and reporting on the first-year program effectiveness on an annual basis.

Recommendation #2:
Foster an Effective and Engaged First Year Instructional Team
The first-year team of instructors and teaching assistants needs to work more in tandem and be better supported and acknowledged for the special approach required to teach effectively in the first year program. This can be fostered through the creation of a College of First Year Instructors to facilitate mentorship and collaboration and to react to real-time feedback, and through improved teaching and TA assignment practices that will ensure an instructional team with proven teaching experience.

Recommendation #3:
Enhance the Fundamentally Strong Learning of Mathematics
The importance of a strong foundation in the core mathematics has been identified, and it is suggested that an increase in passing standards for those courses be considered and accompanied by improved course and program design to better support student learning.

Recommendation #4:
Address Discrepancies in Prerequisite Backgrounds in Mathematics and Computer Programming
Students with differing mathematical and computer programming backgrounds need to be provided with better preparation and completion options for their introductory courses. Online mathematical and computer programming diagnostic tests should be made available to incoming first-year students in the July prior to arrival. Online modules covering core mathematical pre-requisite concepts would be made available to students at that time, along with a comparable set of remedial tutorials throughout September. Alternate pathways for students to complete the Calculus I and computer programming courses should be developed. These could include courses with reduced lecture hours or an alternate tutorial design for advanced students.

Recommendation #5:
Incorporate Numeric Computation into the Core Curriculum

Facility with numeric computation tools is becoming increasingly important for our students, both to succeed in the Faculty's upper-year programs as well as in the workforce. As well, a numeric computation component in the curriculum would enable students to develop their visualization capabilities and their ability to present, analyze, critique, manipulate, and draw conclusions from graphical representations of complex data. This would also allow for more real-world engineering problems to be incorporated into the mathematics and science courses through mathematical modeling exercises. It is recommended that the use of a numeric computation tool be introduced to students through an additional one-hour laboratory component added to Linear Algebra. The facility gained with this tool would then be leveraged within the curriculum through specially designed homework problems and assignments in the students' other courses.

Recommendation #6:
Create a new First-Year Seminar Course to Support the Transition into Engineering

This seminar for-credit course would help students acclimatize to the engineering academic environment, gain a greater appreciation for how engineers "think" and make use of the fundamental mathematics and sciences, and understand the various engineering disciplines in both educational and career experiences. It would consist of six hours of lectures and 13 hours of small group seminars, led by an upper-year undergraduate mentor. Marking for the course would involve relevant student-designed and chosen assessments, rather than strictly an attendance-based grade.

Recommendation #7:
Create Opportunities for Program-Specific Hands-On Learning that Facilitate the Transfer of Fundamental Knowledge to Practical Problems

Feedback from faculty, students, and alumni strongly emphasized the lack of hands-on, practical experience of our first-year students and ultimately our graduates. It is recommended that a significant effort be made to improve the opportunity for students to engage in the building and testing of a physical object or system. Besides being an excellent opportunity for our students to enthusiastically engage with their program, the supportive development of the "maker-engineer" provides essential skills in engineering judgment, testing, iteration, optimization, and learning from failure. Through this experience, students would complete a hands-on project which would give them a greater appreciation for the complexity of real engineering problems, have an experience in learning from failure within a safe environment, be introduced to a systems thinking approach to problem solving, and allow them to transfer fundamental concepts to a practical situation.

To incorporate such an opportunity, two proposals are suggested for further discussion. The first would involve the creation of a set of program-specific Introduction to Engineering courses in the winter term. The second would be to re-organize the second Engineering Strategies and Practice course to incorporate a program-specific laboratory component.

Recommendation #8:
Support New Pedagogical Approaches and Opportunities for Self-Directed Learning

The culture within the Core 8 and TrackOne first-year programs should foster innovation in engineering education through careful implementation of research-based practices. Ongoing renewal of course delivery as new approaches and technologies are developed should be a common practice within the program. The Faculty should facilitate this renewal by creating Course Innovator positions, through which instructors and TAs can be supported financially to improve the student learning experience within the first-year program. Increased opportunities for self-directed projects and learning pathways (e.g., online or hybrid sections of courses) should also be offered to students.

Recommendation #9:
Carefully Review the Content and Delivery of Engineering Strategies and Practice

It has been over ten years since the Engineering Strategies and Practice (ESP) courses were added to the Core 8/TrackOne curriculum. While these courses have certainly evolved significantly over this decade, there has never been a formal Faculty-wide review of this critical component of our program. It was clear through our consultations that there is widespread uncertainty, misunderstanding, and ambivalence towards these courses. It is recommended that a careful review of the content and delivery of ESP I and II be conducted by a panel of representatives from each department. This review should be guided by the findings of the Task Force as described below.

Recommendation #10:
Develop an Assessment Protocol for the Effectiveness of the First-Year Program

A recurring broad-based strategy for the assessment of the effectiveness of the first-year program needs to be developed and implemented. This assessment should go beyond the standard metrics of course grades and student evaluations, and be related to the core learning outcomes for the first-year program.

At the end of the report, two curriculum models are proposed by the Task Force which address the major findings of this review. In addition, an implementation plan is suggested which calls for immediate action on many of these recommendations, and more cautious pilot implementations for the more significant changes. The first action will be to create an Implementation Working Group, which will have broad membership to ensure that all departments and programs are well represented. This Working Group will consider the Task Force's recommendations in greater detail and implement the necessary changes using the proposed implementation plan as a guide.

As the premier engineering school in Canada and one of the very best in the world, we must maintain our leadership role in the education of the engineers of the future. This report calls for a restructuring of our Core 8 and TrackOne programs to put the student learning experience at the heart of all that we do within the program. Through integrated program design and careful use of students' time, with coordinated, collaborative and effective teaching amongst our instructing team, with critical content review and ongoing assessment across a variety of metrics, and through real-world learning opportunities to begin the development of key engineering habits of mind, our first-year students will be extremely well-equipped to proceed in their program and develop as leading innovators and engineers of the future.

BACKGROUND

Terms of Reference

In March 2013, a decanal Task Force was created to review the current core curriculum for the Core 8 and TrackOne programs. This Task Force consisted of Micah Stickel (chair), Jason Bazylak, Tim Bender and Costas Sarris, and was supported by Colleen Kelly and Jennifer Fabro from the First Year Office. Evan Bentz also participated prior to the start of his sabbatical in July 2013. The terms of reference for the Task Force were to:

1) Examine the existing content and delivery of all of the course offerings in first year,
2) Examine the student response to these course offerings,
3) Identify the strengths and weaknesses of our existing course offerings,
4) Assess the existing and evolving foundational educational needs of all FASE programs,
5) Explore opportunities to develop synergies, or provide allowance for transferability, between programs,
6) Examine the best practices in engineering education including examining the first-year curricula and delivery at other leading comparative engineering educational institutions,
7) Recommend changes, if any to the content or delivery of the first-year courses, and
8) Identify and recommend a course of action for implementation of any proposed changes.

To address these terms, the Task Force has:

1) Conducted two major rounds of consultations in summer 2013 and winter 2014 with students, instructors and departments. These included the use of online surveys, focus group sessions, informal discussion lunches and meetings, departmental presentations, and interviews with targeted people and groups,
2) Analyzed the student course evaluations from 2008-2013,
3) Carefully reviewed the current practices at peer institutions throughout North America, and
4) Reviewed the engineering education literature as it relates to best practices in current and future first-year engineering program content and delivery.

2001 FASE Curriculum Review

The most recent formal curriculum review within the Faculty occurred in 2001 with a decanal Task Force consisting of Professors Richard Bonert, Kim J. Vicente, and Kim A. Woodhouse. This review was broader in its scope as its purpose was to propose change to the entire four-year undergraduate U of T engineering program. Within this review, the Task Force identified seven fundamental core competencies that engineering students should develop through their undergraduate curriculum experience. These are summarized in Table 1.

The most important change that came from this review was the introduction of a significant design, communication and teamwork emphasis throughout the four-year programs. The introduction of Engineering Strategies and Practice (ESP) in the Core 8 programs, and Praxis in Engineering Science, was done in part due to this review.

Departmental curricula within the Faculty have continued to evolve over the past 12 years and major initiatives within the undergraduate programs have been introduced, such as the engineering minors and certificates, the creation of the Institute for Leadership Education in Engineering (ILead), and increased opportunities for study and research abroad experiences. As a result, the Faculty's undergraduate programs have provided new and additional ways for students to develop many of these core competencies.

Table 1: 2001 University of Toronto Engineering Decanal Task Force Core Competencies

Basic Science & Math / Technological Competency		
Design	Independent Learning	Oral & Written Skills
Problem Solving Skills	Systems Thinking	Team Skills

INTRODUCTION

Engineering is a unique profession in which the creativity of the individual is harnessed and directed by the needs of society, and brought together with keen understanding of fundamental laws and principles to collaboratively formulate and solve complex problems. Successful engineers have a very strong technical foundation from their formal education, yet can also learn quickly and adapt to new technologies and developments in their field. Increasingly, engineers also need to be globally aware and be able to communicate and work effectively in and lead diverse and multi-disciplinary teams.

As the premier engineering school in Canada, we must ask how we can address the needs of today's engineering graduates, while building on our strengths to improve the learning experience for our future undergraduate students and better prepare them to face the great problems that engineers will be called upon to solve. Indeed, our ever-changing world is filled with such opportunity and potential, yet in the years to come, humanity will face a number of significant challenges: adequate high-quality food and clean water for all, the continued improvement of and demand for healthcare, the intelligent use of rapid technological advancements, and the protection of the earth and its precious ecosystems upon which we all depend. Change is so rapid that "we are currently preparing students for jobs that don't yet exist, using technologies that haven't been invented, in order to solve problems we don't even know are problems yet."[4]

We at the University of Toronto have a responsibility to prepare our graduates to thrive within this climate of rapid change and to use their talents to solve challenges both known and those of which we are not yet aware. We are a unique institution, centrally located in one of the world's most livable, vibrant and multicultural cities, with students from over 100 countries. Our graduates receive a truly global education, and the experiences we provide are transported around the world, with the potential to impact the entire globe.

Given our important place within engineering education, it is essential that we continue to take a leadership role within our undergraduate education, as we have in our continued excellence in research and graduate studies. In 2003, we were on the leading edge in the creation of a first-year engineering design experience, which is now commonplace in most Canadian engineering schools. As the career landscape for our graduates of 2014 is very different than that for our class of 2004, we must enable our students to develop skills that will transcend this continual evolution. Technical excellence is a hallmark of our graduates and this will not change. What must change is how we enable our students to learn to transfer and apply this technical knowledge in new and unexpected ways. Our students must graduate as complete engineers, technically brilliant problem-solving experts, who can design effectively in diverse teams, clearly articulate their thoughts and ideas, understand the importance of self-reflection and independent learning, and appreciate their potential impact on society and the environment as systems thinkers.

[4] Did You Know? (3.0), Researched by Karl Fish, Scott McLeod, and Jeff Brenman on the exponential pace of information technology and content generation, https://www.youtube.com/watch?v=YmwwrGV_aiE

The four primary messages of this report are that our first-year programs for Core 8 and TrackOne students should:

1) Ensure students have a world-leading innovative education in a broad range of foundational principles including mathematics, physics, chemistry, materials science, computer programming, engineering design, communication and teamwork,
2) Deliver the programs in such a way that the courses work in concert through intelligent curriculum design, careful use of students' time, and strong collaboration and coordination within the instructional team,
3) Provide intentional transitioning from the learning strategies used by our students at the high-school level to the university environment, thus enabling them to begin to discover their own methods for successful life-long learning, and
4) Enable students to begin to develop core engineering skills of learning from failure, optimization, visualization, estimation, systems thinking, and real-world problem solving by applying fundamental knowledge to a practical scenario through a program-specific hands-on experience.

A proposed mission statement for the Core 8 and TrackOne first-year program is:

As a student in the First-Year Core 8 and TrackOne Engineering Program at the University of Toronto, you will be given the opportunity to:

1) *Create a* ***strong and transferable technical foundation*** *in essential mathematical and scientific ideas, concepts, and principles,*
2) *Appreciate the* ***relevance*** *of your courses to your development as an engineer,*
3) ***Design*** *creative engineering solutions to real-world problems,*
4) *Understand the positive impact you can have as an engineer on* ***society and the environment****,*
5) *Communicate a persuasive* ***engineering argument rooted in reason*** *through appropriate written, graphical, and oral communications,*
6) *Connect the value of* ***professionalism and ethical conduct*** *of engineers with social justice,*
7) ***Lead and be led****, and to recognize when to do which, and*
8) *Aspire to* ***personal and career goals*** *fitting with your* ***passions, values, talents & skills, and needs.***

SUMMARY OF MAJOR FINDINGS

The strengths of our Core 8 and TrackOne first-year programs are many, including a strong foundational background in a broad range of topics, the opportunity to develop interpersonal and communication skills through a community-based design project, and a talented group of faculty and staff who are dedicated to student success.

The recommendations of the Task Force will work to augment these strengths by addressing the most important deficiencies and concerns that have been raised through our consultations with faculty members, students, staff, and alumni, and our review of the national and international engineering education landscape and relevant research literature. To help frame the discussion, Appendix A summarizes the current Core 8/TrackOne curriculum; a detailed summary of the process and outcomes of the student, faculty, and alumni consultations is presented in Appendix B; and Appendix C provides an overview of the current first-year curricula at peer engineering schools across North America.

Through our consultations, review, and subsequent discussions and careful consideration, ten core recommendations have emerged and are presented below. While these relate directly to curriculum content and delivery, summaries for two additional considerations are also included. These are further discussion of the possible move to a common first-year program and the potential integration of the Core 8 and Engineering Science cohorts. The report concludes with a set of two proposed curriculum models and a suggested implementation plan which have been developed to address the recommendations for change described below.

Strengths and Areas of Improvement – Faculty and Students

Broadly speaking, our undergraduate program is valued as one which provides our graduates with a very strong theoretical base and solid foundation in the ability to critically analyze problems. Specific to the first-year Core 8 and TrackOne curriculum, students report appreciation for the variety and breadth of the program and the interest and challenge of the material. Students report that their professors are approachable and willing to help and that we have a talented group of staff to support their success. Many students commented that they valued the opportunity to develop relevant professional skills through the client-based design experience, teamwork, and course content involved with the Engineering Strategies and Practice courses. Faculty also noted their appreciation with the receptive, motivated, and enthusiastic group of students who take their learning seriously and are willing to work hard.

A number of areas of improvement were identified by students and faculty relating to the content of our Core 8 and TrackOne curriculum. Students identified the following critical needs for:

- More effective and cohesive delivery of the first-year lectures, tutorials and assessments,
- Improved consistency of instruction and grading in Engineering Strategies and Practice,
- Inclusion of numeric computation,
- A more discipline-specific introduction to the engineering profession,
- Improved relevance of the core courses to engineering applications and upper-year courses,
- Enhanced preparation for job opportunities and career development,
- Improved blending of curricular and co-curricular activities,
- Greater opportunity for hands-on experiences,

- Intentional transition to the university academic environment,
- Better management of the discrepancies in background preparation in mathematics and computer programming,
- Improved relevance of the programming language to the particular discipline, and
- Introduction to important software such as Excel, MATLAB, and AutoCAD.

Additionally, faculty suggested the curriculum needs to support students to:

- Develop stronger skills to work with advanced mathematics in an engineering setting,
- Develop core engineering skills such as estimation, unit analysis, thinking across length and size scales, and solving problems through numeric computation,
- Focus more specifically on logical and computational thinking,
- Develop the ability to work in three dimensions (e.g., Cartesian, cylindrical, and spherical systems) and a greater capacity for spatial visualization,
- Understand the complexity of "real" engineering problems,
- Work to improve the retention of concepts and material into the second year and regularly assess this retention,
- Specifically develop their problem-solving skills.

Introduction to statistics and exposure to Excel were highlighted by members of a few departments as current curricular deficiencies. A number of instructors in second-year courses noted that students struggle to carry with them the key concepts and ideas from first year and lack an ability to transfer their fundamental knowledge to engineering problems.

Students within the focus group sessions did not express a significant concern with the overall workload in the program, yet some did complain about the "cycle of catching up" that they faced. A number of faculty members also found the workload to interfere with students' ability to absorb and integrate new concepts through independent review and consideration. Indeed, faculty raised concerns with the prevalence of students "surviving from one assessment to the next" and felt that this inhibits students from developing effective techniques of "how to learn." As one professor put it, "students lack a culture of doing problem sets to learn rather than to get through them." Also, over 30% of the Core 8/TrackOne students responding to the 2013 first-year exit survey indicated that the first-year workload was unmanageable, while only 40% agreed that they led a "balanced" life in first year. On average, over a third of the class reported spending over 20 hours a week on course work and studying outside of class.

Comparisons with Peer Institutions

In relation to other Canadian engineering schools[5], we have been a leader in engineering education through our introduction of engineering design, communications, and teamwork in the first-year experience over a decade ago. Almost all Canadian engineering programs have since created a similar curriculum component to ensure that first-year students are exposed to these basic practices of working engineers.

Canadian Institutions

Six of the seven Canadian programs studied here have a common first year-program, with the exception of the University of Waterloo. As detailed in Appendix C, the first-year mathematics curricula at Canadian engineering schools are quite similar, with differences observed in science and computer programming. Most have three mathematics courses: Calculus I and II, and Linear Algebra. About half have three physics courses (as we do for some of our programs), while the others have some variant of a standard Physics I and II sequence. For Queen's, this is Mechanics (Statics) and then Dynamics/Electricity and Magnetism, while for McMaster this is Mechanics (Statics and Dynamics) and then Waves and Electromagnetism. Many have one chemistry course, with two programs including some materials science into this course. Two programs delay the materials science coverage to second year, while two others have specific courses on this topic in first year. There a varied approach to computer programming with languages such as C, C++, Python, MATLAB, and a single course using C, MATLAB, and Excel. McGill does not have a first-year programming course.

Not all programs focus on teamwork-based engineering design in the first year, with both McGill and University of Alberta providing opportunities for complementary studies elective(s) instead. The other programs invest significant contact hours over the two terms into design, communication and teamwork, ranging from six hours (Calgary) to 16 hours (Queen's). The Queen's approach is one of the few that enables students to gain client-based design experience through a design project in the winter term. Within this engineering design sequence, they also have courses that focus on Complex Problem Solving (integrated with MATLAB), the development of Laboratory Skills, and Engineering Graphics.

Four of the seven programs offer a curricular component that allows students to learn about the engineering profession and the various types of engineering disciplines, exposing them to potential career opportunities. These are typically a one- or two-hour seminar one-term course, although the University of Alberta runs this course over two terms.

American Institutions

A careful analysis of the first-year programs at nine leading American engineering institutions has shown that in general, the first-year curricula in the US cover less material than our program[6]. Indeed, in terms of the total contact hours for both terms, many Canadian schools are in the 50-55 hour range for the entire year (split about equally between the two terms), whereas most US schools

---

[5] For the purpose of this review, the schools were: University of Alberta, University of British Columbia, University of Calgary, McGill University, McMaster University, Queen's University, and the University of Waterloo.

[6] These include Carnegie Mellon, Cornell University, Georgia Institute of Technology, MIT, Northwestern University, Princeton, Purdue University, University of California Berkeley, University of Illinois at UC, and University of Michigan.

are closer to 40-45 total contact hours. Most programs covered less mathematics, physics, and chemistry/materials science, instead delaying this extra content to relevant second-year programs as needed. Nearly all programs have only two first-year mathematics courses, Calculus I and II, and Linear Algebra is generally delayed until the second year for programs that require this material. A few programs integrated the first part of linear algebra (matrix theory) into their other mathematics or physics courses, and one program has a two-hour per week course on this material. The physics content coverage is also less, with most offering a single classical mechanics course (statics and dynamics) with electricity and magnetism covered in second year. Only Georgia Tech and MIT have a two-term sequence of physics courses (Classical Mechanics and Waves, then Electricity and Magnetism). All but two of these first-year programs use MATLAB in their first-year program. In four of them, MATLAB is the exclusive programming language. Python is used at Carnegie Mellon, Cornell, and MIT as their programming language of choice either exclusively or as an alternate to MATLAB, depending on the program.

Innovative Programs

In comparison with our program, there are some innovative approaches to first-year engineering curriculum both in Canada and in the US:

- *The Maker Experience*:
  McMaster has recently introduced the EPIC lab (Experiential Playground and Innovation Classroom) for first-year students. The goal of this lab is to "go beyond the textbook" and "build and experiment" to "excite and motivate first-year engineering students with opportunities to have hands-on experience with 3D prototyping printers, video games, Android tablets, Scribbler and Fischertechnik robots."[7] Students can book equipment and space in this drop-in lab, and complete course projects or participate in extra-curricular organized competitions and projects. This supports their stated mandate to place a strong emphasis on "experiential learning, facilitating students with the skills and the understanding to become 21st century engineers, ready to tackle the most challenging and exciting problems of the coming decades."[8]

- *Introduction to Engineering Courses with Specialized Focus*:
  a. First-year students at **Cornell**[9] must choose a one-term Introduction to Engineering course which provides them with an open-ended problem solving experience through a specialized focus. Possible choices include **Lasers and Photonics**, **Engineering Applications of Operational Research**, **Modern Structures**, **Water Treatment Design**, **Materials: The Future of Energy**, and **Biomaterials for the Skeletal System**.
  b. **Carnegie Mellon**[10] offers a similar experience with students having to take two Introduction to Engineering elective courses, one for breadth and one for depth. Each department offers their own course, i.e., Introduction to Chemical Engineering, Introduction to Electrical and Computer Engineering, Introduction to Biomedical Engineering, etc.

---

[7] http://epiclab.mcmaster.ca/
[8] See http://www.eng.mcmaster.ca/excel/index.html or https://www.youtube.com/watch?v=ZkoOefu3wUo
[9] http://courses.cornell.edu/preview_program.php?catoid=22&poid=10884
[10] http://engineering.cmu.edu/current_students/first_years/introductory_electives.html

c. As part of the Illinois Engineering First-Year Experience (IEFX) at the **University of Illinois at Urbana-Champaign**[11] (UIUC), the ENG100: Engineering Lecture consists of a four-week orientation to engineering component (12 lectures), and an eight-week elective experience with options such as: **Aspirations to Leadership**, **Engineering for Global Development**, **Live Like a Learner: Theory**, **Application, and Acquisition of Learning Skills**, **MATLAB & Excel Essentials**, and **Spatial Visualization**. These make use of undergraduate Engineering Learning Assistants as a means to provide additional support to new first-year students.

d. In 2010, select programs in the **MIT**[12] School of Engineering introduced their Flexible Engineering Program that "responds to the evolving desires of our undergraduate students, and emerging changes in the engineering professions, while remaining true to the School of Engineering's tradition of rigorous technical education." Students complete the core departmental requirements and declare an additional concentration, which can be interdisciplinary in nature (i.e., energy, transportation, or the environment) or can be applied to multiple fields (i.e., robotics or engineering management).

- *Integrated First Year Curriculum*:
  a. For many years, **Northwestern** has had an integrated program called Engineering First. One component of this program is their *Engineering Analysis 1*, *2*, *3*, and *4* courses which combine linear algebra, statics, dynamics, computer programming, and differential equations[13].
  b. Recently, **Princeton**[14] created an optional integrated presentation of Engineering, Math, and Physics through three new courses. The first two courses combine mechanics and thermodynamics and multivariable calculus with an emphasis on engineering applications. The third course focuses on important topics in modern engineering including energy conversion and its environmental impact, robotic remote sensing, and wireless communications.

---

[11] http://www.iefx.engineering.illinois.edu/#!iefx-electives/c1xqq
[12] http://engineering.mit.edu/programs/flexible
[13] These course titles are: Computational Methods and Linear Algebra, Linear Algebra and Mechanics, Dynamic Systems Modeling, and Differential Equations which is taken in second year (http://www.mccormick.northwestern.edu/academics/undergraduate/core-curriculum/engineering-first.html)
[14] http://kellercenter.princeton.edu/learn/emp/overview/

Related Engineering Education Literature

A significant body of research has emerged over the past 50 years relating specifically to first-year engineering education. For example, numerous papers have been published through peer-review in the *Journal for Engineering Education*, *IEEE Transactions on Education*, and the First-Year Programs Division at the annual *American Society for Engineering Education* (ASEE) conference. While much of this research has focused on retention in engineering, first-year engineering design experience, and first-year transition, the reporting of the design and impact of first-year curriculum innovations has also received much attention.

A number of important papers related specifically to this review have been identified. Froyd, et. al. [1], recently presented a comprehensive review of the five major innovations in engineering education from the past 100 years. These include the shift in engineering curricula from a primarily applied experience (i.e., surveying, machine shop, and drawing) to the current program models which emphasize a more theoretical science and math-based approach. The authors also highlight the innovations associated with a renewed emphasis on design, a shift to outcomes-based assessment, and the influence of education, learning, and social-behavioral sciences research on curriculum design and delivery. They conclude with a discussion on how technologies and alternate architectures such as Technology Enhanced Active Learning (TEAL) spaces have and will continue to change the learning experience in engineering education programs.

The concept of an integrated first-year curriculum in which the fundamental mathematics, sciences, and computer programming courses are more tightly connected with each other through engineering projects and applications has been around for nearly two decades. First proposed by Froyd and Winkel in 1988 [2], numerous papers have followed, with the review article in 2005 providing a summary of the primary motivations, outcomes, and future directions [3].

The majority of research took place in the late 1990s and early 2000s, in part due to the creation of the Foundation Coalition that was supported by the National Science Foundation until 2004. This coalition consisted of nine US engineering schools and supported the development and piloting of a new approach to the first-year engineering curriculum. This approach worked to develop both integrative and analytical thinking, improve transfer of knowledge through the "de-compartmentalization" of courses and content, and increase diversity and retention within the engineering program. The new curricula were based on the creation of intentional learning communities [4] and its basic components were [5, 6]:

- Clustering of students in common courses,
- Teaching and using teamwork among students and faculty,
- Using active and cooperative learning methods,
- Encouraging industry involvement,
- Using technology-enhanced classrooms,
- Incorporating undergraduate peer teachers,
- Integrating the introductory sequences of physics, chemistry, mathematics, and engineering,
- Facilitating faculty team teaching, and
- Using rigorous assessment to evaluate performance.

The pilot programs and studies showed improved student disciplinary learning, with the integrated cohorts outperforming the traditional cohorts, sometimes by very wide margins. Students in an integrated program at Arizona State University had 30% higher averages than their traditional counterparts on the standardized physics Force Concept Inventory [7], University of Massachusetts Dartmouth saw a 5% to 14% improvement on common exam questions in first-term calculus, physics and chemistry [6], and students in an integrated program at Rose-Hulman demonstrated better performance in second-year courses than their traditional counterparts [8]. Faculty at Rose-Hulman also rated the students from the integrated program more highly on "*areas of their communication skills, ability to integrate the use of technology for problem solving, ability to develop their ideas to appropriate conclusions, and ability to integrate previous knowledge into their current work.*" [8]

A more recent analysis found that students who had progressed through a first-year integrated experience had a higher GPA in one of their second-year courses (2.78 versus 2.33), and a significantly lower repeat rate (6.5% versus 17.1%) [9]. Another consistent finding amongst the institutions that piloted integrated programs in the mid- to late-1990s, was the reduced number of students achieving marks of D or F, or withdrawing from the program (i.e., DFWs). North Carolina State University saw that 69% of its students in the integrated program achieved marks of C or better, compared with 52% for the comparison group. They also found that fewer students in the pilot program experienced academic difficulty. More recently, Ohio State saw their DFW rate decrease from 12% to 9% in their first-year program [10].

The literature on integrated first-year programs also report 10% to 25% increases in first-year retention rates (see for example [10] and [11]), and this new type of program had an even greater influence on the retention of women and underrepresented minorities [5]. Similar positive results were also observed with graduation rates, as higher proportions of students in the integrated curricula (~84%) graduate versus the traditionally-taught comparison group (~66%) [12]. It was also found that students in the integrated programs were completing their foundational requirements more quickly, taking an average of only 3.6 semesters as compared to 4.1 semesters [13].

Even with these positive results for learning community-based integrated curricula, it is nonetheless understandable why a number of the original pilot programs were not fully institutionalized. Challenges include (a) requirement for the same student cohorts in connected courses, which is sometimes challenging when many courses are shared with other departments, (b) administrative cooperation amongst participating departments, and (c) significant financial and personnel investments in developing and sustaining the new curriculum.

Despite these challenges, a number of institutions have either continued with this approach for their core curriculum[15], or have more recently developed similar approaches[16]. Departments at some schools have also worked to improve the course-to-course connections, such as Texas A&M [9] and the University of Waterloo [14, 15].

[15] These include University of Massachusetts Dartmouth, Louisiana Tech, North Carolina State University, and Northwestern through their Engineering First Program (http://www.mccormick.northwestern.edu/academics/undergraduate/core-curriculum/engineering-first.html)
[16] Princeton and the University of Cincinnati being two examples.

Engineers of the Future and the Evolution of Engineering Education

In a number of recent publications that address the future of the engineering profession, there has been a consistent call to ensure that engineering graduates have a multi-faceted skill set [16] - [21]. In 2004, a panel of industrial, academic, and governmental experts from the US released the Engineer of 2020 report [16]. This report highlighted *strong analytic skills*, *practical ingenuity*, *creativity*, *communication*, *leadership*, *professionalism*, *resilience and flexibility*, and *lifelong learning skills* as the key attributes of the future engineer. The full set of attributes (shown in Table 2) is based on the panel's identification of the following primary principles that will shape the work of the engineer of the future: (a) a rapid pace of technological change, (b) a more globally interconnected world, (c) an increasingly diverse population who are involved with or affected by technology, (d) an understanding that technological innovation will be based on social, cultural, political, and economic forces, and (e) the presence of technology that will be even more ubiquitous and significant than ever.

Table 2: Engineer 2020 Essential Attributes

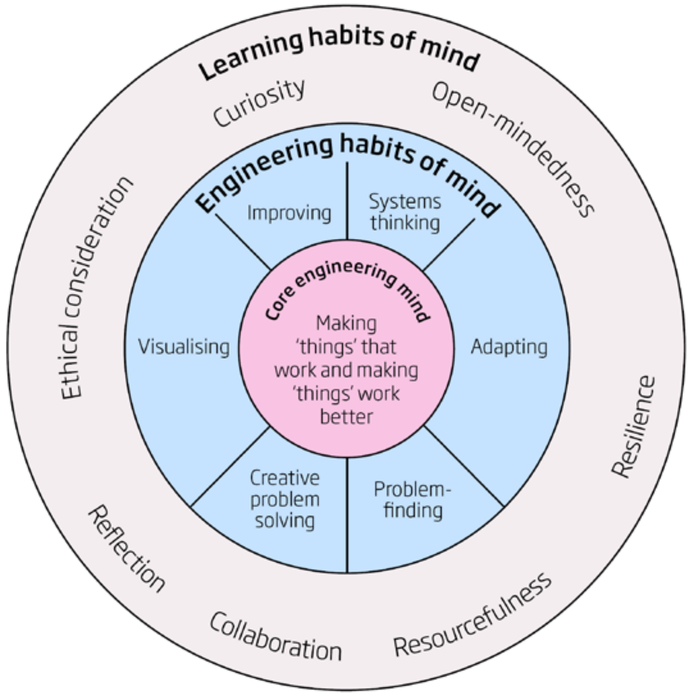
Strong analytical skills	Good communication	Have high ethical standards and strong sense of professionalism
Practical ingenuity	Understand the principles of business and management	Be agile and flexible in the presence of rapid technological change
Creativity	Understand the principles of leadership	Be lifelong learners

In the first phase of a multi-year project on Transforming Undergraduate Engineering Education, the National Science Foundation and American Society for Engineering Education identified the "High-Priority Knowledge, Skills, and Attributes" for engineering education [19]. Topics such as communication skills, technical fundamentals, problem solving, critical thinking, and teamwork skills were identified as the primary responsibility of academia, while the development of project management skills, economics and business acumen, and systems integration were deemed to be the shared responsibility of academia and industry. A few of the items expected to become significantly more important in the workforce over the next ten years – such as global perspective, systems integration, decision-making, project management, and able to adapt to rapid change – had a majority rating of fair or poor within current engineering graduates.

Similar messages have been found within the Canadian context, with a recent collection of articles advocating for more professional skills development, connection between academic preparation and workplace practice, and the move towards alternative learning, teaching, and delivery models [20]. From an industry perspective, a 2007 Engineering and Technology Employer Survey [18] found that while 87% of employers were satisfied with the science-based skills of recent engineering graduates (0 – 5 years of experience), only 64% were satisfied with the graduates' non-technical skills.

Finally, a more recent report written from the British perspective [21], identified six core Engineering Habits of Mind (EHoM) through an extensive consultation with a wide variety of engineers and engineering educators. These are summarized in Figure 1. The authors present unique examples of how the EHoM are being incorporated into K-12 and university education, and suggest that the well-known *Conceive Design Implement Operate* (CDIO) approach to engineering curriculum design is aptly suited to develop these habits. The authors specifically note how University of Liverpool, Imperial College, and University College London support the EHoM through increased "problem/project-based learning with real-world projects, active learning that fosters systems thinking, peer learning fostering collaboration, or CDIO fostering integration across the engineering curriculum." [21, pg. 39]

Figure 1: Centre for Real-World Learning Engineering Habits of Mind (taken from [21]**)**



Within Canada, there is a strong correlation between these reports and the Canadian Engineering Accreditation Board's (CEAB) set of 12 graduate attributes, listed in Table 3.

Table 3: CEAB's Twelve Graduate Attributes

Knowledge Base	Problem Analysis	Investigation
Design	Use of Engineering Tools	Individual and Team Work
Professionalism	Communication Skills	Impact of Engineering on Society and the Environment
Ethics and Society	Life-long Learning	Economics and Project Management

Engineering programs across Canada are working to develop learning outcomes based on these graduate attributes, and valid assessment methods to facilitate their move from the invisible to the visible in their curricula.

RECOMMENDATIONS

The picture that emerges from these many sources is that our core curriculum is quite strong and has ultimately served our graduates reasonably well up to this point. However, the needs of our graduates are changing and there is a greater call to prepare the "whole engineer," one who (a) can creatively adapt their strong analytical skills and technical knowledge to new challenges, (b) view problems from a systems level and incorporate multiple constraints simultaneously, (c) work effectively in teams, (d) communicate clearly, (e) develop personalized learning skills, and (e) have strong visualization abilities.

What role can a modified core curriculum play to address these evolving needs? The first-year program is a foundational year and it is essential that it continue to provide the required prerequisite material for the upper-year courses. The following recommendations, as they relate to curriculum content and delivery, aim to strengthen the technical foundation through an increased ability to retain and transfer knowledge to new contexts. They will also fill the deficiencies identified by students, faculty, and the broad review of the future needs for engineering education.

In short, the recommendations of the Task Force are to:

Recommendation #1:
Improve the Relevance and Integration of the Foundational Courses

Recommendation #2:
Foster an Effective and Engaged First Year Instructional Team

Recommendation #3:
Enhance the Fundamentally Strong Learning of Mathematics

Recommendation #4:
Address Discrepancies in Prerequisite Backgrounds in Mathematics and Computer Programming

Recommendation #5:
Incorporate Numeric Computation into the Core Curriculum

Recommendation #6:
Create a new First-Year Seminar Course to Support the Transition into Engineering

Recommendation #7:
Create Opportunities for Program-Specific Hands-On Learning that Facilitate the Transfer of Fundamental Knowledge to Practical Problems

Recommendation #8:
Support New Pedagogical Approaches and Opportunities for Self-Directed Learning

Recommendation #9:
Carefully Review the Content and Delivery of Engineering Strategies and Practice

Recommendation #10:
Develop an Assessment Protocol for the Effectiveness of the First Year Program

The details of each recommendation are described in the sections below.

Recommendation #1:
Improve the Relevance and Integration of the Foundational Courses

This recommendation relates to two main ideas:

- **Relevance**: The extent to which the foundational material in the first-year is connected to an engineering context, and
- **Integration**: The extent to which the individual courses are intelligently woven together and specific learning communities are fostered and leveraged throughout the program.

Instructors within the second-year programs identified as one of their primary concerns the difficulties students have transferring their understanding of a theoretical concept to a new more applied situation. As well, when first-year students were asked at the end of their year how the might be improved, the most popular theme related to the “relevance” of the main concepts to their work as an engineer. This was further supported within many of the nine student focus group sessions, where students said they would like the material to be more connected to their upper-year courses, and to the “bigger picture” of their work as engineers.

Faculty and students also raised concerns about the disconnection between the content and work within different courses. There is an opportunity to develop a more cohesive curriculum in which the efforts and work in one course are carefully built upon and used in the assignments and learning experiences of other courses. The development of vectors as a general notion in Linear Algebra is directly applicable to the analysis of trusses and beams in Mechanics. The analysis of problems relating to the curvilinear motion of particles in Dynamics requires strong understanding of unit vectors, derivatives, and polar coordinates. Perhaps the basics of vector algebra could be applied to implement a *k*-nearest neighbour classifier for a biometric verification system, as was recently reported on [22]. Many other linkages exist, it is a matter of carefully considering where these might be and then creating intentional connections.

As the related literature has shown, an integrated program facilitating active and cooperative learning experiences through intentional learning communities and team teaching can support better retention and the transfer of foundational knowledge.

Recommended Actions

A. **Hire a First-Year Curriculum Coordinator**: Create a teaching-stream faculty position within the Faculty and the First Year Office to identify opportunities for course integration in terms of content and delivery, and to work with the teaching staff in all participating departments to facilitate this integration. This position would also develop curricular materials and resources to facilitate course integration, teach into the design curriculum of the first-year program, and coordinate and report on the first-year program effectiveness on an annual basis. These duties would be distinct and in addition to the administrative work that the Chair, First Year position manages, which includes oversight of the First Year Office, the Engineering Student Outreach Office, and The Engineering Student Recruitment and Retention Office.

B. **Create a Curriculum Map of the First-Year Program**: In order to facilitate the intentional integration of courses, a detailed curriculum map should be created. This would be a living online resource incorporating course syllabi and samples of solved problems relating to the various concepts. It would greatly benefit instructors in second-year courses as they could see exactly what students had learned in the first-year program. It would also encourage the use of a common vocabulary between first- and second-year courses and/or would facilitate the intentional translation by the instructor of significant changes in notation or common terms. It should also be connected to the CEAB graduate attributes that are tracked for continual curriculum renewal.

C. **Carefully Assess the Current Curricular Coverage**: A greater awareness of the material covered in the first-year courses is required amongst our faculty members, particularly those who teach in the second-year programs. It is recommended that a set of panels with representatives from the Core 8 programs carefully review the fundamental aspects of the mathematical, science, and computer programming coverage, and how it relates to their existing second-year programs.

D. **Carefully Assess the Student Workload**: Student workload should be reduced to allow students increased opportunities to reflect on new material and to afford opportunities for self-development through extra-curricular involvement. Workload consists of three major components: time spent in-class, time for studying and reflection, and time to complete assignments and projects. A review of students' time spent on these three components is recommended, and – in collaboration with the course coordinators and instructors – a holistic plan for workload reduction should be implemented.

E. **Create a First-Year Core 8 Curriculum Committee**: This committee will contain faculty representatives from each program and both first- and second-year student representatives. The faculty members should have specific experience with the Core 8 first-year program. The initial tasks of this committee will be to implement the recommended changes supported by the departments and students, and to facilitate the deeper curricular reviews called for in this report.

F. **Support the Creation of Intentional Learning Communities**: Through careful scheduling, students should be grouped into appropriate communities through which they progress through the program. At the same time, the Engineering Strategies and Practice courses should continue to provide an opportunity for students to interact with students outside their own learning community.

G. **Develop an Example Repository of Reusable Learning Objects**: A collection of high-quality reusable learning objects should be created that instructors and/or teaching assistants within the mathematics and science courses could use in their interactions with students. These would be drawn from disciplinary and multi-disciplinary examples.

Recommendation #2:
Foster an Effective and Engaged First Year Instructional Team

During our consultations with our peers, it became apparent that there is universal concern that the first-year curriculum and its delivery is not effectively preparing students for the upper years within their respective programs. In general, students rated the quality of first-year instruction very highly and felt that our faculty were engaged and willing to help. However, students also suggested that improvements are needed to in-class and TA instruction.

With regards to TA instruction, concerns were raised around the preparedness of the TAs, their ability to comment on the material delivered in class, and their consistency with the opinions and subject matter of the instructor.

It was also noted that a proportionally larger number of first-year courses are given by sessional lecturers (including mathematics courses).

As well, many students commented that course assessments need to be more authentic (i.e., related to prior material and learning experiences) and well-structured, and they sought assurance that grading is well-supervised and coordinated. As an example, the idea of ‘inauthentic testing’ was voiced: the evaluations were not evaluating material in the same fashion, or with the same emphasis or priorities as communicated in the classroom. This was a particular concern regarding the first-year math curriculum. Concerns were also raised that the first-year math curriculum relies on students’ ability to know or memorize mathematical ‘tricks’ in place of conceptual understanding.

ESP was identified as key, appearing in numerous student complaints about the first-year experience. A primary concern is the perception of inconsistent instruction, philosophies and grading between the Communication Instructors, and between the TAs and instructors. Another concern focused on the technical merits of the engineering problems students were asked to solve in the ESP project (i.e., failure to convince students that projects such as workflow design are engineering work rather than “interior design”). Finally, concerns about the grading practice in ESP were voiced; specifically the lack of consistency between TAs, and the need for individual TAs to have a defined distribution of marks.

Recommended Actions

A. **Each department should adopt a practice of assigning instructors with proven teaching experience to first-year courses.** The aim of this recommendation is to move to a culture where the departments and instructors place quality of instruction and preparation of the students for upper year courses above all other considerations. The first-year learning experience requires both clear and organized instruction as well as support in the development of good learning habits through mentorship and modeling. An instructor with a proven track record of high-quality teaching is well suited to provide our first-year students with these unique needs. In order to attract high-quality teachers into the first-year program, it may be necessary to give the instructor more than a 1.0 teaching credit. This increase in teaching credit may be further justified by some of the recommendations that follow.

B. **A ‘College of First Year Instructors’ should be established within the Faculty.** This idea leverages some of the recent initiatives of the First Year Office which has been facilitating first-year instructors meetings during the past two academic years. The college would continue this activity, and strengthen the relationship between first-year instructors and provide special recognition of the unique role of first-year teaching. The college would also facilitate coordination between courses (including mathematics courses), so that instructional ideas, updates on the progress of the first-year class, dissemination of feedback from first-year students and concerns about the first-year program (from any level) can be shared in relative real time during the fall and winter semesters. Real time discussion in place of retrospective and post-mortem discussion is clearly more beneficial to the students, instructors, TAs and the entire first-year team. Opportunities for content integration within the first year, especially in mathematics, would also be possible within a college. In addition, the college could consider best practices in first-year evaluation, assessments and grading, and would be an avenue for senior first-year instructors to provide mentorship to instructors that are new to the first-year program.

C. **High value should be placed on TA support within the first year.** Just as high quality instructors should be placed in first year, so should the highest quality TAs. An intentional appointment process for TAs should be put in place which might include testing on subject matter, and a formal interview conducted to judge their potential to successfully contribute to first-year instructional activities. Our Faculty should also implement pre-assignment training, during-assignment support, and a mentorship program for first-year TAs who may be taking on the role for the first or second time. To facilitate this, course instructors should attend as many of the tutorial and laboratory sections as is required to ensure these sessions are of high-value for the students, and that TAs are receiving all the support they need in their development as educators. For courses with multiple instructors, a change in the current practice of random placement of students in tutorials would have to be made so the instructor knows which tutorial/lab section(s) corresponded to their lecture section(s). As well, it should become practice for TAs to attend course lectures if deemed necessary for them to improve their teaching capabilities. We recognize that these efforts may require an additional allocation of TA hours to the first-year courses, and that instructors may need more than a 1.0 teaching credit to support these activities in acknowledgement of the extra time commitment. The Faculty should, in coordination with CTSI, support TA training programs for first-year course TAs.

Recommendation #3:
Enhance Fundamentally Strong Learning of Mathematics

Calculus and linear algebra are pre-requisites for fundamental courses in all Core-8 programs. Hence, comprehensive coverage of these in the foundation curriculum is essential for the successful transition of students into the more specialized second and upper-year programs.

It is also important to recognize that the understanding of the fundamental concepts and the development of problem solving capabilities gained through the first-year mathematics courses underpinned most technological breakthroughs of the past and will likely (at least) influence those of the future. Our graduates will remain successful in a volatile and globally competitive job market if they know not just the current state of the art in their discipline, but also its mathematical foundation.

Our review has found:

- Amongst faculty, there is broad concern over students' inadequate understanding of fundamental mathematical concepts, which affects their performance in upper-year courses, as well as in graduate courses and their professional careers,
- Students indicate that they have a hard time relating the material they see in their first-year courses on mathematics (calculus, linear algebra) to their upper-year courses. On one hand, these courses fail to deliver an appreciation of mathematical skills as <u>transferrable</u>, problem-solving skills with broad applicability in career paths in engineering and beyond. In addition, further efforts need to be made in terms of presenting motivating, authentic examples of mathematical concepts applied to engineering problems, and
- It has been observed that domestic high-school curriculum changes have further eroded the background of a large portion of our incoming students. Eventually, this limits their chances to do well in first-year mathematics and sciences courses and transfers the problem to the upper years.

Recommended Actions

As a leading engineering institution, we have a great share of responsibility for the quality of engineering education and the overall preparation of our students for the globally competitive market they will enter upon graduation. While recent high school curriculum changes have produced a younger (by one year) and less well prepared generation of first-year students, our response has not yet risen to this challenge. We recommend that a **"Stepping-Up Program for Mathematics"** be developed. This would be a comprehensive program of higher standards, accompanied by stronger support for our first-year mathematics courses, with important components described below.

A. **Value High-Quality First Year Instruction in Mathematics:** The Faculty should try to limit, if not completely deny, the appointment of sessional instructors with limited or no prior teaching experience to first-year mathematics courses. Instead, it should provide incentives for faculty members with proven teaching track records to assume first-year teaching responsibilities (for example, the previously mentioned teaching load reduction). In addition, the expected Interdivisional Teaching Agreement should provide a framework to facilitate action on this recommendation.

B. **Set Higher Standards:** Given the importance of the fundamental mathematical concepts to upper-year courses, higher standards for the demonstration of understanding should be set for these courses; for example, a 60% average to pass the first-year mathematics courses. Alternatively, a required remedial support program in the winter and/or summer terms for students who have passed with a lower average (perhaps in the 50%-60% range) would focus on improving the understand of the most critical topics. These higher standards should be accompanied by an instruction team that is better equipped to teach effectively (see Recommendations #2 and #8), and greater support in the academic transition (Recommendation #6) so that students have all the support they need to reach the high standard expected of them. In addition, more authentic assessments which accurately measure the desired learning outcomes for these courses must be developed.

C. **Enhance Relevance of Content for Calculus I and II:** In collaboration with the previously mentioned content review for the mathematics courses, it is suggested that the material on limits and derivatives be abbreviated to a modest degree such that a greater introduction to differential equations can take place in Calculus II.

Recommendation #4:
Address Discrepancies in Backgrounds in Mathematics and Computer Programming

Depending on their high school and country of origin, incoming students join the Faculty with a background in mathematics and computer programming that varies from complete ignorance (for example, no exposure to computer programming at all) to profound expertise (for example, students who have completed intensive programming courses at high school and are at an advanced programming level on day one). These discrepancies exist in all subjects, but are particularly pronounced in math and programming. The extent of discrepancies observed invalidates the approach of addressing the relevant courses to the mean student, since the main problem is how to serve students that occupy these opposite ends of the spectrum of background preparation in the same lecture and tutorials/lab.

Consultations with faculty members within the Faculty, the Department of Mathematics, and the Department of Computer Science have provided a comprehensive picture of the problem. For example, our calculus courses dedicate almost half of their time to high school mathematics review. While this review is accompanied by a more rigorous and deeper approach, some students find the first calculus course to be quite repetitive and easy. Indeed, the course evaluations from 2008-2013 consistently show below average levels of difficulties for Calculus I and very high ratings for repetition. While the difficulty level for the Calculus II course is typically on par with the courses, the degree of repetition ratings are still well above average. Introductory programming courses in computer science adopt the approach of the compressed classroom, to give advanced students the opportunity to bypass class resources that are geared towards less advanced students.

Recommended Actions
To address these issues the specific recommendations are to:

A. **Create a set of Early Online Mathematics and Computer Programming Diagnostic Tests:** In order to help students understand how prepared they are for the Core 8 and TrackOne first-year program, a set of online diagnostics tests for mathematics and computer programming should be developed and made available to incoming students in the beginning of July.

B. **Provide Students with a set of Online Mathematical Modules, and Implement a Group of Special Tutorials in September:** A set of online modules relating to core mathematical concepts should be developed and be made available to students who need additional support before starting Calculus I. At minimum, the topics would be trigonometry, exponentials and logarithms, and limits and derivatives. A series of tutorials throughout the month of September would support those students who were unable to participate in the summer programming and/or were identified to be in need of additional help through a live diagnostic test in early September.

C. **Customize Delivery of Calculus I**: In order to better address the needs of our incoming students, three proposals are suggested for further consideration:
   - **Proposal 1**: Keep the first calculus course within the curriculum common to all students, but tailor the tutorial coverage both in style and in contact hours. This will address students' unique learning needs based on an online diagnostic test that they will be required to take before the beginning of the fall term.
   - **Proposal 2**: Offer two versions of Calculus I. For strong students, a course with two hours of lecture per week that would contain a different pacing of the content, while following the same problem sets and tests and exams; for students with a weaker background, three full hours of lecture per week. The ultimate goal should be for all students to cover the same set of concepts in the first year, at a pace that is best suited to their incoming background. All students would complete the same assessments for this course and then take the same Calculus II course.
   - **Proposal 3**: Provide the option for strong students to take the Calculus I course offered through Engineering Science, MAT194. This would enable the Engineering Science and Core 8 students to interact, and provide a deeper presentation of the material for those with a strong high-school background including AP or IB calculus credits.

D. **Customize Delivery of Computer Programming Courses**: The variation in prior experience in computer programming amongst our first-year students has been an ongoing concern for both our students and faculty members. Possible ways to alleviate the effects of this variation include the proposals below. In all cases, a diagnostic test must be developed:
   - **Proposal 1**: Maintain that all students take the same course, but change the course delivery such that the more advanced programmers can act as peer mentors for novice programmers. An approach that incorporates peer instruction or the use of the inverted classroom would help to facilitate those kinds of collaborative learning.
   - **Proposal 2**: Offer an alternate stream for the course, with fewer contact hours than the regular stream. While the in-term assignments could vary, the major assessments (i.e., the midterm(s) and final exam) would be the same.
   - **Proposal 3**: Consider offering two distinct courses, one for the novice programmer and one for students with a more advanced programming background.

Recommendation #5:
Incorporate Numeric Computation into the Core Curriculum

Facility with numeric computation tools such as MATLAB is becoming increasingly important for our students, both to succeed in the Faculty's upper-year programs as well as in the workforce. It is critical that the foundation for this type of engineering problem-solving approach be introduced within the first-year program. A numeric computation component would also enable students to develop their visualization capabilities and their ability to present, analyze, critique, manipulate, and draw conclusions from graphical representations of complex data. Finally, this would enable more real-world engineering problems to be incorporated into the mathematics and science courses through mathematical modeling exercises.

Recommended Action

A. **Incorporate Specific Instruction on how to use Numerical Computation to Solve Mathematical, Scientific, and Engineering Problems into the Fall and Winter Terms:** A one-hour per week laboratory should be incorporated into the existing fall term Linear Algebra course. This component would be taught by engineering faculty and teaching assistants, and would cover both the basic functionality of the numeric computation tool, such as using matrices and vectors, 2D and 3D plotting, writing scripts and functions, and an introduction to mathematical modeling. No other changes would be made to the existing coverage or delivery of Linear Algebra.

   While it would be expected that some basic theory of numerical computation would be discussed, the focus would be on developing the requisite skills needed to use numerical tools to approximate solutions relevant problems. It is important that this additional component not simply become skills training; this tool should be used in service of a greater, more widely-applicable purpose. To do this, the use of the tool should be integrated into the homework and assessment exercises for the other courses in the curriculum.

   In the winter term, a focus on enabling students to develop competencies in visualization, data management and analysis, and modeling would be integrated throughout the program. This would be implemented through a well-coordinated effort across the courses to include problems within weekly assignments and assessments that would require numeric computation.

Recommendation #6:
Create a First-Year Seminar Course to Support the Transition into Engineering

The Faculty currently offers a series of pre-arrival programming in July and August to help students become better prepared to start their first year in September. Success 101 is a free program consisting of three afternoon sessions covering time management, university resources, engineering problem solving, wellness, and the student academic experience. Despite running Success 101 three times in the summer and abbreviated evening versions, only about one-quarter to one-third of our incoming class attend these sessions. Overall, the feedback for this program is quite positive, yet students mention that some of the material has little impact as they don't really understand how it can be applied, given that they haven't yet started their undergraduate studies.

During the term, we also offer two main support programs, First Year Fridays and Peer Assisted Study Sessions (PASS). First Year Fridays is a weekly one-hour optional seminar which reiterates some of the Success 101 content, but places it in context within the student's current experience. Even though the student focus groups and exit surveys demonstrate that students see the value in these topics and experiences, participation is very low (~ 5 to 20 students out of a possible audience of 1200). While a number of creative ways to market these programs have been used over the years, widespread acceptance of the programs remains very limited since they are not required.

Recommended Action

A. **Create a Fall Term First-Year Required Seminar Course:** The course will focus on the intentional transition to the engineering academic learning environment, the study and practice of engineering, and how engineers think. Through this course, students would become more effective learners through the reflective development of important life skills. They would gain an appreciation for the work done by engineers of all disciplines and the potential careers available. Finally, they would better understand how engineers use fundamental mathematics and sciences to approach problems through techniques such as estimation and optimization.

   Many of the main topics and key outcomes of this course would be incorporated into students' entire first-year experience to provide ample opportunity for continued development and greater appreciation for the other aspects of the program. The course would be as interactive as possible, incorporating meaningful but reasonable assessments with key support from upper-year undergraduate TA mentors in small-group tutorials. The final course design and assessment plan would be developed in collaboration with a group of current engineering students from different years, however, the course should have a grade associated with it on the students' transcript, even if it is a credit/no-credit, rather than strictly an attendance-based grading scheme. The course should consist of a bi-weekly one-hour interactive lecture, and a weekly one-hour small-group tutorial.

Recommendation #7:
Create Opportunities for Program-Specific Hands-On Learning that Facilitate the Transfer of Fundamental Knowledge to Practical Problems

One of the strong pieces of feedback from faculty, students, and alumni is the lack of hands-on, practical experience of our first-year students and graduates. A significant effort be must be made to improve the opportunity for students to engage in the building and testing of a physical object or system. Besides this being an excellent opportunity for our students to enthusiastically engage with their program, the supportive development of the "maker-engineer" provides essential skills in engineering judgment, testing, iteration, optimization, and learning from failure.

It might initially seem reasonable to simply adjust the current design project in APS112: Engineering Strategies and Practice (ESP) II such that it becomes more technical and requires specific prototyping of the team's design. However, the current client-based design experience in this course focuses on the problem definition and client interaction stage of the design process. It enables students to work in departmentally diverse teams, develop specific project management skills, identify the real problem for a client (i.e., problem finding), and gain the practical experience of communicating and interacting with, and reporting to an external client. This is a distinct and extremely valuable open-ended design experience that serves a separate purpose in the development of our first-year students as engineers. This is currently one of the components of our Core 8 and TrackOne curriculum that is highly regarded within the engineering education community, has been recognized by national educational awards, and is valued by many of our upper-year students and graduates. Thus, an alternate approach is recommended by the Task Force.

Recommended Action

A. **Each Department Should Develop a Program-Specific Opportunity for Practical Engineering Prototyping Experience in First Year.** This component would serve two primary purposes, allowing students to:
   - Transfer and apply the fundamental concepts learned in the other core courses to discipline-specific problems, and
   - Complete a "build" project(s) that is centered on a relevant theme taken from one of the core areas of work or research in that program. This project should be the same for all students and would be more constrained than the open-ended design experience of ESP II.

   Within the overall design of our Core 8 and TrackOne curriculum, this type of experience has distinct advantages. First, the opportunity to "do engineering" will provide students with an invaluable learning experience in the realities of prototyping and project implementation, and this will enhance their professional "portfolio" of engineering projects. Second, programs or departments will be able to do something of significance with their students, since the resource requirements are for a smaller proportion of the entire Core 8 and TrackOne cohort. It would now be more feasible for civil engineering students to compete in a bridge-building project, perhaps mechanical engineering students would be able to build a biomechanical energy harvester, and maybe chemical engineering students could develop and test a remediation process for contaminated soil. There would even be potential for programs to have their teams work on a subsystem and then integrate them into a greater multidisciplinary project.

   It is expected that these experiences would be designed to make good use of the proposed prototyping facilities, design spaces, and the Technology Enhanced Active Learning (TEAL) rooms in the new Centre for Engineering Innovation and Entrepreneurship building.

   In terms of specific action, two proposed options should be considered by the Faculty:

   Proposal 1: *The Creation of a new set of Winter Term Introduction to Engineering Courses*
   This solution would have each program or department create a winter term course with two hours of lecture, three hours of lab, and one hour of tutorial. While it would be possible to introduce some program-specific technical content through this new course, it is the experience that will have the greatest curricular value. The course could be structured around one large project that is broken up into smaller pieces, or a series of smaller projects that cover a wider range of specialties within that program. In terms of balancing student workload, it would be critical that this course does not become a second significant design experience, instead it should be structured such that the hands-on work is isolated to the laboratory hours.

   The specific advantages of creating such a course are that it can:
   - Provide students with a high-level overview of that field of engineering and its areas of specialty,
   - Enable students to gain further fundamental technical knowledge related to the program,
   - Provide students with an exposure to a systems-thinking approach to problem solving, and

- Enable a greater degree of flexibility in the first-year program to respond to the rapidly changing technological landscape and the modern challenges that engineers face.

One way to incorporate this new set of courses into the first-year curriculum is presented in Proposed Curriculum Model #1, as described below. The inclusion of such a course would improve the first-year curriculum by emphasizing the experience of transferring foundational knowledge to a practical problem and the development of “the engineering mind.” It would better equip the students with the problem-solving and critical thinking skills they need to be successful in upper-year courses, and would support the increased retention of the fundamentals through contextualization. This model also suggests that all students have exposure to the core physics of dynamics, electromagnetism and circuits through a combined Physics for Engineers II course. This will mean that students in some departments would now have more physics coverage in their first-year program, while others would have less.

Similar types of courses have been implemented at other institutions. Two notable examples are:

Carnegie Mellon’s set of Introduction to Engineering courses: Of the seven courses offered in this set, all first-year students at Carnegie Mellon must take two. One is specified by the department (depth) and one is a student elective (breadth). Two examples are presented below, with additional options included in Appendix C:

- **Fundamentals of Mechanical Engineering**: The purpose of this course is to introduce the student to the field of mechanical engineering through an exposition of its disciplines, including structural analysis, mechanism design, fluid flows, and thermal systems. By using principles and methods of analysis developed in lectures, students will complete two major projects. These projects will begin with conceptualization, proceed with the analysis of candidate designs, and culminate in the construction and testing of a prototype. The creative process will be encouraged throughout. (3 hrs. lec., 2 hrs. recitation or lab)
- **Introduction to Electrical & Computer Engineering**: The goals of this freshman engineering course are to:
  - Introduce basic concepts in electrical and computer engineering in an integrated manner,
  - Motivate basic concepts in the context of real applications,
  - Illustrate a logical way of thinking about problems and their solutions, and
  - Convey the excitement of the profession.

These goals are attained through analysis, construction and testing of an electromechanical system (e.g., a robot) that incorporates concepts from a broad range of areas within Electrical and Computer Engineering. Some of the specific topics that will be covered include system decomposition, ideal and real sources, Kirchhoff's Current and Voltage Laws, Ohm's Law, piecewise linear modeling of nonlinear circuit elements, Ideal Op-Amp characteristics, combinational logic circuits, Karnaugh Maps, Flip-Flops, sequential logic circuits, and finite state machines.

MIT - ECE Department's 6.01: Introduction to Electrical Engineering and Computer Science: "6.01 explores the application of key engineering principles, such as abstraction and modularity, in the design of systems that operate in the natural world. Topics include measuring and modeling system behaviors; assessing errors in sensors and effectors; specifying tasks; designing solutions based on analytical and computational models; planning, executing, and evaluating experimental tests of performance; refining models and designs."[17]

Examples from other schools are described in more detail in Appendix C.

For students in the TrackOne program, it is suggested that two options are available. First, students would be given the choice to select the program-specific course of their choice. Second, a multidisciplinary course would be created that spans three or four programs through either a series of distinct hands-on experiences, or a single design project that incorporates fundamentals from a these programs. For example, the University of Cincinnati has created a course titled Engineering Foundations, which "aims to introduce students to the types of activities engineers perform and provide information on some of the engineering program options available at UC. Students are introduced to several engineering disciplines through four hands-on experiments. The students work in groups of two or three to complete activities, such as building and testing bridges, analyzing basic circuitry, and taking performance measurements of a fuel cell system." [23]

Proposal 2: *Modification of Engineering Strategies and Practice to Incorporate a Prototyping Project*

This proposed solution involves modifying the current sequence of Engineering Strategies and Practice I and II in one of two ways.

The first would involve reducing the ESP II lecture hours by one and replacing this with a one-hour per week laboratory component. This component would include 4 three-hour laboratory sessions in which students would engage in program-specific hands-on activities. These activities could include a reverse engineering experience as well as "build and test" opportunities. This lab would run in parallel with the existing client-based open-ended design experience. Proposed Curriculum Model #2 is based on this approach.

The second possible tactic would shift the client-based project earlier in the sequence of courses, such that students' begin to interact with their clients and do their initial "problem-finding" in November of the fall term. This would culminate in the students completing the Project Requirements and Project Management Plan before the end of the term. This would allow student teams to complete their open-ended design project by the end of February of the winter term, such that they could spend the remaining five weeks participating in the program-specific "build and test" experience. One important consideration relating to this approach is the possibility of changes in the composition of the student teams from ESP I to ESP II as a result of transfers into the Core 8 programs from Engineering Science, transfers out of the Faculty, or students not progressing from the fall term.

[17] http://sicp-s4.mit.edu/cat-soop/6.01_spring14/information

Recommendation #8:
Support New Pedagogical Approaches and Opportunities for Self-Directed Learning

The culture within the Core 8 and TrackOne first-year program should be one that fosters innovation in engineering education through careful implementation of research-based practices. Ongoing renewal of course delivery as new approaches and technologies are developed should be a common practice within the program. Two examples of potential new approaches include the recent work relating to inverted and hybrid teaching (e.g., [24] - [26]), and the inclusion of modelling and model-eliciting activities (MEAs) in first-year courses (e.g., [27] - [30]). As well, notable work relating to intrinsic motivation as a means for becoming a more self-directed learner demonstrates the importance of individual choice in assessment activities in first-year curricula [31, 32].

Recommended Actions

A. **Appoint Course Innovators:** We recognize that many first-year instructors and teaching assistants may have ideas on how to innovate their delivery of a course to better facilitate the transition from high school to university, or to apply their subject matter directly to engineering problems used in class. Innovation may take other forms, such as experiments in inverted classrooms, lecturettes, development of reusable learning objects, and course integration. Innovation clearly takes time and given our time-pressed colleagues, we feel the only way to see real innovation is to give first-year instructors time credit for innovation.

   It is recommended that a process be created for the appointment of Course Innovators. This would be available to first-year instructors and teaching assistants, and would provide them with appropriate teaching relief or specific hours in their job description, so that they could improve the student experience through innovations made to the delivery of the lectures, tutorials, and/or laboratories. This would clearly be a negotiable item and, in partnership with the office of the Chair of First Year, we would like to see each department deal with this in a manner fitting to their own priorities.

B. **Provide Students with Options for Different Course Delivery:** It should become common practice to allow students to learn course material in a way that works best with their learning style. Thus, it is recommended that the Faculty continue to expand the development of high-quality online content for the core curriculum. This content should be used to offer students distinct learning options, such as a fully online course or a lecture section taught using an inverted classroom approach. Of course, the major course assessments would continue to be the same for all students.

C. **Provide the Opportunity for Self-Study Projects:** Where possible, the curriculum should support opportunities for students to explore their own interests. For example, the proposed first-year seminar course could encourage them to develop a personal plan on how they might apply their technical knowledge to solving some of the Engineering Grand Challenges.

Recommendation #9:
Carefully Review the Content and Delivery of Engineering Strategies and Practice

It has now been over ten years since the Engineering Strategies and Practice (ESP) courses were added to the Core 8/TrackOne curriculum. While these courses have certainly evolved significantly over this decade, there has never been a formal Faculty-wide review of this critical component of our program. It was also clear throughout our consultations that there is widespread uncertainty, misunderstanding, and ambivalence towards these courses.

Recommended Actions
It is recommended that a careful review of the content and delivery of ESP I and II be conducted by a panel of representatives from each department. This review should result in clear actions to improve the assessments within the course, ensure a reasonable course workload and better integration with other first-year courses, and improve awareness of the purpose and outcomes of these courses within the departments and Faculty.

The brief summary below of the major concerns the Task Force has identified should assist in guiding this review:

A. **Guidance, Feedback, and Marking of Major Assessments**: The most vocal concerns we have heard regarding ESP are the perceived:
   i. Ambiguity in the assignment instructions and tasks associated with the course due to the difficulty students have dealing with open ended problems,
   ii. Inconsistency in the instruction students receive from the course instructors, communication instructors, project managers, and teaching assistants, and
   iii. Variations in marking and feedback given to students on the major course assessments. Thus a review of the current calibration/grading policy with the development of an enhanced degree of quality assurance, such as senior TAs marking papers marked by others and a careful review of the highest and lowest scores.

B. **Lack of Integration with Other First-Year and Upper-Year Courses**: From a curriculum design perspective, ESP is a unique set of courses because it collects student performance data on 11 of the 12 Canadian Engineering Accreditation Board's (CEAB) graduate attributes. The diverse range of skills that the course is instructing, allowing students to practice, and then evaluating are:

Problem Analysis	Professionalism*	Individual and Team Work*
Investigation*	Impact on Society and Environment*	Communication*
Design*	Ethics and Equity	Life-Long Learning*
Use of Engineering Tools	Economics and Project Management*	

For a number of these attributes (indicated with an *), ESP is the only place in the first-year curriculum where they are formally addressed and directly evaluated. These skills need to be incorporated outside of ESP. It currently seems that the learning outcomes of

ESP are isolated from the rest of the first-year courses and within the upper-year technical and design courses. This isolation facilitates the dismissal of ESP as "unimportant" by students who are struggling with attributes that they may feel unequally prepared for, in comparison to their technical knowledge. It is suggested that a greater awareness of the purpose of these courses within the four-year program would alleviate this isolation.

C. **Enhanced Student Participation:** Many students indicated that they would appreciate having greater input and ownership over the project selection and team formation. It is suggested that the review provide some suggestions on how to best to engage students more fully in the course without significantly changing the purpose of the course. It was noted that the current practice of random team assignments accurately reflects the industrial experience. As well, there may be additional benefits gained from intelligent team formation based on a variety of factors such as learning styles and educational or cultural background. However, the most recent practice of allowing students to choose their own fall-term seminar topics was very positively received by students and seminar leaders.

D. **Improved Marketing of the Course:** Both students and faculty would benefit from a greater effort to highlight the importance of the course content and experience. For example, increased opportunities for guest lectures from current or former PEY students and recent alumni would help clarify the purpose of the course for students. Perhaps a more publicly marketed end of year showcase that allows the teams to present and share their work with more than just their client would increase the exposure of the course within the Faculty.

E. **Inclusion of Ethics:** The review should identify how to best incorporate engineering ethics into the courses. This should be considered in collaboration with the content contained within the proposed First-Year Seminar course.

Recommendation #10: *Develop an Assessment Protocol for the Effectiveness of the First-Year Program*

Currently the primary assessments of effectiveness of the Core 8 and TrackOne first-year program rely on course grades and student evaluations. Most course grades are primarily based on the students' performance on the major assessments, which measure a student's degree of understanding of the course content, and their ability to apply the requisite procedural knowledge to a problem. It is recommended that a strategy for broader measures of the effectiveness of the first-year program be developed and adopted.

Recommended Actions

A. **Identification of Core Outcomes for the First Year Program:** Through a multi-department working group, a set of core outcomes should be identified for the Core 8 and TrackOne first-year program. These should be categorized according to the key knowledge, attributes and skills that first-year students develop within the first-year program and carry with them into their second-year programs. This work should be done in collaboration with the curriculum mapping project recommended above and with an awareness of the CEAB graduate attributes.

B. Create and Implement an Ongoing Assessment Strategy: For each of the core outcomes identified by the working group, specific measure(s) should be integrated into the regular assessment of the Core 8 and TrackOne first-year students. Specifically, it is suggested that a group of broader measures be considered. For example, retention of core content can be assessed at the beginning of second year, and an evaluation of the first-year program on characteristics such as critical thinking [28] [33] or spatial visualization [34] [35] could be done through pre- and post-instruction tests.

ADDITIONAL CONSIDERATIONS

Common First-Year, Transferability, and the TrackOne Program

As described above, six of the seven peer engineering schools in Canada have a common first-year program. These have the advantage of providing all students with a broad foundation and allowing them more time to learn about the individual disciplines before they must decide on their career path. However, this limits the departmental specificity of the first-year program, both in terms of content and level of instruction (e.g., tailored difficulty for quality of departmental cohort).

Our current Core 8 and TrackOne curriculum, summarized in Appendix A, has many common elements. Four of the five courses in the fall term are the same for all students (Calculus I, Linear Algebra, Mechanics, and ESP I). The winter term is different in that only two of the five courses are now common (Calculus II and ESP II). One of the fundamental questions the Task Force considered was whether or not our Core 8 program should become the same for all departments.

Through our review, it was clear that there was no consensus on this question. Some students advocated for this, citing the importance of having the chance to better understand the engineering profession, with others indicating a preference for a more departmental-specific experience in first year since they were confident in their choice from high school. A number of faculty members from various departments were very enthusiastic supporters of a common first-year, yet many were against the approach. What a majority of students agreed upon is the ability for students to transfer with reasonable ease between programs at the end of first year. Indeed, this is also observed in recruitment as there is a growing interest in common or general first-year programs. For example, within our Faculty, the number of applications to the TrackOne program has grown by 82% since 2008, as compared to the Faculty average of 42%

In considering other implementations of common first-year programs, distinct challenges emerge around facilitating program choice at the end of first year. The model used by Queen's Engineering for many years includes a fully common year with guaranteed transfer to any program if the student successfully completes their first year. This presents administrative challenges for individual departments, as they can see potentially significant variations in their second-year cohort sizes. A second model that has been used at other institutions, such as McMaster and the University of Calgary, is a common first-year with a competitive program choice based on first-year GPA. At these schools, reports of 80% of classes being placed in one of their top three choices demonstrate the limitations of this model on the career options of students. As well, this is significantly less attractive from a recruitment perspective, given the uncertainty of the choice.

Given this review, the Task Force suggests that in general our Faculty maintains its current practice of direct-entry admissions for its Core 8 programs, with a general first-year program (TrackOne) of approximately 20% of the full Core 8 cohort (around 200 students). As well, the Faculty should continue to value program-to-program transfer and view it as a great benefit to our students, supporting their success, personal development and ultimate satisfaction with their program and career. Thus, it is recommended that any changes to the core curriculum be made with the intent to continue to provide opportunities for transfer, without the requirement to make up additional courses.

Discussions on Engineering Science and Core 8/TrackOne Cohort Integration

The Task Force considered possible avenues of integration of the Engineering Science and Core 8/TrackOne cohorts in order to counter the isolation that the Engineering Science students can experience. The Task Force thought that meaningful integration should involve opportunities for collaborative or team-based work or experiences, such as within the first-year design courses, Praxis and ESP.

To explore potential options, the Task Force organized a number of meetings with Professors Mark Kortschot and Jason Foster from Engineering Science, and Patricia Sheridan, who has had extensive TA experience in both ESP and Praxis courses. Through our discussions a number of key ideas emerged:

<u>Primary Objectives for Integration</u>

1) To promote mutual understanding and respect across students in the Core 8/TrackOne and Engineering Science programs,
2) To improve student satisfaction through improved student engagement, and
3) To improve student performance in the design course sequence by allowing students the flexibility to choose the design experience that best aligns with their learning style and career goals[18].

<u>Concerns Related to Design Course Integration</u>

Overall, our discussions identified a number of concerns related to the integration of these cohorts through the design course experiences. These include:

1) How do we adequately clarify for students the differences between Praxis and ESP, so they can make an informed choice before they arrive?
2) There are a number of logistical challenges which exist if the class sizes of Praxis and ESP are not known months in advance.
3) Currently, Praxis is a core part of the Engineering Science first-year identity, which would change if it were made available to the Core 8 cohort.
4) The coordinated team formation needed to ensure integration goes against the current pedagogical underpinnings of these two courses.

<u>Conclusions</u>

In the end, the group was hesitant to radically change a system that is working reasonably well for both cohorts. The Task Force agreed that there are potential benefits to cohort integration, and concluded that perhaps there are other means to achieve this integration. Possibilities warranting further considerations are:

1) The integration of the Core 8/TrackOne cohort with the Praxis or other fundamental courses. For example, the more advanced students in the Core 8/TrackOne cohort could have the option to take the Engineering Science calculus sequence,
2) The development of a combined course experience that could involve engineering mathematics and incorporate team work opportunities,
3) Curricular opportunities through shared or common assignments, and/or
4) Co-curricular opportunities through supplemental instruction (e.g., peer-assisted study groups), or other enrichment activities.

---

[18] Praxis typically follows a more global, entrepreneurial and "self-defined" design approach, while ESP focuses more on a sequential, client-driven, consulting design approach that is based on a general design framework.

CONCLUSION

Given the findings, considerations and recommendations detailed in previous sections, the following curriculum models for the Core 8 and TrackOne programs are proposed for further consideration within the Faculty. In addition to satisfying many of the core recommendations of this report, these models address a number of other key additional, administrative, and logistical considerations.

Proposed Curriculum Model #1

<u>Proposed Core 8 and TrackOne Fall Term (Common)</u>

Course Title	Lecture	Lab	Tutorial	Weight
Engineering Strategies & Practice I	3		2	0.5
Engineering Chemistry and Materials Science	3	1	1	0.5
Linear Algebra	3	1	1	0.5
Calculus for Engineers I	3		1	0.5
Engineering Physics I - Mechanics	3		2	0.5
Orientation to Engineering	0.5		1	0.25
	Total Contact:		25.5 hours	

<u>Proposed Core 8 and TrackOne Winter Term (One Program Specific Course)</u>

Course Title	Lecture	Lab	Tutorial	Weight
Engineering Strategies & Practice II	2		2	0.5
Computer Programming Fundamentals*	3	2	1	0.5
Calculus for Engineers II	3		1	0.5
Engineering Physics II – Dynamics, Electromagnetism, and Circuits	4	1	2	0.5
Introduction to Engineering (Program Specific)	2	3	1	0.5
	Total Contact:		27 hours	

* It is envisioned that two programming courses will be offered, one based on C and one based on Python with TrackOne students making their own informed choice.

Some further considerations for this model are:

- **Program Specific Experience Without Inhibiting the TrackOne Program and Transfer**:
  This model satisfies the strong interest amongst students and faculty to have a program-specific first-year experience, yet does not inhibit the existence of the TrackOne program or possible program-to-program transfer for qualified students. Indeed, one of our competitive strengths from a recruitment perspective is our hybrid model of direct program entry *and* a general first-year program (TrackOne). This model gives our students significant control over their future career direction, since it has become common practice to approve all program-to-program transfer requests over the last four

years. Indeed, over the last three years the total Core 8-to-Core 8 program transfers have been 89, 107, and 70 (which ranges from 9% to 13% of the entire Core 8 cohort). Since students are leaving as well as entering the various programs, the average change for a department's second year cohort size ranged from -18 to 14. The majority of transfers into departments come from TrackOne (typically around 55%) and Engineering Science (typically around 21%) students, with the rest being students exiting a Core 8 program (~12%) and those entering a Core 8 program (~12%). Given that some students are unsure of the types of careers various engineering disciplines lead to, this hybrid approach with open opportunity for transfer is of great advantage to both the students and to the departments, as students in those second-year programs are generally happier to be there.

- **Provides a Broad Foundation for all Students**:
  One of the identified strengths of the program was that it provides a strong, broad foundation to our first-year students. Indeed, many students commented on their appreciation of learning material relating to disciplines other than their own. However, this must be balanced, as some students and faculty noted either too much or too little coverage of particular areas. For example, industrial engineering students felt they were required to take too many physics courses, yet civil engineering faculty thought their students should have more exposure to physics, namely dynamics. The lack of exposure to electric circuits was noted by some departments whose students do not take ECE110: Electrical Fundamentals. As well, students in electrical and computer engineering essentially repeat almost all of the material in ECE110 through two of their second-year courses. It was also noted that transferring students going into second-year mechanical engineering can repeat MIE100: Dynamics in the winter term, indicating that this material is not critically important for their fall term of second year.

  The proposal to consolidate the current Dynamics and Electrical Fundamentals courses into a more standard Physics II courses, as other engineering schools do, will provide all students with a strong foundation in core physics material. Similarly, the proposal to provide all students with an introduction to chemistry and materials science in the fall term stems from the desire to ensure all students have this foundation. It is hoped that this change will not significantly affect the upper-year programs of the different Core 8 programs.

  This broad foundation was also proposed based on observations made for transferring TrackOne students. During the review, it was clear to the Task Force that, given the success of TrackOne students in the second-year programs of all departments, the necessity of the current program-specific offerings in the winter term was called into question. For example, TrackOne students do very well in the Civil and Mineral Engineering programs without the CIV/MIN specific CME185: Earth Systems Science. Similarly TrackOne students take only APS104: Introduction to Materials and Chemistry, yet do quite well in second year chemical engineering without the three course sequence of CHE112: Physical Chemistry, MSE101: Introduction to Materials Science, and CHE113: Concepts in Chemical Engineering.

Proposed Curriculum Model #2

Proposed Core 8 and TrackOne Fall Term (Common)

Course Title	Lecture	Lab	Tutorial	Weight
Engineering Strategies & Practice I	3		2	0.5
Engineering Chemistry and Materials Science	3	1	1	0.5
Linear Algebra	3	1	1	0.5
Calculus for Engineers I	3		1	0.5
Engineering Physics I - Mechanics	3		2	0.5
Orientation to Engineering	0.5		1	0.25
		Total Contact:	25.5 hours	

Proposed Core 8 Winter Term (Two Program Specific Courses)

Course Title	Lecture	Lab	Tutorial	Weight
Engineering Strategies & Practice II	2	1	2	0.5
Computer Programming Fundamentals*	3	2	1	0.5
Calculus for Engineers II	3		1	0.5
Program Specific Course #1	-	-	-	0.5
Program Specific Course #2	-	-	-	0.5
		Total Contact:	26 to 27 hours	

Program Specific Course Title	Lecture	Lab	Tutorial	Weight
Engineering Physics II - Dynamics, Electromagnetism, and Circuits	3	1	2	0.5
Dynamics	3		2	0.5
Electrical Fundamentals	3	1	2	0.5
Concepts in Chemical Engineering	3	1	2	0.5
Introduction to Materials Science	3		2	0.5
Earth Systems Science	3	2	1	0.5
Others?				

Proposed TrackOne Winter Term

Course Title	Lecture	Lab	Tutorial	Weight
Engineering Strategies & Practice II	2	1	2	0.5
Computer Programming Fundamentals*	3	2	1	0.5
Calculus for Engineers II	3		1	0.5
Dynamics	3		2	0.5
Electrical Fundamentals	3	1	2	0.5
		Total Contact:	26 hours	

* It is envisioned that two programming courses will be offered, one based on C, one based on Python with TrackOne students making their own informed choice.

Some further considerations for this model are:

- **Maintains Many Features of the Current First-Year Core 8 and TrackOne Curriculum**:
  While adding new components such as the first-year seminar course and the laboratory component to ESP II, this model maintains much of the current collection of first-year courses and foundational material.
- **Notable Changes**: The current APS104H1S: Introduction to Materials and Chemistry course would be reimagined as a new fall term Engineering Chemistry and Materials Science course. As well, a second-term physics course, Engineering Physics II – Dynamics, Electromagnetism, and Circuits, is proposed for departments to consider as an option for a more broad exposure to physics for their students.

Some common considerations for both models are:

- **Common Fall Term**:
  Our current program is very nearly a common fall term with four of the five courses for all programs being the same. The move to a fully common fall term has a number of advantages. First, it will simplify the coordination and integration of the courses, both in terms of content and delivery. Since all students will be taking the same courses, the support programming associated with the program, such as the Orientation to Engineering seminar course and the Peer Assisted Study Sessions (PASS), will also be easier to incorporate into the student experience. Finally, the creation of strong learning communities will be easier to schedule and facilitate. As the literature suggests, these learning communities could be designed to continue on in their defined lecture cohorts in the winter term.

- **Computer Programming**:
  Two versions of this programming course would be offered, one based on C and one based on Python, and both would be offered in the winter term. The choice of which course to take would be up to the departments to decide for their students. TrackOne students would be allowed to make their own choice.

- **Engineering Ethics**:
  The APS150H1F: Ethics in Engineering course would be removed from the program and ethical conduct in the academic setting would be formally presented in the Orientation to Engineering course and integrated into the experiences of the other courses. Students would be introduced to professional engineering ethics within ESP, providing them with a foundation for their future engineering ethics studies in the upper-year programs.

- **Engineering Strategies and Practice**:
  Reducing the number of lecture hours in the winter term by a third, from three to two, will streamline the content for that course and allow that hour to be used in better ways. A preliminary trial of this is being attempted in the winter 2015 term.

Comparison of Proposed Curriculum Model #1 with Current Program (52.5 hrs. total contact)

Curriculum Component	**Contact Hours (total 52.5 hrs.)[+]**	**Course Titles (Lect./Lab/Tut.)**	**Present TrackOne Curriculum Hours (total 51 hours)**
Engineering Design, Communication and Teamwork	9	Engineering Strategies and Practice I and II (3/0/2 and 2/0/2) (F&W)	10
Mathematics	13	Calculus for Engineers I and II (3/0/1) (F&W), Linear Algebra (3/1/1) (F)	12
Computer Programming	6	Computer Programming Fundamentals (3/2/1) (W)	6
Engineering Physics	12	Engineering Physics I (Mechanics) (3/0/2) (F) Engineering Physics II (Dynamics, Electromagnetism, Circuits) (4/1/2) (W)	16
Chemistry and Materials Science	5	Engineering Chemistry and Materials Science (3/1/1) (F)	5
Introduction to Engineering (Program Specific)	6	Introduction to Engineering (2/3/1) (W)	-
Professional Development	1.5	Engineering Orientation (0.5/0/1) (F)	2

[+] Note: While the contact hours do appear to have increased, the total number of lecture hours (i.e., the presentation of "new" content) is effectively the same (about 15 hours in each term). There are gains in the supportive hours of tutorials (TrackOne – 14 hours, Proposed Model – 15 hours), and labs (TrackOne – 5.5 hours, Proposed Model – 8 hours).

Proposed Implementation Plan

The recommendations within this final report will take time to be considered, assessed, and progress through governance. Many challenges exist for these changes, but the Task Force believes these are attainable and reasonable improvements that will significantly improve the student learning experience within our first-year Core 8 and TrackOne program. The Task Force has also observed a collective will to implement many of the primary recommendations.

A detailed timeline to implement these recommendations is suggested in the table below, calling for immediate action on some items, with more prudent piloting of some of the more significant changes. Assessment of the impact of these changes is necessary throughout. The first action will be to create an Implementation Working Group, which will have broad membership to ensure that all departments and programs are well represented. This Working Group will consider the Task Force's recommendations in greater detail and implement the necessary changes using the proposed implementation plan as a guide.

The plan suggests that certain components of the new model be implemented in the next academic year, while a full pilot implementation of the proposed curriculum model take place with the TrackOne cohort in the 2016/17 academic year. Following the assessment of that pilot, full implementation would be expected by 2017/18. For the purposes of this initial plan, the proposed curriculum model #1 has been chosen.

Start Date	Related Action	Key People/ Groups Involved	Notes	Deadline for Implementation
January 2015	Set up an Implementation Working Group	Dean's Office, Chair, First Year, Departmental Chairs	• **Goal**: Create a Working Group with broad representation across the Faculty	Ongoing
Recommendation #1: ***Improve the Relevance and Integration of the Foundational Courses***				
January 2015	#1A: Hire a First-Year Curriculum Coordinator	Dean's Office, Chair, First Year	• **Goal**: Hire new First-Year Curriculum Coordinator	September 2015
January 2015	#1B: Create a Preliminary Curriculum Map of the First-Year Program	Chair, First Year, First Year Office, Administrative Support	• **Goal**: Create a curriculum map of current first-year Core 8 courses	May 2015
February 2015	#1E: Create a First-Year Core 8 Curriculum Committee	Chair, First Year, Departmental Chairs	• **Goal**: Create a committee of nine members with each Core 8 program represented	April 2015
April 2015	#1D: Carefully Assess the Student Workload	First Year Office, First Year Students, Administrative Support	• **Goal**: Create a holistic review of student workload	September 2015
April 2015	#1C: Carefully Assess the Current Curricular Coverage	First Year Core 8 Curriculum Committee, Departmental Working Groups	• **Goal**: Develop a revised set of required material for the core mathematics and science courses • **Goal**: Develop a glossary of common vocabulary relating to the first-year program	December 2015
September 2015	#1F: Support the Creation of Intentional Learning Communities	First Year Office, Registrar's Staff, Administrative Support	• **Goal**: Identify best practices and approaches for creating intentional learning communities	September 2016 and 2017
January 2016	#1G: Develop an Example Repository of Reusable Learning Objects	First Year Office, Departmental Working Groups, Instructors	• **Goal**: Create a suite of reusable learning objects that will promote the integration of foundation courses	September 2016
Recommendation #2: ***Foster an Effective and Engaged First Year Instructional Team***				
December 2014	#2A: Assignment of Faculty with Proven Teaching Track Records to First-Year Courses	Chair, First Year, Department Chairs and Associate Chairs, Faculty Members	• **Goal**: Develop viable approaches for encouraging professors with proven experience to teach in the first year program. Work to assign the best instructors possible.	March 2015
May 2015	#2B: Establish a College of First-Year Instructors	Chair, First Year, First Year Office	• **Goal**: Develop a framework for the College of First Year Instructors to implement for the 2015/16 year	July 2015

Start Date	Related Action	Key People/ Groups Involved	Notes	Deadline for Implementation
May 2015	#2C: Place a High Value on TA Support	Chair, First Year, First Year Office, Departmental UG Offices, Engineering Mathematics Working Group	• **Goal #1**: Identify ways to assign TAs with proven experience to first-year courses. • **Goal #2**: Develop a plan for the creation of a First-Year TA Community	July 2015
Recommendation #3: ***Enhance Fundamentally Strong Learning of Mathematics***				
January 2015	#3A: Value High-Quality of First Year Instruction	Chair, First Year, Departmental Associate Chairs, Engineering Mathematics Working Group	• **Goal**: Create a plan that will allow for the collaborative hiring of sessional instructors if these are required. This process would be implemented for the 2016/17 academic year.	December 2015
September 2015	#3B: Set Higher Standards	First Year Office, Registrar's Office, First Year Core 8 Curriculum Committee, Examinations Committee	• **Goal**: Assess the merits of raising the passing standards for the mathematical and science courses, or the possibility of some required remedial work for those students in a discretionary range. This process would be implemented for the 2016/17 academic year.	March 2016
September 2015	#3C: Enhance Relevance of Content for Calculus I and II	First Year Core 8 Curriculum Committee, Departmental Working Groups, Engineering Mathematics Working Group, Undergraduate Curriculum Committee (UCC)	• **Goal**: Based on the outcome of #1B and #1C, adjust the coverage of Calculus I and II • Prepare for approval at the February 2016 Faculty Council for the 2016/17 academic year	September 2016
Recommendation #4: ***Address Discrepancies in Backgrounds in Mathematics and Computer Programming***				
March 2015	#4A: Early Diagnostic Test Creation	First Year Office, Departmental Support, Administrative Support	• **Goal #1**: Create an online early diagnostic test for mathematics and computer programming that can be taken by newly admitted students in July 2015.	July 2015
March 2015	#4B: Online Mathematical Modules and September Tutorials	First Year Office, Administrative and Student Support	• **Goal #1**: Create a series of three to five short online modules that incoming students can use to ensure they are well-prepared for September • **Goal #2**: Develop a plan for September remedial tutorials for September 2015	July 2015 and September 2015

Start Date	Related Action	Key People/ Groups Involved	Notes	Deadline for Implementation
May 2015	#4B: Customize Delivery of Calculus I and II	First Year Core 8 Curriculum Committee, Engineering Mathematics Working Group, Undergraduate Curriculum Committee (UCC)	• **Goal**: Consider the three proposals for managing the discrepancies in background preparation, and decide upon a plan for implementation in September 2016 • Prepare for approval at the October 2015 Faculty Council for the 2016/17 academic year	September 2016
May 2015	#4C: Customize Delivery of Computer Programming	First Year Core 8 Curriculum Committee, Departmental Working Groups, Administrative Support, Undergraduate Curriculum Committee (UCC)	• **Goal #1**: Consider the three proposals for managing the discrepancies in background preparation, and decide upon a plan for implementation in Sept. 2016 • **Goal #2**: Develop an appropriate diagnostic test to assess programming background. • Prepare for approval at the Oct. 2015 Fac. Council for 2016/17	September 2016
Recommendation #5: ***Incorporate Numeric Computation into the Core Curriculum***				
December 2014	#5: Incorporate Numeric Computation into the Core Curriculum	First Year Core 8 Curriculum Committee, Undergraduate Curriculum Committee (UCC), Engineering Mathematics Working Group	• **Goal**: Implement the inclusion of this new curricular component for all programs in September 2015 • Prepare for approval of change to the Linear Algebra contact hours at February 2015 Faculty Council • Develop an inverted approach to this new lab component in Linear Algebra through summer 2015	September 2015
Recommendation #6: ***Create a new First-Year Seminar Course to Support the Support the Transition into Engineering***				
December 2014	#6: Create a new First-Year Seminar Course	First Year Office, Undergraduate Curriculum Committee (UCC), Student Working Group	• **Goal**: Implement this course for all programs in September 2015 • Prepare for approval at February 2015 Faculty Council • Course assessments and final content to be developed through summer 2015	September 2015

Start Date	Related Action	Key People/ Groups Involved	Notes	Deadline for Implementation
Recommendation #7: ***Create Opportunities for Program-Specific Hands-On Learning that Facilitate the Transfer of Fundamental Knowledge to Practical Problems***				
May 2015	#3: Considering Proposal #1 - Create a new set of Introduction to Engineering Courses	First Year Core 8 Curriculum Committee, Undergraduate Curriculum Committee (UCC)	• **Goal**: Implement a pilot course for TrackOne students in winter 2017 • Prepare for approval of pilot course at the October 2015 Faculty Council	January 2017
September 2015		First Year Core 8 Curriculum Committee, Departmental Working Groups, Undergraduate Curriculum Committee (UCC)	• **Goal**: Implement 8 program specific courses in winter 2018 • Prepare for approval of 8 courses at the October 2016 Faculty Council	January 2018
Recommendation #8: ***Support New Pedagogical Approaches and Opportunities for Self-Directed Learning***				
July 2015	#8A: Appoint Course Innovators	Chair, First Year, Department Chairs and Associate Chairs, Faculty Members	• **Goal**: Create a process that will encourage curricular innovation amongst the faculty and TAs. This process would be implemented for the 2016/17 academic year.	September 2015
July 2015	#8B: Provide Students with Options for Different Course Delivery	Chair, First Year, Associate Chairs	• **Goal**: Offer students in September 2015, alternate learning pathways for Calculus I and II and Mechanics	September 2015
January 2016	#8C: Provide Opportunity for Self-Study Projects	First Year Core 8 Curriculum Committee, First Year Office	• **Goal**: Identify places within the curriculum in which students could help to define their assessment focus. • Work with course coordinators to embed this into the program for the 2016/17 academic year.	September 2016
Recommendation #9: ***Carefully Review the Content and Delivery of Engineering Strategies and Practice***				
April 2015	#9: Carefully Assess the Current and Delivery of Engineering Strategies and Practice I and II	First Year Core 8 Curriculum Committee, a Departmental Working Group, ESP Team	• **Goal**: Following the framework described above, a report should be produced that suggests ways to address these core concerns.	December 2015

Start Date	Related Action	Key People/ Groups Involved	Notes	Deadline for Implementation
Recommendation #10: ***Develop an Assessment Protocol for the Effectiveness of the First Year Program***				
May 2015	#10A: Identification of Core Outcomes for the First Year Program	First Year Office, First Year Core 8 Curriculum Committee	• **Goal**: In parallel with the careful review of the course content, a detailed list of knowledge, attributes, and skills should be developed.	December 2015
May 2015	#10B: Create and Implement an Ongoing Assessment Strategy	First Year Office, First Year Core 8 Curriculum Committee	• **Goal**: Identify relevant metrics for the effectiveness of the first year program based on the identified outcomes and suggest a plan for ongoing measurement of these metrics.	March 2015

REFERENCES

[1] J. E. Froyd, P. C. Wankat and K. A. Smith, "Five Major Shifts in 100 Years of Engineering Education," *Proceedings of the IEEE*, vol. 100, pp. 1344-1360, 13 May 2012.

[2] F. J. E. and B. J. Winkel, "A New Integrated First-Year Core Curriculum In Engineering, Mathematics, and Science: A Proposal," in *Frontiers in Education Conference Proceedings*, 1988.

[3] J. E. Froyd and M. W. Ohland, "Integrated Engineering Curricula," *Journal of Engineering Education*, pp. 147 - 164, January 2005.

[4] S. N.S. and J. Levine, Creating Learning Communities: A Practical Guide to Winning Support, Organizing for Change, and Implementing Programs, San Francisco: Jossey-Bass, 1999.

[5] R. Caso, C. Clark, J. Froyd, A. Inam, A. Kenimer, J. Morgan and J. Rinehart, "A systemic change model in engineering education and its relevance for women," in *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition*, 2002.

[6] N. Pendergrass, R. Kowalczyk, J. Dowd, R. Laoulache, W. Nelles, J. Golen and E. Fowler, "Improving First-Year Engineering Education," *Journal of Engineering Education*, vol. 90, no. 1, pp. 33-41, 2001.

[7] R. Roedel, M. Kawski, B. Doak, M. Politano, S. Duerden, M. Green, J. Kelly, D. Linder and D. Evans, "An integrated, project-based, introductory course in calculus, physics, english, and engineering," in *Frontiers in Education Conference, 1995. Proceedings., 1995*, 1995.

[8] J. Froyd and G. Rogers, "Evolution and evaluation of an integrated, first-year curriculum," in *Proceedings of 1997 Frontiers in Education Conference*, 1997.

[9] M. Holtzapple, K. Toback and C. Holtzapple, "Foundation coalition: Impact on chemical engineering education at Texas A&M University 20 years later," in *Proceedings of the 6th First Year Engineering Experience (FYEE) Conference*, College Station, TX, 2014.

[10] G. Bucks, K. Ossman, J. Kastner, F. Boerio and J. Torsella, "First year engineering courses effect on retention and student engagement," in *Proceedings of 2014 American Society for Engineering Education Annual Conference and Exposition*, 2014.

[11] A. Fentiman, J. Demel, R. Freuler, R. Gustafson and J. Merril, "Developing and implementing an innovative first year program for1000 students," in *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*, 2001.

[12] B. Olds and R. Miller, "The effect of first-year integrated engineering curriculum on graduation rates and student satisfaction: A longitudinal study," *Journal of Engineering Education*, vol. 93, no. 1, pp. 23-35, January 2004.

[13] J. Morgan and A. Kenimer, "Clustering courses to build student community," in *Proceedings of 2002 Frontiers in Education Conference*, 2002.

[14] N. L. Cress, M. A. Robinson, L. Corner, R. L. Legge and L. A. Ricardez-Sandoval, "Problem-solving and concept integration using a computational tool in first-year undergraduate chemical engineering," *Education for Chemical Engineers,* vol. 7, no. 3, pp. e133-e138, 2012.

[15] C. Hulls, C. Rennick, M. A. Robinson, W. Melek and S. Bedi, "Integrative Activities for First-Year Engineering Students – Fuel Cell Cars as a Linking Project Between Chemistry, Mechatronics Concepts, and Programming," in *Proceedings of 2014 Canadian Engineering Education Association Conference,* Calgary, 2004.

[16] National Academy of Engineering, The engineer of 2020: visions of engineering in the new century, National Academy Press, 2004.

[17] National Academy of Engineering, Educating the Engineer of 2020: Adapting Engineering Education to the New Century, National Academies Press, 2005.

[18] Prism Economics and Analysis, "Engineering and Technology Labour Market Study: 2007 Engineering and Technology Employer Survey," Engineers Canada and Canadian Council of Technicians and Technologists, 2008.

[19] American Society for Engineering Education, "Transforming Undergraduate Education in Engineering - Phase I: Synthesizing and Integrating Industry Perspectives," American Society for Engineering Education, 2013.

[20] IEEE Canadian Review, "Special Focus Issue: The Future of Engineering and Technology Education," *IEEE Canadian Review,* 2013.

[21] B. Lucas, J. Hanson and G. Claxton, "Thinking Like an Engineer Implications for the Education System," Royal Academy of Engineering, 2014.

[22] R. Ramachandran, K. Dahm, R. Nickel, R. Kozick, S. Shetty, L. Hong, S. Chin, R. Polikar and Y. Tang, "Vertical Integration of Biometrics Across the Curriculum: Case Study of Speaker, Face and Iris Recognition," *Circuits and Systems Magazine,* vol. 14, no. 3, pp. 55-69, 2014.

[23] G. Bucks, K. Ossman, J. Kastner, J. Torsella, R. Roseman and F. J. Boerio, "Extended Abstract–Flipping and Integrating the First-Year Engineering ExperiencE," in *Proceedings of the 5th First Year Engineering Experience (FYEE) Conference,* Pittsburgh, PA, 2013.

[24] J. L. Bishop and M. A. Verleger, "The Flipped Classroom: A Survey of the Research," in *Proceedings of 2013 ASEE Annual Conference & Exposition,* Atlanta, GA, 2013.

[25] K. A. Ossman and G. W. Bucks, "Effect of flipping the classroom on student performance in first year engineering courses," in *Proceedings of 2014 ASEE Conference & Exposition,* Indianapolis, IN, 2014.

[26] D. Horton, M. Craig, J. Campbell, P. Gries and D. Zingaro, "Comparing outcomes in inverted and traditional CS1," in *Proceedings of the 2014 Conference on Innovation & Technology in Computer Science Education (ITiCSE '14)*, Uppsala, Sweden, 2014.

[27] J. Gainsburg, "Learning to Model in Engineering," *Mathematical Thinking and Learning,* vol. 15, p. 259–290, 2013.

[28] J. A. Kaupp and B. Frank, "Practical, authentic and sustainable development and assessment of critical thinking in engineering through model eliciting activities," in *Proceedings of the 2014 ASEE Conference & Exposition*, Indianapolis, IN, 2014.

[29] "MEDIA: Modeling: Elicitation, Development, Integration, Assessment," [Online]. Available: http://modelsandmodeling.net/Home.html. [Accessed 25 11 2014].

[30] L. J. Shuman, M. E. Besterfield-Sacre, K. M. Bursic, N. S. Vidic and N. Siewiorek, "CCLI: Model Eliciting Activities," in *Proceedtions of the 2012 ASEE Conference & Exposition*, 2012.

[31] J. Stolk, R. Martello, T. Lobe, B. Taratutin, K. C. Chen and R. Herter, "Work in progress: En route to lifelong learning? Academic motivations, goal orientations, and learning conceptions of entering first-year engineering students.," in *Proceedings of Frontiers in Education Conference (FIE)*, 2012.

[32] G. L. Herman, M. H. Somerville, D. E. Goldberg and K. A. Green, "Creating Low-Cost Intrinsic Motivation Course Conversions in a Large Required Engineering Course," in *Proceedings of the 2012 ASEE Conference & Exposition*, 2012.

[33] L. Elder, R. Paul and R. Cosgrove, "Online Critical Thinking Basic Concepts Test," The Critical Thinking Community, [Online]. Available: http://www.criticalthinking.org/pages/online-critical-thinking-basic-concepts-test/679. [Accessed 5 November 2014].

[34] S. A. Sorby and B. J. Baartmans, "The Development and Assessment of a Course for Enhancing the 3-D Spatial Visualization Skills of First Year Engineering Students," *Journal of Engineering Education,* vol. 89, no. 3, pp. 301-307, 2000.

[35] E. S. i. Engineering, "Spatial Visualization Skills Teaching Resources," [Online]. Available: https://www.engageengineering.org/?107. [Accessed 5 November 2014].

APPENDIX A

Current Core 8 and TrackOne Curriculum

Our current Core 8/TrackOne curriculum is summarized in three tables below, which indicate:

1) The number of contact hours allocated within each department's first-year program to different components of the core curriculum, and
2) The particular set of courses and course sequence that are taken by students in the different departments.

A few key observations can be made:

1) Progression of TrackOne Students

- Students in TrackOne, our general first-year program, can currently transfer to any of the Core 8 second-year programs without the need to make up any additional courses.
- Therefore, TrackOne students moving into Civil or Mineral Engineering have not taken CME185H1S: Earth Systems Science, while those moving into Chemical Engineering have not taken CHE112H1F/S: Physical Chemistry, CHE113H1S: Concepts in Chemical Engineering, and MSE101H1F: Introduction to Materials Science.
    - o It is accepted that the APS104H1S: Introduction to Materials and Chemistry course is a sufficient substitute for the combination of CHE112 and MSE101.

2) Introduction to Engineering Discipline Courses

- Currently only the ECE and MIE departments have a first-year seminar course that introduces students to the various sub-disciplines available within those departments.
- TrackOne students benefit from a general Introduction to Engineering Course, in which all eight of the core departments present and discuss their specific program and career opportunities.

3) Commonality

- There is a common focus on Engineering Design, Communication and Teamwork, Mathematics, and Computer Programming within all eight programs.
- Significant differences exist in how much each departmental program emphasizes the basic sciences.
- Currently, it is common practice for any student to be granted free transfer into any program at the end of first year[19]. Normally, no additional courses need to be taken or made up. The only case in which this is required is if a CHE, CIV, MIN, or MSE student transfers into MIE (in this case they need to make up MIE100, but typically this is done is such a way that this is not an extra course in their overall program).

4) Ethics in Engineering Course

- This course is a basic introduction to ethical conduct within the university and professional engineering environments.
- The course consists primarily of self-study of posted lecture videos and materials, with a final multiple-choice exam in early November.

[19] Over the past three years the number of requests for transfer at the end of first-year from one Core 8 program to another Core 8 program has been 70 (2012), 107 (2013), and 89 (2014). In all three years all requests were granted regardless of standing.

Table A-1: Curriculum Contact Hours for Each Departmental Program

	Curriculum Component *Italicized entries indicate aspects of that department's curriculum that differ from those of the other departments*								
	Engineering Design, Communication and Teamwork	**Mathematics**	**Computer Programming**	***Engineering Physics***	***Chemistry***	***Materials Science***	***Earth Science***	***Professional Development***	**Total Contact Hours**
Chemical Engineering	10	12	6	*5* Mechanics only	*12* *All courses*	*5* *Intro to Mat. Sci.*	-	*1* *Ethics*	**51 hrs.** 24 Fall 27 Winter
Civil and Mineral Engineering	10	12	6	*5* *Mechanics only*	*5* *Physical Chemistry*	*5* *Intro to Mat. Sci.*	*6*	*1* *Ethics*	**50 hrs.** 24 Fall 26 Winter
Mechanical and Industrial Engineering	10	12	6	*16* *All courses*	-	*5* *Intro to Mat. Sci.*	-	*2* *Ethics, Intro to MIE*	**51 hrs.** 24 Fall 27 Winter
Materials Science Engineering	10	12	6	*11* *Mechanics and Elec. Fund. Only*	*5* *Physical Chemistry*	*5* *Intro to Mat. Sci.*	-	*1* *Ethics*	**50 hrs.** 24 Fall 26 Winter
TrackOne/ECE	10	12	6	*16* *All courses*	*2.5* *Half of APS104*	*2.5* *Half of APS104*	-	*2* *Ethics, and Intro course*	**51 hrs.** 25 Fall 26 Winter
Courses	Engineering Strategies and Practice I and II (5 hrs. each)	Calculus I and II, and Linear Algebra (4 hrs. each)	C-Based Programming Courses (6 hrs. each)	Mechanics (5 hrs.) Dynamics (5 hrs.) Electrical Fund. (6 hrs.)	Physical Chemistry (5 hrs.) Concepts in Chem. Eng. (7 hrs.) APS104H1S Intro to Materials and Chemistry (5 hrs.)	Intro to Materials Science (5 hrs.)	Earth Systems Science (6 hrs.)	Ethics (1 hr.) Intro to MIE (1 hr.) Intro to ECE (1 hr.) Intro to Eng. (1 hr.)	

Table A-2: First-Year Courses – Fall Term

	APS111 Engineering Strategies & Practice I	CIV100 Mechanics	MAT186 Calculus I	MAT188 Linear Algebra	APS150 Ethics in Engineering	CHE112 Physical Chemistry	MSE101 Introduction to Materials Science	APS105 Computer Fundamentals	ECE101 Introduction to ECE
Chemical	✓	✓	✓	✓	✓	✓			
Civil	✓	✓	✓	✓	✓	✓			
Mineral	✓	✓	✓	✓	✓	✓			
Materials	✓	✓	✓	✓	✓		✓		
Mechanical and Industrial	✓	✓	✓	✓	✓		✓		
Electrical and Computer	✓	✓	✓	✓	✓			✓	✓
TrackOne	✓	✓	✓	✓	✓			✓	

Table A-3: First-Year Courses – Winter Term

	APS112 Engineering Strategies & Practice II	MAT187 Calculus II	APS106 Fundamentals of Computer Programming	ECE110 Electrical Fund.	MIE100 Dynamics	MSE101 Intro to Materials Science	CME185 Earth Systems Science	APS104 Introduction to Materials and Chemistry	CHE113 Concepts in Chemical Engineering	CHE112 Physical Chem.	MIE191 Intro to MIE	APS191 Intro to Eng.
Chemical	✓	✓	✓			✓			✓			
Civil	✓	✓	✓			✓	✓					
Mineral	✓	✓	✓			✓	✓					
Materials	✓	✓	✓	✓						✓		
Mechanical and Industrial	✓	✓	✓	✓	✓						✓	
Electrical and Computer	✓	✓		✓	✓			✓				
TrackOne	✓	✓		✓	✓			✓				✓

APPENDIX B

Process for Consultations and Review

Since March 2013, the Task Force has addressed the terms of reference through:

1. *Departmental Consultations*
   Each of the Core 8 departments have been consulted with through a variety of means. These include online surveys, individual consulting, and group meetings. Two distinct rounds of consultations took place, summer 2013 and winter 2013/2014.

2. *Assessment of Student Experience*
   In May 2013, we conducted an exit survey of our 2012-13 first-year class to assess their first-year experience. Included in this survey were questions relating specifically to the first-year curriculum. We have also summarized and reviewed the course-related questions from the official Faculty Course Evaluations for each of the 19 first-year courses over the period of 2008-2013. A second round of student consultations took place in March and April of 2014 and included eight focus group sessions, through which over 65 students participated providing broad representation of all departments and years 1, 2, and 3.

3. *Targeted Consultations*
   The Task Force has engaged with instructors who had taught first-year mathematics courses over the past two years through an online survey. We have also met with alumni through a focus group session in which ten former and current PEY students discussed their views on the undergraduate curriculum relative to their experience within industry. Finally, the Task Force has held a series of meetings with guest speakers who have long-term experience with or expertise in the different areas of the core curriculum, including computer programming, engineering fundamentals, and mathematics.

4. *Review of Current Course Content and Overall Curriculum*
   The Task Force has reviewed the overall organization of the current curriculum as well as the content of each individual course. In particular, consideration has been given to the current obstacles for ease of transfer between programs.

5. *Best Practices in Engineering Education and Review of Peer Institutions*
   A thorough review of the relevant literature in current best practices within engineering education as it pertains to first-year programs and the evolving needs of future engineering graduates was completed. In addition, a careful survey of current first-year programs at highly-rated Canadian and American engineering schools was done.

6. *Discussions of Cohort Integration Between Core 8/TrackOne students and Engineering Science Students*
   Opportunities for cohort integration have been discussed by the Task Force along, with representatives from Engineering Science. A particular focus for these discussions has been on the potential option of allowing incoming students to choose their first-year design experience between Praxis and Engineering Strategies and Practice.

Summary of Student and Faculty Consultations

Student Response

The student perspective on our current first-year curriculum was assessed in three primary ways:

1) *First-Year Exit Survey 2013*
   Of the 940 Core 8 students, 260 responded to the 2012/13 exit survey (28% response rate).

2) *Course Evaluations 2008 – 2013*
   A review of the course-specific questions from the official course evaluations was done. This involved assessing the responses relative to the department mean for that year, so reasonable year-to-year comparisons could be made.

3) *Student Focus Group Sessions – March and April 2014*
   Eight focus group sessions covering students from each department and the program years 1, 2, and 3 were held in March and April of 2014. Over 65 students participated, which broadly represented each of the departments and years.

4) *Alumni Focus Group Session – July 2013*
   A group of 10 Calgary-based alumni and current students completing internships or PEY placements met with Micah Stickel for an hour to discuss how well their undergraduate experience has prepared them for their industry experience.

Through these means, a clear picture has emerged about the student perspective on our current and future first-year curriculum:

Relevance
Students have indicated that they value how our current first-year program relates the fundamental material to an engineering context, yet it is also clear that they would prefer that this was done on a broader scale. Indeed, in the exit survey, this was the most common suggestion for program improvement and was one of the suggested improvements that consistently rated as "most important" within the focus group sessions.

Effectiveness of Instruction and Assessments
In general, students rated the quality of first-year instruction very highly and felt that our faculty were engaged and willing to help. However, students also suggested that improvements are needed to both in-class and TA-based instruction, both in terms of professionalism, preparation, and coordination with the other aspects of the course. As well, many comments related to the need for assessments to be more authentic (i.e., related to prior material and learning experiences), and well-structured, and to ensure the grading is properly supervised, coordinated, and standardized.

Opportunity to Develop Fundamental Engineering Skills Alongside a Strong Technical Foundation
It was very clear from the alumni and student focus groups that the curriculum needs to provide more opportunities for students to develop their fundamental engineering skills, such as communication, teamwork, problem solving, estimation, independent learning, and project management skills. They reiterated the parallel need to maintain the strong technical foundation that is a current strength of the program.

Workload
In the survey and course evaluation results, some concern was expressed with the current first-year workload. Over 30% of the Core 8/TrackOne students indicated that the first-year workload was unmanageable, while only 40% of students agreed that they led a "balanced" life in first year. The concern of "the cycle of catching up" was noted by a number of students within the focus groups.

First-Year Exit Survey 2013

An online survey was sent to the existing first-year students in 2013. The survey consisted of primarily quantitative measures, but concluded with a set of qualitative general comments questions. Of the 940 Core 8/TrackOne students who were sent the survey via email, 260 responded giving a response rate of 28%. A descriptive statistical analysis was conducted on the quantitative questions of the survey and a thematic analysis was conducted on the related qualitative questions.

The primary themes identified in the two qualitative questions are found in Table B-1 and Table B-2 ranked by their commonality.

Table B-1: Q60. What did you really like about the first year curriculum?

Primary Themes	Number of Responses
The variety and breadth of courses	28
Interesting courses and program	16
Challenge of program	13
Interconnection of courses, relevance of course material to engineering	13
Computer Programming	11
Engineering Strategies and Practice (ESP, APS111/112): General understanding of engineering as a profession	10
Professors	9
APS112: Working with a real client and project	8
Extra exposure to engineering discipline, discipline-specific seminars	8
Some courses were a review of High School material	8
MIE100: Dynamics	7
Peers	7
Scheduling and midterm/test coordination	7
Laboratory Experiences	6

Table B-2: Q61. How do you think the first year curriculum could be improved?

Primary Themes	Number of Responses
Ensure material has relevance, more applied to engineering	18
Improved instructor/faculty teaching	18
ESP: Course organization, flow of material	13
ESP: Evaluation process, TA bias	12
Improved TA teaching	12
Reduce overall workload in the program	11
Fairer marking/fairer tests and exams	10
More opportunities for laboratory/hands-on experiences	10
ESP: Reduce workload	8
Improve APS104H1S: Introduction to Materials and Chemistry	8
Discipline specific courses	8
More strategic scheduling of classes	7
ESP: Improve lectures, make them more interesting	5
Improve the balance of the two terms in terms of difficult courses and workload	5
Introduce additional learning supports (e.g., lecture videos, posted notes, help sessions, better textbooks)	5
Reduced class and/or tutorial size	5

Table B-3: Summary of quantitative responses

Quantitative Questions	Agree	Neither Agree nor Disagree	Disagree
I felt that I led a balanced life during my first year of studies in engineering.	41%	14%	46%
I felt that the work load in first year was manageable.	47%	22%	31%
My previous years of education prepared me to do well in my courses in first year.	49%	15%	36%
I found my professors approachable and willing to help.	65%	23%	11%
Course content was interesting and challenging.	66%	20%	15%
I was able to understand how the material in my mathematics courses related to my Engineering studies.	60%	17%	23%
I can see how each of my courses in first year is important to my future Engineering studies.	53%	16%	31%

Figure B-1: Q34. How did your first year compare with your expectations?
Data from 2011/12 First-Year Exit Survey also included (n = 303)

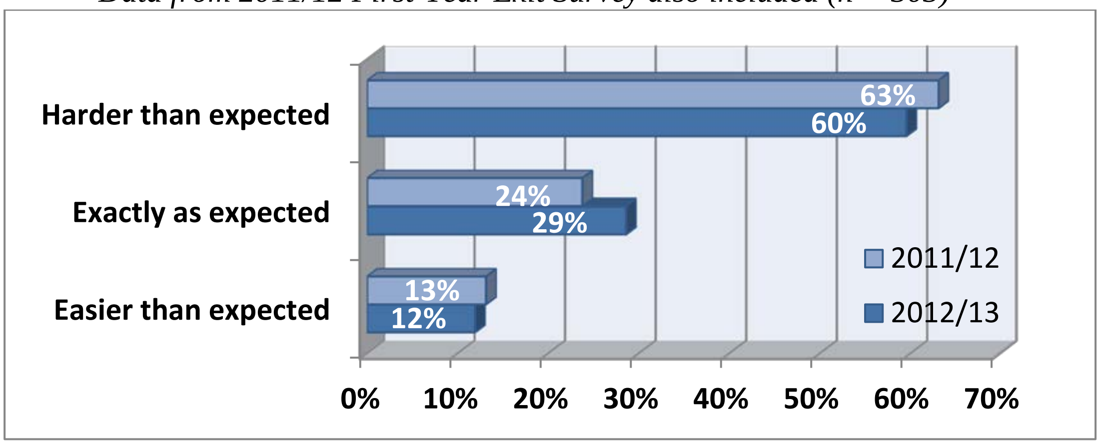
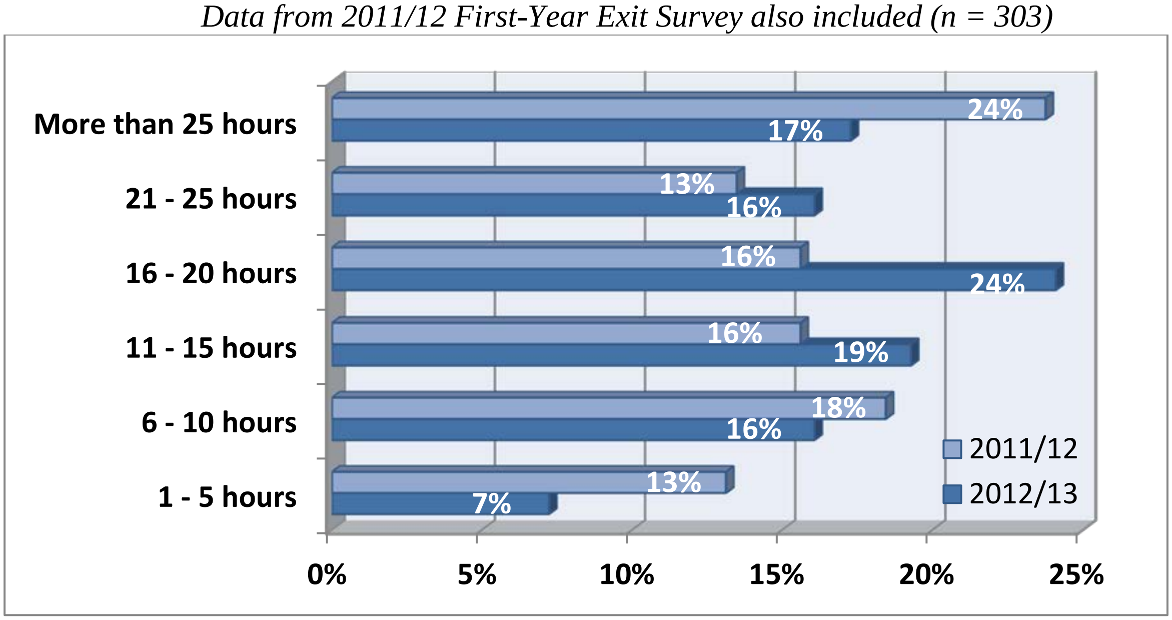


Figure B-2: Q36. Outside of classes, tutorials and labs, how many hours in a typical 7-day week did you spend on course work and studying?
Data from 2011/12 First-Year Exit Survey also included (n = 303)



Student Focus Groups Winter 2014

After the presentation of its interim report in November 2013, the Task Force, together with the individual departmental undergraduate offices, organized and held eight different student focus group sessions relating to this review. These were held throughout March and April of 2014. One session was held for each department, a session was held with current first-year students, and two sessions were held with Engineering Society representatives. Over 65 students participated, with all departments and years 1, 2, and 3 being equally represented. While this was an open discussion, five questions were used to guide the sessions:

1) What was the most challenging part of your academic transition from high school to university?
2) How might the first-year curriculum better support your academic transition into university?
3) Currently there is a Faculty Task Force that is considering a set of possible changes to the first-year curriculum. Of the following suggestions, which would you say are the two most important changes?
    a. **Relevance and Integrated Courses**: Developing a curriculum in which the math and science courses are more integrated with each other, and that the fundamental content is motivated through specific engineering applications.
    b. **Development of Engineering Skills**: Part of the curriculum is focused on the development of core engineering skills, such as problem solving, systems modeling, independent learning and critical thinking, and project management.
    c. **Common First Year and Transferability**: Creation of a more common first-year Core 8 curriculum to enable easier transfer at the end of first year.
    d. **Improved Coordination and Training for First-Year Instructional Team**: Ensure that there clear communication between course instructors and their TAs and provide additional support and training for TAs in first-year courses.
    e. **Numeric Computation**: Introduce students to numeric computation (e.g., Matlab) throughout the first year. This would be integrated into many of the first-year courses.
4) For those in upper-years, how could the first-year curriculum better prepare you for your upper-year programs?
5) For the suggestions in question 3), are there any that you see as being not important? Do you have any other suggestions for improvements to the first-year curriculum?

In reviewing the notes taken by the undergraduate counsellors at these sessions, the major themes that emerged from these eight sessions were:

- A “bigger picture” is needed through applications of calculus and linear algebra.
- More relevance to chosen discipline and upper-year courses, it is hard to translate first-year courses to second-year courses.
- More hands-on experiences is needed, which “would allow them to explore their disciplines.”
- Numeric computation would be useful.
- Better understanding of “ideal answer versus approximation in real world.”
- Exposure to software such as AutoCAD, Excel, and MATLAB.
- Need to use a better (more relevant to discipline, “such as MATLAB”) choice of programming language.

- Programming courses should focus on logical thinking and problem solving, rather than “just teach code.”
- Would like more intentional transitional support into first-year.
- The pace of learning is a big difference from high school, particularly after the review of high school materials ended.
- Found the workload in second-term to be particularly challenging.
- Challenge of catching up in courses once behind, “missing current material due to midterm prep,” “cycle of catching up.”
- Focus on grades counterproductive at times, consider MIT’s model of not counting the first-term GPA,
- Would like to know more about “how things work” in the Faculty and University (e.g., common grading practices, importance of going to lectures (“incentives needed”), adapting to the “scale of the school”),
- Need better advertisement of resources (e.g., FSGs, tutors, course.skule.ca),
- Less reliance on rote math learning (i.e., learning the required “tricks” and reliance on past exams and tests to do well on assessments).
- Foster greater ability to solve mathematical problems by “thinking outside the box” and independent learning.
- Concerns with the grading and evaluations in APS111/112 (ESP I and II), including clarity of assignment instructions and expectations and consistency in grading
- Difficult in adjusting to the writing styles required within APS111/112, compared to prior experience in English courses.
- Improve delivery of teaching (lectures and tutorials), first-year students need more attention and support.
- Large class sizes problematic, inhibited the asking of questions and connections to instructors.
- Lack of professionalism and preparation by some TAs.
- Lectures, tutorials, textbooks, tests, and exams should be better connected and coordinated.
- Have the best professors teach in first year.
- Students would appreciate more personal experiences and “research stories” from their professors, “how did they struggle through school,” “what they like to do.”
- Students noticed and felt the effect of discrepancies in background preparation in mathematics and computer programming courses. For some, this negatively impacts their self-efficacy and confidence.
- More exposure to a discipline-specific answer to what engineers do.
- Need increased opportunity to develop practical skills such as estimation, engineering judgment, and problem solving.
- Importance of career development through networking and professional development opportunities needs to be highlighted and supported by professors.
- Important to begin to work on “skills for employability in year one,” “Waterloo does this better.”
- Students noted they had little time to “explore other interests” and wished they had the opportunity for a “better work/life balance.”
- Suggestion of a common first-year not of interest, but opportunity for program transfer very important.

Course Evaluations 2008 - 2013

For the 19 Core 8/TrackOne first-year courses, the course-specific evaluation questions were tabulated and reviewed. In order to meaningfully compare the results from different years, each question was normalized to the departmental mean of that year for that question.

For the most part, students evaluate the first-year Core 8/TrackOne courses quite positively. Specific observations relating to the relevant questions are:

1) *Enthusiasm*: Only seven of the nineteen courses consistently had a higher ranking of enthusiasm for the course material at the end of the course as compared to their enthusiasm at the outset of the course.

2) *Course Workload*: A general trend for many courses shows that the rating of the difficulty of the course workload has been declining over the years. However, it was observed that there was an increasing trend over the past few years for the workload in both the ESP courses (APS111/112). In addition, these courses have the highest relative workload ratings within the program.

3) *Course Material Repetition*: When asked, “Extent to which this course repeats material from other courses is…”, nine of the 19 courses indicated above average repetitions. In particular, Mechanics, Dynamics, Electrical Fundamentals, and Introduction to Materials Science and all the Calculus courses were above average in this category. Courses with very low ratings of repetition include Computer Programming (both), ESP courses (APS111/112), and Earth Systems Science.

4) *Relevance*: Many courses had a consistent rating on par with the departmental average for “The relevance of this course to your professional development is…”. Courses that had consistent lower than average ratings include Linear Algebra, Fundamentals of Computer Programming (for CHE, CIV, MIN, MIE, and MSE), Introduction to Materials and Chemistry, Physical Chemistry, ESP Courses (APS111/112) and Earth Systems Science.

5) *“Would you still have taken the course?”*: Ten of the 19 courses maintained a fairly consistent pattern in that more than 70% of the students said they would take the course again, disregarding the requirement for the credit. This includes all the Calculus courses, all the Physics courses (Mechanics, Dynamics, and Electrical Fundamentals), and the Computer Programming course for TrackOne and ECE students. Some courses had an average of fewer than 40% of students indicate they would take the course again, including APS111/112, and APS104.

Alumni and Current Student Focus Group Session

In July 2013, a group of ten Calgary-based alumni and current students met to discuss their experience within their engineering undergraduate program, and how that prepared them for their industrial positions. The group included a current second-year student completing a summer internship, a couple of third-year PEY students, and alumni who had graduated between one to ten years previously.

Most spoke quite highly of their undergraduate experience but had specific suggestions relating to potential improvements. When asked to “describe the most useful aspect of their undergraduate experience,” they commented on:

1) Communication skills,
2) Experience to develop the ability to find and critique required information,
3) Engineering design process and experience (in particular ESP and Praxis),
4) Team building and resolution of problems,
5) Good technical foundation,
6) Basic programming skills and data manipulation (primarily using VBA in Excel), and
7) Project management.

When asked “How the first-year program could be improved?” they offered the following suggestions:

1) Provide students with the opportunity for problem definition in addition to problem solving (such as the approach used in Praxis),
2) Support the development of students’ problem solving skills, in particular their ability to clearly define the “true” problem (e.g., parsing a word problem),
3) Help students appreciate the need to use mathematics to solve an engineering problem, and understand the necessary approximations and the limitations of that solution,
4) Ensure that the foundational material is placed in the proper context and is related back to engineering,
5) Introduce students to engineering as a mindset and not simply a collection of technical knowledge,
6) Provide students with some exposure to shifting deadlines and the true dynamics of engineering project management,
7) Create opportunity for peer mentoring of first-year students with upper-year undergraduate students to support their transition to university.

Departmental and First-Year Instructors’ Responses

The needs of the eight departments were investigated through a call for consultation with all faculty members. In addition, a special focus was given to those directly involved in the instruction of either first- or second-year departmental and mathematical courses. The primary goal of the consultations was to ask the faculty three questions:

> *Q1: What are the most important skills and attributes you would like your incoming second-year students to have? What key technical knowledge would you like your incoming second-year students to have?*
>
> *Q2: Identify any deficiencies that currently exist within our first-year curriculum*
>
> *Q3: Suggest a set of improvements to the first-year curriculum content and/or delivery that should be considered by the Task Force.*

This data was collected using surveys, individual interviews, group discussions, and focus groups. A thematic analysis was conducted on the departmental and instructors data and presented to the Task Force. Through discussion, the Task Force categorized the primary themes into four core areas: Mathematics, Sciences (including physics, chemistry, and materials), Computer Programming, and “The Evolution of the Engineering Brain.” These primary themes grouped by category are below.

Mathematics

- Math content needs to be **more applied**, **more integrated with Engineering**, without reducing the current coverage of the **math fundamentals**
- Students have difficulty with **visualization** in three dimensions
- Students need specific exposure to **numeric (scientific) computation (e.g., MATLAB)**
- Students need to be better able to use **unit analysis** and work with **fundamental constants**
    - These topics need to permeate throughout the first-year curriculum
- **Concept Deficiencies**:
    - Application of math to engineering economic calculations (or examples)
    - Basics of logic and set theory (Discrete Math fundamentals)
    - Optimization

Sciences (Physics, Chemistry, and Materials)

- Delivery of basic science content needs to be improved, by
    - Identifying **essential concepts** and focus courses on these
    - Changing delivery to **improve retention** of these fundamental concepts
- Specific Topics:
    - Fundamentals of **electricity and magnetism**
        - Physics behind linear circuit elements (resistors, capacitors, and inductors)
    - **Structure of matter**
    - **Energy transformation within systems**
    - Understanding of the **earth's atmosphere** and the **water cycle**
    - Chemistry: importance of clearly **identifying the "type" of chemistry** that is relevant for each department, considering the three main views

Computer Programming

- There is a need for all students to improve their **logical thinking** or **computational thinking**
- **ECE** students require **exposure to C** so that they have a greater appreciation for memory management through **pointers**
- **Other departments** require a course that focuses on the **development of programming fundamentals** based on a language that reduced the challenge of learning unique syntax
- Other important software and computer-related skills
    - Word, Excel
    - 3D Drawing Tool (SketchUp AutoCAD)
        - Improve students ability to visualize and work in three dimensions
    - Unix commands

Evolution of the Engineering Brain (Professional Practice and Engineering Fundamentals)

- There is a need for greater emphasis on helping students to **develop their problem solving skills**
- They need to better understand the **true complexity of engineering problems**
- Students need to develop their **investigation skills** and **critical thinking skills**
- Students need to better understand **engineering as a profession**, specific to each **department**
- A better sense of **professionalism** needs to be instilled in the students
- Students need to be better supported in their development of **good study habits**
- Greater focus on developing students as **effective team members** is needed
- More time should be allocated for **independent learning** and self-study
- No additional focus on communications is needed

After the Task Force presented its interim report in November 2014, follow-up meetings were held with each department in December 2013 and January 2014. From these sessions, the major themes were:

- Students do a lot of "problem answering, but not a lot of problem solving"
- Concerns that the proposals might result in "doing a little bit of everything not very well"
- How the changes affect second-year programs?
- Is this more about presentation (i.e., delivery) rather than content?
- Concerns with mathematical backgrounds of incoming students
- Retention of concepts into second year should be measured
- This work should be connected to our assessment of the graduate attributes
- Need flexibility in course delivery, offering of different tracks, perhaps an honours track
- Strong understanding of foundational mathematics and sciences is critical
- Transferability should be limited to only honours students
- Consider enabling transfer after first term to allow for program specific courses in second term
- Ease of transferability is strongly supported
- The teaching of calculus needs to change, content needs attention
- Need for logical, deductive reasoning experiences in the formal solving of problems
- Are these recommendations based on educational fads?
- Importance of teaching Excel, and use of VBA
- Numeric analysis should be incorporated into courses rather than have its own course
- To incorporate numeric computation properly, need facilities to test properly
- Often content relevant to electrical, mechanical, and industrial engineering marginalized
- Reduce contact hours to allow for time to reflect, time to acquire the knowledge they need
- Concerns raised about pushing too much required or remedial content into the summer months

Summary

Both faculty and students have identified a number of similar priorities for the first-year curriculum. From both a programmatic and student experience perspective, there is a common view that a stronger effort is need to create a more cohesive and relevant curriculum. In addition, there is shared interest in providing better transitional support into university and more distinct instruction on and opportunity for the development of fundamental engineering skills, such as estimation, problem solving, critical thinking, investigation skills, and life-long learning skills. Both faculty and students see the value of embedding numeric computation into the curriculum and making better use of the students' time so that they have the opportunity to properly reflect and absorb the material they are being taught.

Students have also noted the need for a more strongly connected teaching team and first-year instructional community, so that instruction is effective and consistent in all aspects of the course. This coincides with the departments' desire for improved retention of the fundamental concepts. They also note interest in greater opportunity for practical or discipline-specific hands-on experiences, and the ability to develop their professional skills.

On the other hand, the departments and instructors have pointed out the need to maintain a strong coverage of the foundational mathematics and sciences, and improving the delivery of these critical courses. As well, they have suggested that specific curricular and concept deficiencies be addressed, including visualization, working in three-dimensions, energy transformation within systems, and environmental impact through the discussion of the water cycle.

APPENDIX C

Current Practice at North American Engineering Institutions

Canadian Institutions

The first-year programs at seven Canadian engineering schools have been carefully reviewed. The programs reviewed were at the University of Alberta, University of British Columbia, University of Calgary, McGill University, McMaster University, Queen's University, and the University of Waterloo. Six of these seven programs have a common first-year engineering curriculum, with the exception being the University of Waterloo.

The details of the curriculum models for these programs are presented in below. Some general observations are:

Contact Hours

The total contact hours for the first year[20] within these programs range from 39 hours (McGill University) to 58 hours (U of Calgary and U of Waterloo).

Mathematics

Most programs cover the traditional Calculus I and II, and Linear Algebra sequence over three courses, with many using the usual Lecture/Lab/Tutorial model of 3/0/1. UBC incorporates MATLAB into its Linear Algebra course.

Both Queen's and Calgary cover a good portion of the Calculus I and II material in one course (Queen's with a 3/0/1 model, and Calgary with a 3/1.5/1 model) and then teach some degree of Multivariable Calculus in the winter term (again with a 3/0/1 model).

Science - Physics

Four of programs (UofA, UBC, Calgary, Waterloo) have three physics courses in first year, for an average of about 15 contact hours. These programs typically have an Engineering Mechanics approach (Statics then Dynamics) along with coverage of Electrical Fundamentals.

The other three programs have only two physics courses, and these usually follow the standard two-course first-year physics curriculum that covers: Mechanics (statics and dynamics), Waves, Electromagnetism, Circuits, and Optics. This reduces the physics contact hours to around eight or nine.

Science – Chemistry/Materials Science/Earth Science

Only one program (Queen's) has an earth science course, which follow a Lectures/Labs/Tutorials model of 3/2/0.

Only two programs have specific courses on Materials Science (Calgary and McMaster), and three programs do not have any coverage of this topic. The other two (UBC, Queen's) incorporate this into one of their Chemistry courses.

Most programs have one five or six contact hour course on Chemistry, and usually this includes a lab (follows a 3/3/0 or a 3/1.5/1 model).

[20] These are the hours students spend each week in lectures, labs, and tutorials for all their first-year courses. Typically, this is equally divided between the two terms, so a total of 50 contact hours for the program would mean students spend roughly 25 hours in class each week in each term.

In total, the Chemistry/Materials Science component of the programs is typically between six to ten contact hours.

Computer Programming

Within the six common first-year programs there are different approaches to teaching programming:

a) Two use C (or C++) (U of Calgary and Queen's),
b) One uses Python (McMaster),
c) One uses MATLAB (U of Alberta),
d) One uses C, and then MATLAB and Excel in the final three weeks (UBC), and
e) One does not have a programming course (McGill).

The typical contact time is between four and a half hours and six hours, and the models vary between the standard Lectures/Labs/Tutorials of 3/2/0, to 2/1/2, to 1/3/2.

Engineering Design, Communication and Teamwork

Not all programs have a focus on engineering design in the first year, with both McGill and University of Alberta providing opportunities for complementary studies elective(s) instead. The other programs invest significant contact hours into design, communication, and teamwork. This ranges from six hours (U of Calgary) to 16 hours (Queen's).

Queen's approach is one of the few that enables students to gain client-based design experience through a design project in the winter term. Within this engineering design sequence, they also have courses that focus on Complex Problem Solving (integrated with MATLAB), the development of Laboratory Skills, and Engineering Graphics.

Professional Development

Within this curricular component, the focus is on providing students with the opportunity to learn about the engineering profession, the various types of engineering disciplines, and exposing them to potential career opportunities. Four of the seven programs offer such a component, typically in a one- or two-hour seminar course. These are often one-term courses, but at the University of Alberta this extends over two terms.

Innovative Programs

There are some examples of innovative programming within the first-year engineering curricula within Canada. Queen's has a unique approach to the development of the important engineering fundamentals, such as problem solving and critical thinking, and laboratory skills. McMaster, through its Engineering I program, offers "a unique and supportive learning environment dedicated to helping you make a smooth and successful transition to the university life." This has the advantage that "small tutorial and lab groups are led by specially trained senior students who appreciate the challenges first-year students face." They have also recently introduced the EPIC lab (Experiential Playground and Innovation Classroom) for first-year students. The goal of this lab is to "excite and motivate first-year engineering students with opportunities to have hands on experience with 3D prototyping printers, video games, Android tablets, Scribbler and Fischertechnik robots."[21] This is a drop-in lab which bookable equipment and space, through which students can complete course projects or participate in extra-curricular organized competitions and projects. Their first-year engineering enrollment is comparable to ours, at around 1250 students.

[21] http://epiclab.mcmaster.ca/

The general curriculum model for these common programs are summarized below (one unit typically represents at three-hour lecture course):

<u>University of Alberta (46.5 hrs. total contact)</u>

Curriculum Component	Contact Hours	Courses/Notes	TrackOne Hours
Engineering Design, Communication and Teamwork	-	No Engineering Design experience	10
Mathematics	12	Calculus I and II, Linear Algebra, all (3/0/1)[22]	12
Computer Programming	**4.5**	MATLAB based course (3/1.5/0)	6
Engineering Physics	**15**	Eng. Mechanics (Statics) (3/2/0) Dynamics (3/1.5/1) Waves, Optics, and Sound (3/1.5/0)	16
Chemistry	**10**	Introduction to University Chemistry I (3/1.5/1) and II (3/1.5/0)	2.5
Materials Science	-	No course on Materials Science	2.5
Professional Development	2	Weekly, year-long seminar series, *Orientation to the Engineering Profession I and II*	2
Complementary Studies	**3**	Elective	-

<u>University of British Columbia (55 hrs. total contact)</u>

Curriculum Component	Contact Hours	Courses/Notes	TrackOne Hours
Engineering Design, Communication and Teamwork	**15**	Engineering Case Studies (3/4/0), Engineering Graphics (1/4/0), University Writing (3/0/0)	10
Mathematics	**10**	Calculus I and II (3/0/0), Linear Systems (with MATLAB) (3/1/0)	12
Computer Programming	**5**	C and MATLAB based course (2/1/2)	6
Engineering Physics	**15**	Physics I (Thermo, Waves, Sound) (2/0/2) and II (E&M, Circuits) (2/3/2) Eng. Mechanics (Statics and Dynamics) (3/0/1)	16
Chemistry	**3**	Chemistry for Engineers (3/3/0) (Part I – chemistry for mat. properties) (Part II – Thermodynamics and kinetics)	2.5
Materials Science	**3**		2.5
Professional Development	**1**	Introduction to Engineering Seminar	2
Complementary Studies	**3**	Elective	-

University of Calgary (55 - 58 hrs. total contact)

Curriculum Component	Contact Hours	Courses/Notes	TrackOne Hours
Engineering Design, Communication and Teamwork	**6**	Engineering Design and Communication (3/3/0)	10
Mathematics	**16**	Calculus I (3/1.5/1), Calculus II (3/1.5/1), Linear Methods (3/1/1)	12
Computer Programming	**5**	C++ course (3/2/0)	6
Engineering Physics	16	Eng. Statics (3/0/1.5) Electricity and Magnetism (4/2/0) Electric Circuits and Machines (4/1.5/0)	16
Chemistry	**5.5**	Chemistry for Engineers (3/1.5/1)	2.5
Materials Science	**6**	Behaviour of Liquids, Gases, and Solids (3/1.5/1.5)	2.5
Professional Development	**-**	-	2
Complementary Studies	**3**	Optional	-

McGill University (non-CEGEP entry) (39 hrs. total contact)

Curriculum Component	Contact Hours	Courses/Notes	TrackOne Hours
Engineering Design, Communication and Teamwork	**-**	No engineering design experience	10
Mathematics	12	Calculus I and II (3/0/1), Linear Algebra (3/0/1)	12
Computer Programming	**-**	No computer programming course	6
Engineering Physics	**11**	Physics I (Mechanics and Waves) (3/1.5/1) Physics II (Electromagnetism and Optics) (3/1.5/1)	16
Chemistry	**9**	General Chemistry I and II (3/1.5/0)	2.5
Materials Science	**-**	No course on Materials Science	2.5
Professional Development	**1**	Introduction to Engineering (1/0/0)	2
Complementary Studies	**6**	Two electives	-

McMaster University (48.5 hrs. total contact)

Curriculum Component	Contact Hours	Courses/Notes	TrackOne Hours
Engineering Design, Communication and Teamwork	10	Engineering Design and Graphics (1/3/2) Engineering Profession and Practice (2/0/2)	10
Mathematics	**15**	Calculus I and II (3/1/1), Linear Algebra (3/1/1)	12
Computer Programming	6	Python-based course (1/3/2)	6
Engineering Physics	**9**	Physics I (Mechanics) (3/1.5/0) Physics II (Waves and Electromagnetism) (3/1.5/0)	16
Chemistry	**5.5**	General Chemistry I (3/1.5/1)	2.5
Materials Science	**3**	Structure and Properties of Materials (3/0/0)	2.5
Professional Development	**-**	-	2

Queen's University (53.5 hrs. total contact)

Curriculum Component	Contact Hours	Courses/Notes	TrackOne Hours
Engineering Design, Communication and Teamwork	**16**	Complex Problem Solving (1/0/2) Laboratory Skills (0/3/0) Engineering Design Project (3/0/2) Engineering Graphics (2/3/0)	10
Mathematics	12	Calculus I (3/0/1), Calculus II (3/0/1), Linear Algebra (3/0/1)	12
Computer Programming	**4.5**	C-based course (1/2/1.5 – Teaching Studio)	6
Engineering Physics	**8**	Physics I (Mechanics) (3/0/1) Physics II (Dynamics, Electromagnetism, Circuits) (3/0/1)	16
Chemistry	**6**	Half of Chemistry and Materials (3/0/1) Chemistry and its Applications (3/0/1)	2.5
Materials Science	**2**	Half of Chemistry and Materials (3/0/1)	2.5
Earth Science	**5**	Earth Systems (3/2/0)	-
Professional Development	**-**	-	2

Waterloo University (Example of Management Engineering Program – 58.5 hrs. total contact)

Curriculum Component	Contact Hours	Courses/Notes	TrackOne Hours
Engineering Design, Communication and Teamwork	**17.5**	Engineering Concepts I (3/3/2) Engineering Economics (3/0/1) Work Design and Facilities Planning (3/1.5/1)	10
Mathematics	**15**	Calculus I and II (3/0/2), Linear Algebra (3/0/2)	12
Computer Programming	**5**	Digital Computation (3/0/2)	6
Engineering Physics	**15.5**	Physics I (Mechanics) (3/0/2) Physics II (Waves and Optics) (3/0/2) Electrical Engineering (3/1.5/1)	16
Chemistry	**5**	Chemistry for Engineers (3/0/2)	2.5
Materials Science	**-**	-	2.5
Professional Development	**1**	Seminar	2

Waterloo University (Example of Chemical Engineering Program – 56 hrs. total contact)

Curriculum Component	Contact Hours	Courses Titles (Lect/Lab/Tuts)	TrackOne Hours
Engineering Design, Communication and Teamwork	**13.5**	Chemical Engineering Concepts I[+] (3/1.5/3) Chemical Engineering Concepts II (3/1/2)	10
Mathematics	**15**	Calculus I and II (3/0/2), Linear Algebra (3/0/2)	12
Computer Programming	**5**	Engineering Computation (3/0/2)	6
Engineering Physics	**10.5**	Physics I (Mechanics) (3/0/2) Physics II (Electrical Engineering) (3/1.5/1)	16
Chemistry	**5**	Chemistry for Engineers (3/0/2)	2.5
Materials Science	**-**	-	2.5
Biology	**4**	Engineering Biology (3/0/1)	-
Elective	**3**	Complementary Studies Elective (3/0/0)	-
Professional Development	**-**		2

[+] *Chemical Engineering Concepts I*: Introduction to basic methods and principles in Chemical Engineering. The fundamentals of engineering calculations (units and dimensions), behaviour of fluids, mass balances, processes and process variables. Laboratory on visual communication: engineering graphics, computer software including spread sheets, computer aided design. Technical communication: word processing software, elements of technical report writing. Aspects of the engineering profession including ethics, safety, and intellectual property. Professional development including résumé skills, interview skills, and preparation for co-op terms.

US Institutions

A careful analysis of the first-year programs at nine leading US engineering institutions has been done[23]. Some general findings relating to the four core curriculum areas are:

<u>Mathematics</u>

Unlike Canadian institutions, almost none of the US institutions have a standalone Linear Algebra course in first year. Most covered only the basic Differential and Integral Calculus sequence. A few interesting programmatic observations are:

Georgia Tech: Covers Differential and Integral Calculus and introduces Linear Algebra through a 2 course sequence (3 hours of lecture per week).

Northwestern: Their Engineering Analysis 1, 2, and 3 course sequence combines Linear Algebra with Engineering Mechanics (Statics), Dynamics, and Computer Programming.

University of Illinois at Urbana-Champaign (UIUC):
Has an Introduction to Matrix Theory course (2 hours lecture per week) that covers the first part of the Linear Algebra material, with just a brief introduction to vector spaces, eigenvalues, and eigenvectors.

<u>Sciences - Physics</u>

The majority of programs had just the one-term Classical Mechanics course, with Electricity and Magnetism covered in second year. Georgia Tech and MIT followed the standard two-term physics sequence (Classical Mechanics and Waves, then Electricity and Magnetism). Only Northwestern had an Engineering Mechanics course (Statics) that is combined with Linear Algebra in their Engineering Analysis 2 course.

<u>Sciences – Chemistry/Materials Science</u>

All programs followed a model in which all students took a general introduction to chemistry course, and a second term course was available to students who were interested in certain fields (e.g., chemical engineering). The majority of the introductory courses included a laboratory experience.

Only one program (UIUC) offered a Materials Science course in first year and this was only required for MSE students.

<u>Computer Programming</u>

C-Based Courses: Of the nine programs reviewed, only the University of Michigan taught a C-based course to all their first-year engineering students.

At Purdue, ECE and IND students took a C-based course.

MATLAB-Based Courses: MATLAB is used in all but two of these first-year programs. In four of them, MATLAB is the exclusive programming language.

Python-Based Courses: Cornell and Carnegie Mellon based their first-year programming courses on Python. At Carnegie Mellon, ECE students follow up with C in second year. At MIT, ECE students are expected to know Python for use in their first-year design course. They offer an online course on Python for those

[23] These include Carnegie Mellon, Cornell University, Georgia Institute of Technology, MIT, Northwestern University, Purdue University, University of California Berkeley, University of Illinois UC, and University of Michigan.

ECE students who are not already proficient in this language. MIT does not have a first-year computer programming course for any of their departments.

Engineering Design, Communication and Teamwork

Most institutions have some curriculum component that introduces students to engineering fundamentals, including engineering design. A few examples are:

Cornell:

The one-term Introduction to Engineering course introduces students to the engineering process and provides a substantive experience in an open-ended problem-solving context. Students choose a specific course that presents this introduction through a particular lens. These include: **Lasers and Photonics, Modern Structures, Introduction to Signals and Telecommunications, and Biomaterials for the Skeletal System.** Some example course descriptions are[24]:

ENGRI 1110: Nanotechnology (also MSE 1110); 3 credits

Nanotechnology has been enabling the Information Revolution with the development of even faster and more powerful devices for manipulation, storing, and transmitting information. In this hands-on course students learn how to design and manipulate materials to build devices and structures in applications ranging from computers to telecommunications to biotechnology. (Fall, 3 credits)

ENGRI 1120: Introduction to Chemical Engineering (also CHEME 1120); 3 credits

Design and analysis of processes involving chemical change. Students learn strategies for design, such as creative thinking, conceptual blockbusting, and (re) definition of the design goal, in the context of contemporary chemical and biomolecular engineering. Includes methods for analyzing designs, such as mathematical modeling, empirical analysis by graphics, and dynamic scaling through dimensional analysis, to assess product quality, economics, safety, and environmental issues. (Fall, 3 credits)

ENGRI 1131: Water Treatment Design (also CEE 1131); 3 credits

Students learn how to design: reservoirs to provide water during droughts, aqueducts to transport water, and water treatment plants to prevent waterborne diseases. The course includes field trips, building a computer-controlled miniature water treatment plant, and exploring new technologies for making safe drinking water. (Fall, 3 credits)

ENGRI 1170: Introduction to Mechanical Engineering (also MAE 1170); 3 credits

Introduction to fundamentals of mechanical and aerospace engineering. Students learn and understand materials characteristics, the behavior of materials, and material selection for performing engineering function. They also learn fundamentals of fluid mechanics, heat transfer, automotive engineering, engineering design and product development, patents and intellectual property, and engineering ethics. In the final project, students use the information learned to design and manufacture a product. (Fall, 3 credits)

ENGRI 1140: Materials: The Future of Energy (also MSE 1140); 3 credits

New technologies are urgently needed to fulfill projected global energy requirements. Materials properties typically limit the performance that can be achieved in generation, transport, and utilization of energy. The experiential learning course will explore how new materials can increase our energy supply and decrease consumption. Materials issues in photovoltaic, fuel cell, battery, wind, transportation, lighting, and building technologies will be studied. Through integrated lab-

[24] Available at http://courses.cornell.edu/preview_program.php?catoid=22&poid=10884, Accessed November 7, 2014.

based activities, students will develop a broad understanding of materials issues in order to successfully design and build and energy generation system. (Spring, 3 credits)

Students also complete a two-course First-Year Writing seminar.

Northwestern:
One of the key components of their **Engineering First** program is their Design Thinking and Communication series of courses. This two-course sequence introduces students to the engineering design process and technical communication through a set of two real client-based design projects. In the fall, these are based on real problems submitted by individuals, non-profits, entrepreneurs, and industry members. In the winter these are based in healthcare, industry, and education.

Purdue:
Their **Transforming Ideas to Innovation I and II** set of courses introduce students to the engineering professions using multidisciplinary societally relevant content. Course focuses on teamwork, engineering fundamentals, logical thinking, and modern engineering tools (Excel and MATLAB). Students also take English Composition and Speech Communication courses.

UIUC:
In the fall term, they offer ENG100: Engineering Lecture, which consists of a core Engineering Orientation component for weeks one to four (12 lectures). This introduces students to the profession and allows them to learn some of the skills they will need to be successful as a student and as a practicing engineer. This includes leadership, professional practice, and life-long learning.

For weeks five through 12, students chose one of 13 different electives which include: Aspirations to Leadership, Engineering for Global Development, Live Like a Learner: Theory, Application, and Acquisition of Learning Skills, MATLAB & Excel Essentials, and Spatial Visualization. These make use of undergraduate Engineering Learning Assistants.

This is part of their new **Illinois Engineering First-Year Experience** (IEFX), which is an interdisciplinary program for all first-year students in which "students' aspirations are respected, supported, fostered within the programmatic initiatives that lay a solid foundation for their collegiate career."

Carnegie Mellon:
One of the requirements for first-year engineering students at Carnegie Mellon is that they must take two Introduction to Engineering courses. One is prescribed by their department and one is a breadth elective. Some example course descriptions are[25]:

06-100 Introduction to Chemical Engineering
We equip students with creative engineering problem-solving techniques and fundamental chemical engineering material for balanced skills. Lectures, laboratory experiments, and recitation sessions are designed to provide coordinated training and experience in data analysis, material property estimation for single- and multi-phase systems, basic process flowsheet, reactive and non-reactive mass balances, problem solving strategies and tools, and team dynamics. The course is targeted for CIT First-Year students.

---

[25] Taken from http://engineering.cmu.edu/current_students/first_years/introductory_electives.html. Accessed November 7, 2014.

27-100 Engineering the Materials of the Future
Materials form the foundation for all engineering applications. Advances in materials and their processing are driving all technologies, including the broad areas of nano-, bio-, energy, and electronic (information) technology. Performance requirements for future applications require that engineers continue to design both new structures and new processing methods in order to engineer materials having improved properties. Applications such as optical communication, tissue and bone replacement, fuel cells, and information storage, to name a few, exemplify areas where new materials are required to realize many of the envisioned future technologies. This course provides an introduction to how science and engineering can be exploited to design materials for many applications. The principles behind the design and exploitation of metals, ceramics, polymers, and composites are presented using examples from everyday life, as well as from existing, new, and future technologies. A series of laboratory experiments are used as a hands-on approach to illustrating modern practices used in the processing and characterization of materials and for understanding and improving materials' properties.

27-100 Engineering the Materials of the Future
Materials form the foundation for all engineering applications. Advances in materials and their processing are driving all technologies, including the broad areas of nano-, bio-, energy, and electronic (information) technology. Performance requirements for future applications require that engineers continue to design both new structures and new processing methods in order to engineer materials having improved properties. Applications such as optical communication, tissue and bone replacement, fuel cells, and information storage, to name a few, exemplify areas where new materials are required to realize many of the envisioned future technologies. This course provides an introduction to how science and engineering can be exploited to design materials for many applications. The principles behind the design and exploitation of metals, ceramics, polymers, and composites are presented using examples from everyday life, as well as from existing, new, and future technologies. A series of laboratory experiments are used as a hands-on approach to illustrating modern practices used in the processing and characterization of materials and for understanding and improving materials' properties.

42-101 Introduction to Biomedical Engineering
This course will provide exposure to basic biology and engineering problems associated with living systems and health care delivery. Examples will be used to illustrate how basic concepts and tools of science & engineering can be brought to bear in understanding, mimicking, and utilizing biological processes. The course will focus on four areas: biotechnology, biomechanics, biomaterials and tissue engineering, and bioimaging and will introduce the basic life sciences and engineering concepts associated with these topics. Pre-requisite OR co-requisite: 03-121 Modern Biology.

Students are also required to take an Interpretation and Argument course which, “introduces first-year students to an advanced, inductive process for writing an argument from sources.”