UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Working Group to Create an Institute for Engineering Education

Draft of Final Report

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ISTEP
Institute for Studies in Transdisciplinary Engineering Education and Practice

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1. INTRODUCTION

In October 2016 Dean Cristina Amon established a working group to make recommendations regarding the creation of a new extra-departmental unit focusing on engineering education (see Appendix 1 – Working Group Terms of Reference). This report outlines the Working Group's findings and recommendations, based on eleven months of consultation and deliberations: the Working Group recommends the creation of an *Institute for Studies in Transdisciplinary Engineering Education and Practice* (ISTe^{2}P) effective July 1, 2018, as an Extra-Departmental Unit, Type A (EDU:A) housed within the Faculty of Applied Science and Engineering (FASE).

ISTe^{2}P will bring together a critical mass of existing faculty who actively collaborate and are strongly engaged in cutting edge education scholarship and exemplary instructional practice. This EDU:A is needed as an academic home that unites these existing faculty along with existing academic programing, and thereby promotes leadership in teaching and learning within the changing landscape of engineering education and practice.

ISTe^{2}P will support a well-established and well-defined area of academic study. The proposed Institute will also create an academic space to promote leadership in teaching and learning, encourage related scholarship and research and contribute to the advancement and development of engineering education as a distinctive and valued field. It will partner with departments and institutes from across FASE to foster research and teaching in engineering education and engineering practice and thereby enable a vibrant scholarly community of faculty who are:

- **Influencing and guiding pedagogical development and teaching innovation across FASE and beyond;**
- **Extending the instruction of engineering to integrate new transdisciplinary[1] competencies;**
- **Pursuing research into practices emerging from other domains[2] that are increasingly being applied across engineering disciplines.**

2. CONTEXT: AN EVOLVING LANDSCAPE

Through consultation, deliberations and review of the literature, the working group identified that major shifts are occurring in the practice and teaching of engineering and the emerging skill set needed by engineers. Transdisciplinarity is becoming more essential to engineering practice with the increasing complexity of society's challenges. Furthermore, the role and activities of engineers are broadening to incorporate practices emerging from domains such as sustainability, entrepreneurship, leadership, education, globalization and innovation. These

[1] The transdisciplinary competencies we describe in relation to ISTe^{2}P are observable as attributes possessed by individual engineers. Engineers who are effective communicators and team players, and are creative, professional, ethical and systems thinkers, demonstrate competencies that can amplify their technical knowledge and strengths.
[2] Examples of these domains in relation to ISTe^{2}P include design, leadership, education, communication and business. Further domains such as sustainability, globalization and entrepreneurship may eventually be added as colleagues become affiliated with ISTe^{2}P.

shifts are expanding the competencies engineers need to make full and productive use of their technical strengths. Major shifts are also occurring in post-secondary educational pedagogy and andragogy that are opening the door to more effective instructional strategies and designs. The creation of this institute will support scholarship and teaching to help FASE and engineering in Canada proactively navigate, and thereby continue to lead and prosper, within this shifting landscape.

2.1 Emerging Practices

The identity of engineering and engineers is in many ways defined by what engineers do. For example, Engineers Canada[3] states that the practice of professional engineering is "any act of planning, designing, composing, evaluating, advising, reporting, directing or supervising that requires the application of engineering principles and that concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment, or the managing of any such act." Core to this definition of engineering practice is safeguarding the public interest in the application of engineering principles of mathematics, chemistry, physics or any related applied subject.

Societal needs and challenges are pushing the boundaries of contemporary engineering practice beyond its traditional definition. For example, some provinces (e.g. Alberta) include teaching engineering at a university within the definition of practice. A decade ago, the US National Academy report on the *Engineer of 2020*[4] triggered a substantial reform of engineering education and accreditation in the US and Canada. This report projected how the practice of engineering might evolve and asked the key question "does it serve the nation well to permit the engineering profession and engineering education to lag technology and society, especially as technological change occurs at a faster and faster pace? Rather, should the engineering profession anticipate needed advances and prepare for a future where it will provide more benefit to humankind? Likewise, should engineering education evolve to do the same?" While considerable progress has certainly been made, much remains to be done in terms of creating changes to help students achieve the desired learning identified in this report.

Since this seminal work, other studies have identified a growing gap between engineering education and the growing domain of modern engineering practice. For example, *A Whole New Engineer*[5] identified characteristics of engineering graduates that extend beyond technical skills to include relational, social and emotional dimensions, and recommended 12 characteristics needed for academic programs seeking to educate this type of graduate. This vision is helping shape or reshape engineering education at universities such as Purdue, University College London and National University of Singapore.

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[3] https://engineerscanada.ca/definition-of-the-practice-of-engineering

[4]The Engineer of 2020: Visions of Engineering in the New Century, National Academies Press 2004. https://www.nap.edu/catalog/10999/the-engineer-of-2020-visions-of-engineering-in-the-new

[5] Goldberg D.E. and Summerville, M "A Whole New Engineer," ThreeJoy Associates Inc. 2014

In a vision for reshaping engineering education at four major universities in the Netherlands, Aldert Kamp[6] concludes that solving the societal and engineering challenges of the 21st century will require "creative workable solutions, the performance and function of which not only depend on technology, but also on human factors and engineering business smarts". Further, he observes that lifelong learning will be key, because "in the new world of work it is no longer what an engineer knows, but how he/she learns and is able to apply what he/she learns that will make his career successful". Lifelong learning is becoming central, as it is "not the creation and dissemination, but the acquisition, sharing and combining of knowledge that will become the key factors of success". Further in this new learning based paradigm, engineering graduates will also need to be better versed at teaching and learning, teaching junior colleagues they supervise while learning continuously themselves. Such shifts will play a strong role in the employability of future generations of engineering graduates. In professional Faculties such as engineering, it is imperative that we prepare graduates for these new realities.

The quest to address societal needs and challenges of increasing complexity is also necessarily broadening the scope of engineering practice to integrate domains such as design, entrepreneurship, innovation, education, business, leadership, management, ethics, sustainability, globalization and optimization. None of these is exclusively the domain of engineering or any specific engineering discipline. Some are in established disciplines (e.g. management). Some are emerging as disciplines in their own right (leadership, globalization). Some are evolving into hybrid forms of practice at their intersection with engineering (e.g. engineering design, sustainability engineering, engineering ethics). Practices from these academic domains are increasingly needed and applied across engineering disciplines while, in turn, engineers are increasingly helping to study, grow and shape the domains themselves. How might practices from these emerging domains that cross engineering disciplines be defined? Sheppard et al[7] provide a useful definition of engineering practice: "the complex, thoughtful and intentional integration of problem solving process and specialized knowledge towards some meaningful end". Broadening this definition to include "practices emerging across engineering disciplines" results in a new definition that the working group promotes: the complex, thoughtful **conceptualization and application** of specialized knowledge and processes from other domains **within an engineering context** towards some meaningful end.

Given the academic breadth of knowledge emerging from these domains, vast opportunities exist for scholarly contributions. However, initial focus is first needed to put an academic foundation in place. ISTe^{2}P will initially focus on strengthening FASE's existing engagement in research and scholarship with respect to design, leadership, education, communication and business. These efforts will help create new knowledge, incorporate related instruction into curricula and understand application of knowledge and practices into engineering. This initial focus may be broadened to include practices from globalization, entrepreneurship and sustainability as colleagues already working in these domains become affiliated with ISTe^{2}P.

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[6] Kamp A. "Engineering Education in a Rapidly Changing World Rethinking the Vision for Higher Engineering Education" TU Delft, Second Revised Edition, 2016

[7] https://www.ijee.ie/articles/Vol22-3/02_ijee1751.pdf

Transdisciplinary Competencies

Engineering skills, competencies and attributes are often used to describe characteristics desired in graduate engineers. These terms describe a continuum from what they can do (skills) to who they are (attributes), with competencies falling in between. The CEAB describes these characteristics in terms of "graduate attributes" while ABET uses "graduate competencies". The Washington Accord[8] describes accreditation criteria in terms of individually assessable graduate attributes that are the components indicative of a graduate's potential to acquire professional competencies. More simply, competencies can be considered as the manifestations of combinations of attributes.

According to Nicolescu,[9] "transdisciplinarity concerns that which is at once between the disciplines, across the different disciplines, and beyond all disciplines". This "between, across, and beyond" distinguishes transdisciplinary from multidisciplinary (applying or coordinating knowledge from different disciplines) and interdisciplinary (linking or blending knowledge from one discipline with that from another). In contrast, transdisciplinary involves transcending or transforming the boundaries between disciplines, often with an overarching perspective so as to go beyond[10,11]. Nicolescu also conceptualises transdisciplinary knowledge as *in vivo* or knowledge that goes beyond the description of "external" objects to bring in the "internal" perspective and values of people. The transdisciplinary competencies we describe in relation to ISTe^{2}P are the synthesis of attributes and internal perspectives that individual engineers bring to their activities to amplify their technical knowledge and strengths. We observe and describe these competencies in terms of the qualities of individuals such as effective communicators, team players, creative, professional, ethical and systems thinkers.

While the concept of transdisciplinarity is not new, its application within the context of engineering is growing, along with the movement from mono-disciplinary to interdisciplinary approaches to global challenges. Last year, Purdue University launched a "transdisciplinary studies in technology" program, designed using a hybrid competency-based education model in which students still complete courses, but learning is directed towards achieving measurable learning outcomes rather than spending a set duration of time in classrooms; learning is the constant across students rather than course-time.

Purdue's program defines a competency as "an individual capability, proficiency, skill, behavior, value, and/or body of knowledge" that "integrate multiple skills, behaviors, values, attitudes, and bodies of knowledge". They identify eight primary competencies:

1. Design thinking
2. Systems thinking

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[8] http://www.ieagreements.org/assets/Uploads/Documents/Policy/Graduate-Attributes-and-Professional-Competencies.pdf
[9] http://www.metanexus.net/archive/conference2005/pdf/nicolescu.pdf
[10] Transdisciplinary professional learning and practice, edited by Paul Gibbs, Springer 2015
[11] http://www.jscimedcentral.com/TranslationalMedicine/translationalmedicine-spid-collaboration-science-translational-medicine-1024.pdf

3. Effective communication
4. Envision and execute independently
5. Social interaction and teamwork
6. Ethical reasoning
7. Innovation and creativity
8. Application of disciplinary knowledge

The program offers students a "combination of individualized plans of study (combining technical disciplines with humanities and business), close faculty mentoring of students, and a competency-based approach". Other institutions have also introduced transdisciplinary related programs[12, 13].

2.2 Engineering Education

Engineering education has been formally recognized in the United States as a distinct area of practice since the formation of the "Society for the Promotion of Engineering Education (SPEE)" in 1893. That body was renamed the American Society for Engineering Education (ASEE) in 1946, and in the late 1960s and early 1970s, the ASEE renewed its focus on the teaching of engineering; the ASEE currently has a global membership of over 12,000[14]. Globally, there are many examples of academic units that were created to promote evolution in the teaching and practice of engineering with over 30 engineering education departments, institutes and formal degree programs[15]. Further, 15 national engineering education societies exist along with 10 journals and almost 40 regular conferences and meetings. For example, the European Society for Engineering Education (SEFI) was established in 1973 to link 21 European universities with engineering programs. SEFI exists in parallel to the various national engineering societies, which support the engineering profession more generally, and focuses on promoting cooperation and diversity among engineering educators. The International Society for Engineering Pedagogy (IGIP) was founded in 1972 to link engineering and pedagogy on a scientific level. IGIP has since developed a model engineering curriculum and has created both the title "International Engineering Educator" and a registry of such titled practitioners. Other countries and regions also have societies, associations and programs devoted to engineering education (see Appendix 2). Globally, the International Federation of Engineering Education Societies, which coordinate efforts across the world, just celebrated its tenth anniversary[16].

Despite all this global activity, Canada has lagged behind, but momentum is growing. The Canadian Design Engineering Network (CDEN) was founded in 2000 with a focus on sharing best practices in engineering design education. CDEN was subsumed by the Canadian Engineering Education Association (CEEA) in 2010, whose mission is to "enhance the competence and relevance of graduates from Canadian Engineering schools through continuous improvement in

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[12] https://www.nmt.edu/graduate-studies/76-graduate-studies/graduate-studies/5904-transdisciplinary
[13] https://www.cgu.edu/why-cgu/transdisciplinary-studies/
[14] https://www.asee.org/about-us/the-organization (accessed Nov28 2016)
[15] http://engineeringeducationlist.pbworks.com/w/page/27610307/Engineering%20Education%20Departments%20and%20Programs%20(Graduate) (accessed Nov28 2016)
[16] http://www.ifees.net/members/ifees-members/

engineering education and design education". CEEA was created in part to provide a forum that could focus on distinctly Canadian issues in engineering education. As Canada becomes a player in this globally important field, the University of Toronto is poised to take a leadership role. The activity in the United States and elsewhere has produced numerous comprehensive reports that explain the evolution of engineering education and point to future directions of interest. Recently, analyses have highlighted three major catalysts for change in engineering education:

<u>The need to generate and incorporate evidence-based teaching methods into engineering education.</u> A 2012 National Academy of Science report,[17] "*Discipline Based Education Research*", summarizes a comprehensive synthesis of the available literature, recommending adoption of evidence-based teaching practices to improve learning outcomes. Specifically, this committee reports that "research-based instructional strategies are more effective than the traditional lecture in improving conceptual knowledge and attitudes about learning." Sadly, they also conclude that education research findings "have not yet prompted widespread changes in teaching practice among science and engineering faculty". The committee suggests that "these efforts are more likely to succeed if they are consistent with research on motivating adult learners, include a deliberate focus on changing faculty conceptions about teaching and learning, recognize the cultural and organizational norms of the department and institution, and work to address those norms that pose barriers to change in teaching practice".

<u>The relationship between innovation and prosperity, and STEM education.</u> The 2015 report[18] ,"*Some Assembly Required: STEM Skills and Canada's Economic Productivity*", from the Council of Canadian Academies, examined the role that STEM skills play in supporting and fostering innovation, productivity and growth. While this panel did not find direct evidence of the impact of STEM skills on innovation, it concluded that "STEM skills are central to a variety of education and job opportunities" and that "they provide individuals with options in uncertain labour markets". The panel also cautioned that "a focus on narrowly specialized STEM skills development to meet short-term labour market requirements may have little relevance for meeting long-term skill requirements. Short-term labour requirements in certain industries may quickly shift (e.g., the dotcom bust). New technologies are also creating industries and occupations that previously did not exist". In response, the panel advocated that education with "flexibility in a range of education and training systems, including universities, colleges, polytechnics, employer-based training, and government programs, is required to help equip the next generation of learners with the STEM skills".

Canada's less-than-impressive standing on the Global Innovation Index (15th) provided context for this report[19]. Canada ranks low among OECD countries in the proportion of 25- to 34-year-old Canadians with a degree in engineering fields (25th, 3.3 per cent). However, the issue is

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[17] National Research Council "Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering," S.R. Singer, N.R. Nielsen, and H.A. Schweingruber, Editors, Committee on the Status, Contributions, and Future Directions of Discipline-Based Education Research, Board on Science Education, Division of Behavioral and Social Sciences and Education, Washington, DC: The National Academies Press 2012

[18] Council of Canadian Academies, "Some Assembly Required: STEM Skills and Canada's Economic Productivity," 2015

[19] http://www.wipo.int/pressroom/en/articles/2016/article_0008.html

more complex than simply the supply of talented students graduating from Canadian universities. How our students are being educated is also playing a role. The Council of Canadian Academies[20] panel concluded that “STEM skills are necessary for many types of innovation, as well as productivity and growth, but they are not sufficient on their own. Other skills such as leadership, creativity, adaptability, and entrepreneurial ability may be required to maximize the impact of STEM skills”.

The explosion and influence of educational technologies. The last decade has seen the emergence of educational technology as a driving force for change. Technology such as software, data systems and computer hardware are now deeply embedded in education systems from K12, through post-secondary, to continuing and professional education. Students, faculty and institutions make extensive use of technology in every aspect of teaching and institutional functionality. Yet the field of educational technology is still relatively new and evolving rapidly. Examples of this growth can be found throughout the sector:

- Apple, Google, Microsoft and Amazon are investing heavily in Ed Tech ($3.1B in 2015).
- The global market value for educational technologies is growing by 25% annually and predicted to reach $586B by 2021[21].
- Ontario is investing heavily in post-secondary e-learning[22]. In 2013-14, 220,000 undergraduate and graduate students registered in 3,400 online courses and there are now 132 fully online programs available across Ontario’s 21 publicly funded universities[23].
- The emergence of massive online education systems such as Lynda.com, edX, FutureLearn and Coursera. Arguably, the first Massive Open Online Course (MOOC) was introduced in Canada in 1998, however the field took off in 2012 with the creation of Coursera, Udacity, edX and later FutureLearn. As this field has matured, there has been a convergence around models of delivery that blend open and closed content as providers grapple with the economic realities of education.

Technology development is expected to spur the infusion of more hand-held devices, artificial intelligence, gamification, virtual reality and collaboration tools[24]. As a result, learning is predicted to become more mobile, interactive, intelligent, personal and global. These shifts have the potential to enhance and drastically alter the role of in-class learning within “bricks and mortar” physical universities. At the same time, the market opportunities are attracting more private sector interest and involvement in education[25] both for altruistic reasons and

[20] Council of Canadian Academies, “Some Assembly Required: STEM Skills and Canada’s Economic Productivity,” 2015
[21] http://www.marketsandmarkets.com/PressReleases/smart-digital-education.asp
[22] https://www.ecampusontario.ca/
[23] http://cou.on.ca/key-issues/education/online-learning/
[24] Contact North “A 2016 Look at The Future Of Online Learning” https://teachonline.ca/tools-trends/exploring-future-education/2016-look-future-online-learning-part-2
[25] https://www.nytimes.com/2017/06/06/technology/tech-billionaires-education-zuckerberg-facebook-hastings.html?smid=pl-share&_r=0

potentially to capture some of this lucrative market; the US alone spends over $1T annually on education, $320B of this on post-secondary education.

To date, departments of Engineering Education in the U.S. have been slow to engage in research on educational technology. There have been some technology start-ups and systems created to enable new ideas that have been generated in Engineering Education, but for the most part this remains an unexplored area of work. In particular, applying engineering methodologies in data systems, network systems, industrial processes, and so on to educational technology is an area of significant opportunity.

These three catalysts create the impetus to not only change the way we educate our graduates, but also to study how we educate in order to make solid connections between educational practice and outcomes. Currently, the only PhD level engineering education offering in Canada is the Collaborative Specialization in Engineering Education at the University of Toronto, an intra-university graduate level offering that provides an additional multidisciplinary experience for students enrolled in and completing the degree requirements of participating U of T PhD degree programs. Students complete their home degree program requirements and the collaborative specialization requirements and receive a parchment reflecting their degree program along with a transcript notation and a frameable document from the School of Graduate Studies reflecting the collaborative specialization. Queen's University and the University of Manitoba have engineering graduate students at the Master's level pursuing engineering education-related thesis research. There is no formal administrative structure in place at Queen's and students pursue degrees through traditional programs (e.g. electrical engineering). The University of Manitoba has recently created a "Centre for Engineering Professional Practice and Engineering Education"[26] as a home for Master's students. Collectively, the drivers for change plus the developing state of engineering education programs in North America and abroad create a crucial opportunity to expand our Collaborative Specialization in Engineering Education to be a more all-encompassing engineering education program within ISTe^{2}P.

3. THE INSTITUTE FOR STUDIES OF TRANSDISCIPLINARY ENGINEERING EDUCATION AND PRACTICE

Creation of ISTe^{2}P will be groundbreaking in Canada and will provide a structure to help put engineering education in Canada on the global leading edge. With a distinct identity synthesized from a solid interdisciplinary academic foundation, ISTe^{2}P will integrate and augment initiatives already begun in the FASE and the University to bring a Canadian perspective to this field, building on our Faculty's culture of excellence and preeminent global position. FASE and U of T are in a position to take yet another leadership role in post-secondary education.

[26] http://umanitoba.ca/engineering/departments/ce2p2e/

This academic community will be a place of synthesis for creating and applying new knowledge that reinforces the collaborative nature of engineering. Already embedded in multiple areas across FASE, the Institute will bring together existing units, existing faculty and existing programing to enhance teaching and learning competencies for the benefit of students, faculty and the broader community. Although several categories of Extra-Departmental Units (EDUs)[27] were rigorously debated (See Appendix 3), the working group recommends that ISTe^{2}P be created as an EDU Type A, as only this structure can hold these existing majority and minority budgetary appointments needed to offer this existing academic programing.

ISTe^{2}P will foster research/scholarship and teaching in engineering education and leadership in educational practice. Its mission will be to:

study and enhance the education of students and practices of today's engineers so as to address tomorrow's societal challenges

By:

- Engaging in the scholarship of teaching and learning;
- Translating research into advances in the delivery of learning experiences and the design of academic programing;
- Providing leadership through the development of new models of effective teaching;
- Extending the understanding of transdisciplinary competencies and translating this knowledge into curricular and co-curricular learning experiences;
- Investigating new practices emerging from other domains to support their incorporation into curricula and engineering practice;
- Partnering in the delivery of existing graduate and undergraduate academic programing in technical communication, leadership, business, design and engineering education;
- Bringing together colleagues within and beyond FASE to promote community and promote scholarly conversation.

This will enable ISTe^{2}P to:

- Promote and strengthen cross-departmental collaboration;
- Help FASE to become a recognized innovator in engineering education;
- Promote U of T's reputation as a global leader in education and related research.

This mission will be executed by an initial contingent of nine existing budgetary appointments, an existing budgetary cross-appointment, along with non-budgetary cross-appointments both from within and beyond FASE. It will offer existing and new undergraduate and graduate courses, undergraduate certificates in Leadership and in Communication, the existing

[27] See the *University of Toronto Guidelines for Academic Units* at http://vpacademic.utoronto.ca/wp-content/uploads/2015/08/edu-guidelines.pdf for characteristics of the four types of EDUs, and Appendix 3: Administrative Structures Considered.

Collaborative Specialization in Engineering Education and will support the delivery of other courses and learning activities (see Appendix 4 for a list of existing courses).

ISTe^{2}P's research will focus on emerging practices, transdisciplinary competencies and the scholarship of teaching and learning. The resulting knowledge will be synthesized, translated and mobilized into academic programing. This programing will promote integrative transdisciplinary learning through active and technology-enriched pedagogy and prepare students to identify, learn and apply the engineering principles, practices and competencies needed to resolve global challenges.

4.1 Existing Academic Foundation

ISTe^{2}P will provide a formal academic home for collaboration to support a strong existing suite of internationally recognized initiatives, helping to preserve their distinct strengths, reputations and identities:

- The Engineering Communication Program (ECP, established 1995) which works with faculty and students across all departments to integrate technical communication into the undergraduate and graduate curriculum.
- The Institute for Leadership Education in Engineering (ILead, established 2010) which provides leadership education in the undergraduate and graduate curriculum.
- The Collaborative Specialization in Engineering Education (established 2014) which is offered to Master's and PhD students registered in FASE and OISE degree programs.

FASE is in a strong position to lead within the area of engineering education and practice, drawing not only from the breadth of its teaching activities but the diverse mix of teaching- and tenure-stream faculty that have contributed to teaching excellence within the Faculty. There exists a strong potential for influencing engineering Faculties across Canada and further enhancing FASE's strong reputation for leadership. To this end, an institute encompassing research and dissemination would aid in fostering the culture and providing the resources for such an undertaking:

- Internally, ISTe^{2}P's scholarship will help enhance student learning and develop models of effective teaching, help make full and effective use of new teaching infrastructure in the delivery of education and create a foundation for new academic programing.
- Externally, mobilization of ISTe^{2}P's research and scholarship will promote scholarly conversation to help shape the evolving nature of engineering practice, develop the underlying competencies and understand the identity of Canadian engineers.

4.2 Academic Focus and Activities

ISTe^{2}P will undertake a range of activities within its academic mandate in order to realize its vision. While categorized in terms of education and research, there will be a continuum between these two dimensions of the Institute's mandate, with synergistic interactions. Much of the research on engineering education and practice will inform and be translated into teaching and learning, which in turn will help identify gaps and questions to guide further research.

4.2.1 Research Mandate

ISTe^{2}P's research will support its mission through the creation, translation and mobilization of knowledge relating to emerging practices, transdisciplinary competencies and the scholarship of teaching and learning. Collaboration with students, alumni, industry and government will be essential in order to ground this research in terms of the changing nature of our students and the many career paths they now take after graduation. ISTe^{2}P's research findings **will help to guide what we teach, how we teach and our understanding of the evolving identity of engineers and the nature of engineering**. Specifically, ISTe^{2}P's research mandate will cover the following themes:

- **Instructional Methods and Tools**: ISTe^{2}P will pursue research on pedagogy, andragogy, learning, instructional design, assessment methods and learning technologies to create knowledge to support the development of teaching methodologies and innovative educational tools. Foci will span the design of digital tools for on-line and technology enhanced learning, to tools and techniques to support active and cooperative in-person learning. Methods will be developed and applied to assess the effectiveness of these teaching tools and techniques.

- **Domains at the Interface of Engineering**: ISTe^{2}P's faculty will investigate how knowledge and practices from other domains are being integrated into the practice of engineering. This research will help to generate theoretical conceptualizations and empirical case studies to help guide the integration of these domains into engineering contexts. For example, research will explore engineering-based leadership, focusing on how this is applied in industry, engineering intensive companies and in broader society. Another theme will be exploring how design is practiced across fields beyond engineering to identify approaches and processes that can enhance engineering design, and how engineering design is in-turn influencing approaches used in these fields. This research will also help Identify essential transdisciplinary competencies to support their integration into engineering curricula, instruction and assessment.

- **Engineering Nature and Identity:** ISTe^{2}P's faculty will pursue scholarly enquiry to create a deeper understanding of the evolving nature of engineering. Related research will codify what it currently means to be an engineer and describe how this is changing. Research will explore how, why and when undergraduate students acquire and enact their engineering identity and how this aligns with their career satisfaction and success after graduation. Studies will examine how engineering identities can better align with other forms of identity, including gender and culture and the related influences along the "life path" of an engineering graduate. A key investigation will be into how gender and cultural identity can influence recruitment into engineering, academic success and career satisfaction and success. These research findings will help engineering Faculties, and other engineering intensive organizations, shape their cultures to attract, support and retain the very best people and help them produce their very best work.

- **Research Translation into Curricular Design**: Research findings on pedagogy, transdisciplinary competencies and emerging practices will be synthesized into the design on new learning experiences and the development of models of effective teaching. Courses will be designed to enable and evaluate integrative transdisciplinary learning through active and technology enriched pedagogies. This learning may, for example, be problem-based rather than content-based, and might focus around solving global challenges. The inherent transdisciplinary course structure will require students to identify, learn and apply engineering principles, practices and competencies from across engineering disciplines. More fundamentally, the learning will be based around a "Global Learning Society" model ("know what you need, know how you can acquire it, know how you can use and apply what you have acquired") rather than the traditional "Knowledge Society" model ("know what you know, know what you can do with what you know"), in order to better promote lifelong learning. These pilot courses will serve as a "test-bed" used to develop and evaluate new holistic approaches to teaching and learning that integrate technical knowledge with competencies and practices using enriched pedagogy.

- **Impact**: ISTe2P's research and scholarship will promote educational leadership. The impact will be manifested through publications, conference presentations, involvement in scholarly societies and translation into teaching and learning. ISTe^{2}P will become renowned for engineering education and practice, nationally and worldwide. Impact will also be achieved by educating Canada's next generation engineering educators and researchers. Overall, ISTe^{2}P's impact will enhance the FASE's visibility in engineering education, both internally and externally, and thereby contribute to building FASE and the University's reputation for scholarly leadership.

4.2.2 Education Mandate

ISTe^{2}P will also pursue its mission by partnering in the delivery of existing courses and certificates, along with the Collaborative Specialization in Engineering Education. Further, ISTe^{2}P will collaborate to help integrate the instruction of transdisciplinary competencies and emerging practices into targeted programing. Finally, ISTe^{2}P will partner to influence and help encourage pedagogical scholarship, the development of high impact practices and teaching innovation across FASE and beyond. Specifically, ISTe^{2}P's education mandate will cover the following themes:

- **Existing programing:** ISTe^{2}P will work with ECP, ILead and the Collaborative Specialization in Engineering Education to support and help build on existing instructional activities. ISTe^{2}P faculty will also deliver courses as part of the First Year and the Business minor. These curricular offerings include 16 undergraduate and 13 graduate courses, 34 courses co-instructed, undergraduate certificates in Leadership and in Communication and the Collaborative Specialization in Engineering Education (see Appendix 4 for a list of courses).

Design and delivery of new programing: ISTe^{2}P will contribute to the design of new courses relating to engineering education, emerging engineering practices and transdisciplinary competencies. These may include new courses on business, communication, leadership, instructional design, education research methodologies and the development of education technology. Courses or instructional modules may be designed to introduce engineering concepts to non-engineering majors. Transdisciplinary courses that bring together engineering and non-engineering students to address local urban issues or global challenges may also be created. At the graduate level, ISTe2P will become the lead unit for the existing Specialization in Engineering Education and will, within its first 10 years, design and propose for approval a broader Graduate Program in Engineering Education and Practice.

- **Support the instruction of engineering through the infusion of transdisciplinary competencies:** ISTe^{2}P faculty already support the instruction or co-instruction of communication and teamwork in a wide range of courses. These include first year design courses, core technical courses, thesis courses and a multidisciplinary capstone course. During the first five years ISTe^{2}P faculty will grow the instruction of team skills into a larger number of technical courses. Instruction of leadership in the multidisciplinary capstone course will also be supported. Similarly, instruction of the other transdisciplinary competencies and practices emerging from other domains (e.g. leadership, education, communication, business and design) will be infused and combined with technical knowledge in selected courses, to create more holistic learning experiences.

  Instruction of transdisciplinary competencies will also be extended beyond the classroom. ILead is currently providing co- and extra-curricular learning opportunities that enable and amplify the development and refinement of leadership competencies. These offerings will be sustained and enriched to leverage additional learning in conjunction with internships, research, entrepreneurial design project experiences and other experiential learning opportunities. A priority in the first five years will be the development of curricular and co-curricular instruction to more comprehensively support and promote work-integrated learning.

- **Influence and guide pedagogical development and teaching innovation across FASE and beyond:** ISTe^{2}P faculty will help build and grow FASE’s strengths in the areas of technology-enhanced learning, cooperative learning, experiential learning and active learning, along with the assessment of learning outcomes. Another focus will be the development of digital learning tools to enhance and enrich undergraduate education and extend FASE’s online offerings; support for lab-based learning may be one component of this thrust. These initiatives will be pursued in conjunction with ISTe^{2}P-related research or as products of the mobilization of this research.

Instructional workshops and seminars will be offered to solidify and grow the community of colleagues engaged in the scholarship of teaching and learning. This will also increase opportunities for research collaboration and co-supervision of graduate students.

Finally, ISTe^{2}P will help to foster FASE initiatives such as the Hart Teaching Innovation Professorships and TEAL Fellows program. Overall, ISTe^{2}P will become a renowned hub for engineering education activities, research and workshops nation-wide and worldwide.

4. FACULTY MEMBERS

FASE now has a critical mass of faculty who are heavily engaged in instructional practice and the scholarship of teaching and learning. As an EDU:A, ISTe^{2}P will provide an academic home for these faculty that allows budgetary appointments and cross-appointments. This will include at the outset the budgetary appointment of 10 existing teaching stream faculty (9 full appointments and 1 cross-appointment) who will be actively engaged in the Institute.

This cohort of core faculty will be supplemented with the cross-appointment of tenure- and teaching-stream faculty from within FASE who are also engaged in the scholarship of teaching and learning (See Table in Appendix 5). It is expected that additional teaching- and tenure-stream faculty in specific engineering and non-engineering disciplinary subfields who are engaged in pedagogical research **may choose** to engage in the work of the unit through non-budgetary cross appointments after ISTe^{2}P is established.

ISTe^{2}P will also provide a structure and mechanism for the full or joint appointment of future teaching- and tenure-stream faculty whose expertise transcends FASE's existing departments and institutes. Cross appointments and possibly future hires will help sustain a critical mass of colleagues with shared expertise and interests and thereby foster a vibrant community and avoid colleagues working in isolation. Externally, faculty members in OISE have indicated interest in non-budgetary cross-appointments and increased involvement of FASE in the integration of engineering in education of future kindergarten to grade 12 teachers through their Master of Teaching program. Further, adjunct appointments of "engineers in residence" from companies and government are envisioned, to help contextualize the instruction of transdisciplinary competencies within FASE.

ISTe^{2}P faculty will initially support instruction in five overlapping areas:

- **Engineering Communication:** The Engineering Communication Program (ECP) provides integrated communication instruction through standalone communication courses, communication and design courses, assignment and rubric design and support for FASE's growing number of multilingual students.

- **Engineering Leadership:** Courses offered by the Institute for Leadership in Engineering Education (ILead) now reach over 500 students a year. Courses are supplemented by rich co-curricular offerings. Leadership learning opportunities are also integrated into core technical and design courses that reach several thousand students per year.

- **First-Year Curriculum:** FASE's first-year program has evolved immensely over the last 10 to 15 years, and now supports the education of approximately 1,200 students. First-year boasts a complex complement of teaching teams that support foundational learning through cross-disciplinary collaboration in teaching, assessment and research and the introduction of new pedagogical techniques, tools and approaches.

- **Cross-disciplinary Design Teaching:** Since 2003, FASE has incorporated instruction of design throughout the undergraduate curriculum. A major step was the introduction of the cornerstone design courses for all first-year students. This instruction of design has now evolved into "design spines" in each program that provide learning from this initial cornerstone course to the capstone courses in fourth year. In 2014, a multidisciplinary capstone course was introduced to further enrich the design related instruction available.

- **Engineering Business Minor**: The Engineering Business minor is a collaborative effort between U of T Engineering and the Rotman School of Management. It is designed specifically for engineering students interested in learning more about the business dimension of engineering—from finance and economics to management and leadership. Courses cover wealth production and creation, accounting, research and development, management, economics and entrepreneurship, all within a global context. ISTe^{2}P will initially only be involved in the Business Minor but its faculty may become involved in future minors such as the proposed Engineering and Public Policy minor.

5. RESEARCH FUNDING

5.1 External Research Funding

Funding for Science Technology Engineering and Math (STEM) education research exists in many countries. For example, the US National Science Foundation (NSF) has devoted a division to Engineering Education and Centers (EEC) since approximately 2005. The National Academy of Engineering (NAE), founded in 1964, also has as one of its mandates supporting projects to enhance engineering education. Collectively the ASEE, NAE and NSF provide leadership, funding and a sense of community to North American engineering educators and engineering education researchers.

Funding opportunities for engineering education research are also growing in Canada but no federal funding programs exist yet. The Natural Sciences and Engineering Research Council of Canada (NSERC) does not have dedicated funding for research into engineering education. The Social Sciences and Humanities Research Council (SSHRC) has supported a small number of engineering education researchers, with that support focusing on either pre-university Science, Technology, Engineering and Mathematics (STEM) education or on issues of gender and culture in undergraduate engineering.

External research funding will be derived through Federal Tri-council agencies (NSERC, SSHRC) and provincial agencies (HEQCO, OCE). It is anticipated that ISTe^{2}P will initially only generate modest levels of research funding, given the current constraints on funding engineering education research, or STEM education research more generally, at the federal level. For example, some funding has been awarded to FASE researchers (McCahan, Evans, Reeve) by HEQCO. Further, ILead has demonstrated continued success in acquiring funding. ILead has also created a very successful Community of Practice that has been support by multiple companies. Ontario is investing heavily in post-secondary e-learning and in 2016-17 over $600k was awarded to the University to promote the creation of online courses, digitals tools and e-textbooks.

Despite this success, there is still a pressing need for federally funded mechanisms to be put in place to support engineering and, more generally, post-secondary STEM education research. STEM education research is a priority in many other jurisdictions where it is supported through substantial funding. For example, last year the United States provided US$7 billion in federal funding to STEM education, which includes US$105 million through their National Science Foundation towards research that will work to improve undergraduate STEM education.[28]

It is worth noting that Engineers Canada has produced a National Position Statement identifying Canada's lack of federal funding for engineering education research as an obstacle to innovation and productivity. Further, the National Council of Deans of Engineering and Applied Science (NCDEAS) started in 2017 to actively lobby the Federal Government to address this issue. A proposal has been submitted to Members of Parliament to:

1. Broaden the Natural Sciences and Engineering Research Council of Canada's (NSERC) existing Chairs in Design Engineering program to create Chairs in Engineering Education.
2. Create a new collaborative program between NSERC and the Social Sciences and Humanities Research Council of Canada (SSHRC) for research on post-secondary STEM education.

NCDEAS notes that these strategic investments will provide returns through increased productivity and prosperity and will help reduce Canada's growing innovation gap.

[28] https://www.whitehouse.gov/sites/default/files/microsites/ostp/stem_budget_supplement_fy_17_final.pdf

5.2 Internal Research Funding

Both UofT and FASE have recognized this need and funding to support education related initiatives is becoming increasingly available. These internal programs are certainly aligned with ISTe^{2}P's mission. It is anticipated that ISTe^{2}P faculty will be active participants in these programs.

- Engineering Instructional Innovation Program: Launched in 2012, this program supports the creation or substantial renovation of an undergraduate course, a closely related group of courses or another type of learning experience. Projects typically have the potential to produce significant and sustainable impact on student engagement and learning outcomes, identify measurable results and include a plan for collecting data on outcomes.

- Technology Enhanced Active Learning (TEAL) Fellows Program: Launched in 2017, this program supports design or redesign of an undergraduate or graduate course to include active learning approaches that leverage the use of technology.

- Hart Teaching Innovation Professorships: In 2017, six U of T Engineering faculty members were named as inaugural Hart Teaching Innovation Professors. These professorships support innovation in engineering education, from technology enhanced active learning to Indigenous outreach.

- Learning and Education Advancement Fund (LEAF): Launched in 2014, this program supports projects that anticipate, leverage and create positive changes in both the modes and mechanisms of undergraduate education at the University of Toronto. The overall goal is to enrich the learning experience of undergraduate students by developing and enhancing the assessment and application of high-impact teaching practices within the range of learning environments.

Additional sources also exist. For example, an initiative to support engineering education in Africa, initially supported through SEED funding from the Dean's Strategic fund, has been successful in winning $460k in further support from the Connaught Global Challenge fund, the Learning and Education Advancement Fund and the Dean's Strategic Fund.

6. MEASURES OF SUCCESS

ISTe^{2}P will track its progress towards achieving its vision by measuring what it has delivered five and 10 years from its establishment in terms of:

<u>Innovative Teaching Initiatives</u>

1) Number of courses adopting new in-person and digital tools and techniques
2) Number of new courses designed and delivered
3) Number of courses that integrate transdisciplinary competencies

Excellence in teaching

1) Student enrolment in courses
2) Student evaluation of programing
3) Number of courses delivered
4) Student enrolment and completion rates
5) Number of courses co-taught

Educational Leadership

1) Number of faculty co-instructing or applying instructional strategies encouraged by ISTe^{2}P
2) Attendance at seminars and workshops
3) Number of future educators that graduate from our Faculty, and propagate their knowledge and experience at other institutions
4) Community size (number of appointed or cross appointed faculty, postdoctoral fellows, and graduate students) to ISTe2P
5) Community breadth in terms of membership within and beyond FASE
6) Number of collaborative initiatives and activities

Engagement and Impact from Scholarly Discourse

1) Reputation in Canada and internationally
2) Recognition as a thought leader based on the level of engagement with, and consultation requested from beyond FASE
3) Engagement in the educational divisions of scholarly societies and education associations
4) Perception of alumni and employers that U of T is producing better engineers

Discipline Based Scholarship

1) Number of research publications and presentations
2) Level of research funding
3) The adoption of instructional knowledge and techniques beyond FASE
4) Contributions at conferences
5) Number of research collaborations and studies with colleagues in other Faculties or external to U of T (nationally and internationally)

Measures of success for individual activities are provided in Appendix 7, along with associated metrics, goals and milestones.

7. CONSULTATION

Extensive consultation was and will continue to be undertaken in support of the development of this proposal, with the following providing input:

Internal to FASE

- Engineering Communication Program (October 2016)
- Division of Engineering Science, consulted with former Chair (October 2016)
- UTIAS, email exchange with Chair (October 2016)
- Graduate students in Collaborative Specialization in Engineering Education (October 2016)
- Jonathan Rose re. the Hatchery and Entrepreneurship (October and November 2016)
- Chemical Engineering and Applied Chemistry departmental meeting (November 2016)
- IBBME (November 2016)
- Electrical and Computer Engineering departmental meeting (November 2016)
- Materials Science and Engineering, consulted with Chair (November 2016)
- Preliminary consultation with the Office of the Vice-Provost, Academic Programs (November 2016)
- Chairs and Directors of FASE (December 2016)
- Mechanical and Industrial Engineering meeting (December 2016)
- Faculty and staff survey (December 2016)
- Discussions at Faculty Council (December 2016)
- President's Teaching Academy (April 2017)
- Head, Engineering and Computer Science Library (April 2017)
- ILead Board of Advisors Meeting (May 2017)
- Faculty with budgetary appointments to ISTe^2P (August 2017)
- Chairs and Directors of FASE (September or October 2017)[a] (a: anticipated)
- Engineering Society of FASE (September or October 2017)[a]
- Distribution of proposal to FASE faculty (October 2017)[a]
- Discussion at Faculty Council (October 2017)[a]

External to FASE

- Clare Brett, Chair of the Department of Curriculum, Teaching and Learning, OISE (November 2016)
- Letters from engineering alumni (December 2016)
- Engineering Alumni Association (April 2017)
- Susan Leiff, Vice-Chair Education and Director of the New and Emerging Academic Leaders Program (April 2017)
- Informal consultation with the broader academic community in Canada at the 2017 Canadian Engineering Education Association Annual Conference which included a visioning workshop on the future of engineering education with ~200 instructors from across Canada (June 2017)
- Deans of Faculties with faculty members who may be interested in actively engaging with Institute (October 2017)[a]

8. LIST OF APPENDICES

Appendix 1: Working Group Announcement and Terms of Reference
Appendix 2: Associations/Societies and Programs Focusing on Engineering Education
Appendix 3: Administrative Structures Considered
Appendix 4: Course List
Appendix 5: $ISTe^2P$ Faculty Members
Appendix 6: Activities Proposed for the First Ten Years

APPENDIX 1: WORKING GROUP ANNOUNCEMENT AND TERMS OF REFERENCE

2016-17/02

MEMORANDUM

To: Members of the Faculty of Applied Science & Engineering

From: Cristina Amon, Dean

Date: October 12, 2016

Re: **Announcement of Working Group to Create the Institute for Engineering Education**

There has been an increasing focus on engineering education in our Faculty over the past few years, with a number of faculty engaged in the pedagogy. We have also seen teaching stream appointments remain constant, between 19-22 since 2010.

I believe the Faculty will be well served by the creation of an administrative home for current and future teaching stream faculty whose focus is on engineering education as well as, potentially, non-budgetary cross appointments. The Institute can also promote teaching and scholarship in this area, and house the existing Collaborative Program in Engineering Education.

Accordingly, after consultations with Chairs and Directors, we have established a Working Group to draft a proposal for the creation of the Institute for Engineering Education as an extra-departmental unit, type A (EDU:A). The terms of reference, process, timing and membership of the Working Group are provided below.

Terms of Reference

1. Consult deeply and broadly on the creation of the Institute, incorporating suggestions and clearly articulating the nature and outcome of that consultation
2. Describe the intended scope of activity of the proposed Institute and provide an academic argument for its creation
3. Clearly describe the academic focus of the Institute, including program delivery, research focus and other activity or programming
4. List the faculty who may be actively engaged in the proposed Institute
5. Articulate the duties of the Institute director, including policies and administrative operationsDescribe expectations relative to the periodic review of the Institute

Process

The Working Group will seek input from key stakeholders across the Faculty and University. Its findings will be documented in the form of a draft proposal to the Dean. If required, a motion based on the proposal (in its entirety or in modified form), will be submitted to Faculty Council and University governance for approval.

Timing

1. Working Group created: October 2016
2. Meetings and consultation: October 2016 through January 2017
3. Report submitted to Faculty Council and University governance for approval: Spring 2017
4. Institute launched: July 2017

Membership

I am grateful to the following individuals who have agreed to serve on the Working Group:

- Greg Evans, Professor, Department of Chemical Engineering and Applied Chemistry (Working Group Chair)
- Kamran Behdinan, Professor, Department of Mechanical and Industrial Engineering
- Jason Foster, Associate Professor, Teaching Stream, Division of Engineering Science
- Sean Hum, Associate Professor, The Edward S. Rogers Sr. Department of Electrical and Computer Engineering
- Dawn Kilkenny, Assistant Professor, Teaching Stream and Associate Director, Undergraduate Programs, Institute of Biomaterials and Biomedical Engineering
- Brenda McCabe, Associate Professor, Department of Civil Engineering
- Elizabeth Smyth, Professor, Department of Curriculum, Teaching and Learning, Ontario Institute for Studies in Education and Vice-Dean, Programs, School of Graduate Studies
- Micah Stickel, Associate Professor, Teaching Stream, The Edward S. Rogers Sr. Department of Electrical and Computer Engineering and Chair First Year
- Deborah Tihanyi, Associate Professor, Teaching Stream and Director, Engineering Communication Program

Members of the Faculty are invited to provide input on the creation of the Institute for Engineering Education by emailing governance.fase@ecf.utoronto.ca.

APPENDIX 2: ASSOCIATIONS/SOCIETIES AND PROGRAMS FOCUSING ON ENGINEERING EDUCATION

Other countries and regions with associations and societies devoted to engineering include Australasia (the Australasian Association for Engineering Education – AAEE), Malaysia (Society of Engineering Education Malaysia – SEEM), Korea (Korean Society of Engineering Education – KSEE), India (Indian Society for Technical Education – ISTE), China (Chinese Society for Engineering Education – CSEE) and South Africa (South African Society of Engineering Education – SASEE). In 2006, the International Federation of Engineering Education Societies (IFEES) was founded to coordinate among the national societies.

Numerous centres and programs focusing on engineering education have been developed in the United States. Those that include formal degree programs include:

- Purdue School of Engineering Education (2004; PhD program in engineering education)
- Virginia Tech Department of Engineering Education (2004; PhD program in engineering education)
- Utah State University Department of Engineering and Technology Education (PhD program in engineering education)
- Clemson University Department of Engineering and Science Education (2006; PhD program in engineering education)

Additional engineering education-related institutes can be found at the University of Florida, Georgia Tech, University of Washington, Northwestern University, University of Georgia, University of Illinois, Tufts University, Michigan State, Texas A&M and many more.

APPENDIX 3: ADMINISTRATIVE STRUCTURES CONSIDERED

The working group considered the advantages and disadvantages of a number of administrative structures that might support the desired academic mandate. This was narrowed down to four rigorously considered options (see Table 1, next page) which are briefly discussed in order of increasing levels of location within the University's organizational structure.

Option A: The EDU:C "sub-unit" option proposes that the Institute and all FASE-appointed faculty reside in and be administered by one of the Faculty's existing departments as an EDU:C. Examples of EDU:Cs include ILead, BioZone, and the Institute for Sustainable Energy. This option minimizes changes to FASE's organizational structure, but it would be a challenge to ensure that the Institute is not perceived as or evolve into serving that one unit only. This option could also impose a major administrative burden on the hosting unit.

Option B: The EDU:B option proposes that the Institute reside alongside the Faculty's departments and institutes, with each faculty member holding a majority budgetary (primary) appointment in the department or institute in which they have the best discipline fit, and a minority budgetary cross-appointment to ISTe^{2}P. An example of an EDU:B in FASE is the Division of Engineering Science. The benefits of an EDU:B are that it would significantly reduce the administrative load for a unit by distributing it amongst the existing units; it would provide the impetus for its members to meet, collaborate and engage; appointed faculty would be more visible across the Faculty; and the only change to the Faculty's organizational structure would be the establishment of the EDU:B. The challenge of an EDU:B is that the faculty cross-appointed to it would still not have an appropriate primary department as their academic home. Without an undergraduate program, it would also be challenging to keep the Institute active and engaged, and it might become a "virtual" organization with no shared academic mission and little day-to-day interaction of its membership.

Option C: Creating ISTe^{2}P as an EDU:A in FASE would allow the Institute to hold primary or majority budgetary appointments; faculty would belong to a distinct unit with similar functionality and responsibilities as a FASE department; Examples of EDU:As in FASE include IBBME and UTIAS. The EDU structure would facilitate interactions and collaboration across FASE and beyond. Non-budgetary cross appointments would allow like-minded teaching-stream and tenure-stream faculty members from other units to join the Institute. ISTe^{2}P faculty could also seek non-budgetary cross-appointments in other departments with which they are aligned. These cross appointments would help all faculty remain aware of initiatives and priorities in sister units, and apprised of pedagogical challenges and opportunities across the University. The key benefit of Option C is that by creating a distinct unit for the Institute with central offices and operations, it would be highly visible; it could also respond to changing needs within the Faculty and engage scholars from across the Faculty, the University and the broader academic community.

Option D: Finally, a multi-Faculty EDU:A would mean that the Institute would be administered by multiple Faculties, similar to IBBME. Cross-appointments to other Faculties would expand the scope of interests and provide broader research and scholarship opportunities. The key challenge of this option is the complexity of multiple-Faculty administration. Further, the desired focus of engineering education could become diluted or lost entirely over time.

Table 1: Issues and Opportunities of the Four Administrative Structures Considered

Issue	Sub-Unit EDU:C Option	FASE EDU:B Option	FASE EDU:A Option	Multi-Faculty EDU:A Option
Provide administrative home to FASE-appointed faculty	Yes Would provide administrative consistency May overburden one Unit	Yes Could result in inconsistencies Would not overburden one Unit	Yes Would provide administrative consistency Would be managed by a new smaller Unit	Yes Would provide administrative consistency Would be managed by a new smaller Unit
Support and enhance a vibrant academic community pursuing a shared vision of engineering education research and practice	Possible but difficult By virtue of being together, they could work toward establishing closer ties and community	Possible but difficult as all members would be cross-appointed to the Institute but reside in different units	Strong capacity to realise a shared vision with a core group acting as one Unit	Strong capacity to realise a shared vision of engineering education that could extend to STEM more generally
Strengthen cross-departmental and collaborative activities	Being together would strengthen collaboration amongst members within sub-unit but the alignment with one disciplinary Unit may diminish impacts on FASE more broadly	EDU:B could provide focus but new cross-departmental hires could be constrained if the academic fit or need within an existing unit can't be justified	Being unattached to disciplinary Units, it would be important to have status-only cross appointments to stay apprised of the challenges of the disciplines. Would enable future cross-disciplinary hires	By partnering with OISE or FAS, aspects of general education or science could be incorporated. Would enable future cross-disciplinary hires
Engagement of faculty beyond FASE	Fit of OISE or FAS faculty with interest in engineering education may restrict cross-appointment to Unit	OISE or FAS faculty with interest in engineering education could be cross-appointed to EDU:B	OISE or FAS faculty with interest in engineering education could be cross-appointed to EDU:A	OISE or FAS faculty with interest in engineering education could have primary appointment in EDU:A

Issue	Sub-Unit EDU:C Option	FASE EDU:B Option	FASE EDU:A Option	Multi-Faculty EDU:A Option
Facilitate the instruction of trans-disciplinary competencies	Over time, it is likely that the sub-Unit would become more closely aligned with that one Unit than the others, thereby losing the ability for trans-disciplinarily	This ability would depend on the willingness of existing units to host new faculty for the Institute and allow it to grow	The unit could be more innovative as it would hold the faculty appointments necessary to drive this initiative	The unit could be broad and innovative Could be drawn into areas not necessarily of interest to engineering
Establish FASE as a leading innovator in educational practice	As a sub-unit, significant and ongoing promotion would be required to ensure that it is seen as a Faculty-wide effort and not of one Unit or discipline	As a EDU:B, it would clearly be a FASE-level Institute. Innovation may be constrained if support from home Units is not continuously provided	As a EDU:A, it would clearly be a FASE-level Institute Provides the greatest chance of success.	As a multi-Faculty institute, FASE may lose its focus Administration can be challenged with additional stakeholders
Ability to directly affect undergraduate and graduate curriculum	As with all curriculum management, changes would be approved by the Unit's curriculum process (undergraduate), SGS process (graduate), and Faculty Council			
Financial cost	Details to be determined; costs expected to be similar in all cases Presumably, the administrative duties and budgets would fit within our current budget model			

After extensive discussion, the working group agreed that the FASE EDU:A holds the fewest barriers and greatest opportunity for success of establishing a vibrant and leading-edge centre for engineering education. Individual faculty members from other Faculties have indicated an interest in affiliation with the proposed Institute but no other Faculty has offered to provide financial support to create a multi-Faculty EDU:A.

The primary difference between an EDU:A and EDU:B is that an EDU:A can hold primary academic appointments whereas an EDU:B cannot; their faculty must be have a primary appointment with a department or another EDU:A, such as IBBME or UTIAS.

APPENDIX 4: COURSE LIST

Undergraduate Courses

1) APS281H1: Language and Meaning
2) CIV282H1: Communication I
3) ESC203H1: Engineering and Society
4) MSE298H1: Communications I
5) CIV382H1: Communications II
6) MSE390H1: Communications II
7) APS320H1: Representing Science on Stage
8) APS321H1: Science and Technology in the Popular Media
9) APS322H1: Language and Power
10) APS324H1: Engineering and Social Justice (new in Winter 2018)
11) APS325H1: Engineering and Science in the Arts
12) APS343H1: Engineering Leadership
13) RE300H1: – Fundamentals of Accounting and Finance
14) JRE410H1: Markets & Competitive Strategy
15) JRE420H1F/S: People Management & Organizational Behaviour
16) APS442H1 The Cognitive and Psychological Foundations of Effective Leadership
17) APS444H1 Positive Psychology for Engineers
18) APS445H1 The Power of Story: Discovering Your Leadership Narrative
19) APS446H1 Leadership in Project Management
20) APS447H1 Ethics (new in Fall 2017)

Graduate Courses

1) APS1011H: Concepts and Applications of Authentic Leadership
2) APS1010H: Cognitive and Psychological Foundations of Effective Leadership
3) APS1019H: Leadership in Project Management
4) APS1027H: Engineering Presentations
5) APS1029H: The Science of Emotional Intelligence and its Application to Leadership
6) APS1026H: Positive Psychology for Engineers
7) APS1030H: Engineering Careers – Theories & Strategies to Manage your Career for the Future
8) APS1203H: Engineering Teaching and Learning
9) APS1204H: Instructional Design in Engineering Education
10) APS1205H: Engineering Education Research Seminars
11) APS1206H: Engineering Education Research Seminars
12) APS1501H: Leadership and Leading in Groups and Organizations
13) APS1502H: Leading Engineering Design Projects

Co-Instructed Courses[a] and Supported[b]

1)**First Year**: APS111[a], APS112[a], APS113[a].
2)**Engineering Science**: ESC101[a], ESC102[a], ESC297[a], ESC301[a], ESC496[b], ESC499[a], AER407[b], BME489[b], BME498[b]
3)**CHE**: CHE204, CHE230[a], CHE299[a], CHE326[b], CHE430[b]
4)**CIV**: CIV201[b], CIV220[b], CIV331[b], CME368[b], CIV382, MIN466[b], MIN430[b], MIN467[b]
5)**ECE**: ECE297[a], ECE496[b]
6)**MIE**: MIE221[b], MIE240[a], MIE243[b], MIE301[b], MIE315[b], MIE350[b], MIE490[b], MIE491[b]
7)**Faculty Wide**: APS490[a]

APPENDIX 5: FACULTY MEMBERS

Faculty with Budgetary Appointments to ISTe^{2}P

Name	**Home Unit (%) prior to establishment of ISTe^{2}P**	**Home Unit (%) after establishment of ISTe^{2}P**	**Appointment Category** (Stream and Rank)	**Appointment to other units (%)**	**Graduate Faculty Membership, Unit & Status** (Associate or Full)
Primary Appointments					
Chong, Alan	Engineering Communication Program (100%)	ISTe^{2}P (100%)	Associate Professor, Teaching-Stream	n/a	none[a]
Marzi, Elham	FASE (100%)	ISTe^{2}P (100%)	Assistant Professor, Teaching-Stream	n/a	none[a]
Irish, Rob	Engineering Communication Program (100%)	ISTe^{2}P (100%)	Associate Professor, Teaching-Stream	n/a	none[a]
Romkey, Lisa	CTL (100%)	ISTe^{2}P (100%)	Associate Professor, Teaching-Stream	n/a	none[a]
Sheridan, Patricia	FASE (100%)	ISTe^{2}P (100%)	Assistant Professor, Teaching-Stream	n/a	none[a]
Tallman, Ken	Engineering Communication Program (100%)	ISTe^{2}P (100%)	Associate Professor, Teaching-Stream	n/a	none[a]
Tihanyi, Deborah	Engineering Communication Program (100%)	ISTe^{2}P (100%)	Associate Professor, Teaching-Stream	n/a	none[a]
Variawa, Chirag	FASE (100%)	ISTe^{2}P (100%)	Assistant Professor, Teaching-Stream	n/a	none[a]
Weiss, Peter	Engineering Communication Program (100%)	ISTe^{2}P (100%)	Associate Professor, Teaching-Stream	n/a	none[a]
Budgetary Cross-Appointments					
Olechowski, Alison	FASE (49%) MIE (51%)	ISTe^{2}P (49%)	Assistant Professor, Teaching-Stream	MIE (51%)	Associate, MIE

a: Teaching stream faculty will apply for Associate Membership once ISTe^{2}P is approved and they have an administrative home.

Faculty with Non-Budgetary Cross-Appointments to $ISTe^2P$

Name	Home Unit (%)	Appointment Category **(Stream and Rank)**	Appointment to other units (%)	Graduate Faculty Membership, Unit & Status **(Associate or Full)**
Behdinan, Kamran	MIE (100%)	Professor	$ISTe^2P$ (0%)	Full, MIE
Evans, Greg	CHE (100%)	Professor	$ISTe^2P$ (0%)	Full, CHE
Foster, Jason	CIV (100%)	Associate Professor, Teaching-Stream	$ISTe^2P$ (0%)	none
Kilkenny Rocheleau, Dawn	IBBME (100%)	Associate Professor, Teaching-Stream	$ISTe^2P$ (0%)	none
McCabe, Brenda	CIV (100%)	Professor	$ISTe^2P$ (0%)	Full, CIV
McCahan, Susan	MIE (100%)	Professor	$ISTe^2P$ (0%)	Full, MIE
Reeve, Doug	CHE (100%)	Professor	$ISTe^2P$ (0%)	Full, CHE
Stickel, Micah	ECE (100%)	Associate Professor, Teaching-Stream	$ISTe^2P$ (0%)	none
Norval, Graeme	CHE (100%)	Associate Professor, Teaching-Stream	$ISTe^2P$ (0%)	none

APPENDIX 6: ACTIVITIES PROPOSED FOR THE FIRST TEN YEARS

Activity or Objective	Metric	Goal	Year
Research Mandate			
Model new instructional approaches, interventions or assessment methods.	# adopted into courses	8	Year 10
Design and evaluate new digital and in-person teaching tools or techniques to enhance learning.	# created	5	Year 5
Investigate and design instruction to facilitate the transition of engineering graduates from school into their careers.	# of instructional interventions introduced	5	Year 10
Pursue research on engineering-leadership with a focus on related practices of engineers in industry and in broader society.	# of instructional interventions # of publications	5 3	Year 10 Year 5
Pursue research on engineering-design, focusing on practices of engineering design that are shared across disciplines.	# of instructional interventions # of publications	6 3	Year 10 Year 5
Investigate the evolving nature of engineering, engineering identities and relationships with broader society and other professions and disciplines.	# of publications	3	Year 10
Investigate the influences of gender and cultural identity on post-secondary engagement in engineering, undergraduate and graduate academic success and subsequent career satisfaction and success.	# of publications	3	Year 5
Strengthen connections with alumni to explore the competencies and attributes that promote career success.	# of studies undertaken	3	Year 10
Engage and support faculty interested in the scholarship of teaching and learning through localized, contextualized and discipline specific knowledge.	Percent of faculty	10% 20%	Year 5 Year 10
Train and support faculty who want to participate in pedagogical research but lack the means to apply proper techniques (e.g. data collection, data analysis and ethics review).	Percent of faculty	5% 15%	Year 5 Year 10
Train highly qualified personnel (HQP) in the form of graduate students to become Canada's future researchers and engineering educators.	# of graduates	10 25	Year 5 Year 10

Become a renowned focal point for engineering education activities, workshops and conferences, nation-wide and worldwide.	External review letters		Years 5 and 10
Publish actively in engineering education and other pedagogy journals and conferences.	# of publications	100	Year 10
Promote engagement in discipline based education research and involvement in the education streams of related academic societies.	# of presentations	50	Year 5
Increase faculty involvement in professional activities in engineering education (conference organization, editorial boards, etc.).	# of faculty	20	Year 10
Translate knowledge to inform Provincial curricula and help shape the implementation of CEAB accreditation criteria.	# of recommendations	5	Year 10
Activity or Objective	**Metric**	**Goal**	**Years**
Education Mandate			
Deliver graduate and undergraduate courses in technical communication, leadership and engineering education.	Number of courses	35	Year 5
Integrate the co-instruction of communication and/or team skills in design and core technical courses.	Number of courses	40	Year 5
Encourage and support technology enhanced or active approaches to instruction in courses.	Number of courses	10% of FASE courses	Year 10
Design and propose an undergraduate course in Engineering Education.	Proposal approved		Year 5
Promote industry-academia exchanges through “engineers in residence” and sabbatical placements in industry.	Number of exchanges	4	Year 10
Present seminars on teaching and learning at other universities.	Number of seminars	10	Year 10
Present workshops and seminars on transdisciplinary competencies and emerging practices at partner companies and government agencies.	Number of seminars	5	Year 10
Collaborate with the Ontario Ministry of Education to incorporate engineering into the Elementary and Secondary curricula.	Number of committees or reports	5	Year 10
Collaborate with DEEP to develop a shared understanding of, and activities to support,	Number of workshops	10	Year 10

developing an engineering mindset in K-12 students.			
Develop and promote seminars to attract faculty interested in learning about pedagogical techniques from leaders in the field. These might be co-sponsored as part of existing departmental Distinguished Lecture Series (e.g. the annual engineering education seminar within Chemical Engineering's series).	Number of seminars	15	Year 10
Investigate and design improvements to the mechanisms through which undergraduate students acquire and enact their engineering identity prior to graduation, how this aligns with their career satisfaction and success and their practice of engineering after graduation.	# of instructional interventions	2	Year 10
Use the new CEIE facilities as a test-bed for assessing new educational approaches involving technology enhanced active learning (TEAL) and other innovative and emerging teaching approaches.	# of instructional approaches tested	5	Year 10