‘Simple service simply given’: Systems theory and systems thinking in Canadian engineering education

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ABSTRACT

Central to questions about engineering practices are questions about engineering education. Confronting uncertain futures of socio-technological changes, engineers reform their education programs to stimulate competencies in pupils who, they hope, will be up for the challenges ahead. Despite a critical focus on technoscientific practices within science and technology studies, scholarship has given little attention to critical perspectives on education.

This dissertation offers a comparative ethnographic study of engineering education reforms, examining education policy formations and educational practices. I study these reforms through two organizations: Engineers Canada and the Engineering Change Lab. I collected historical data from Engineers Canada's archive (1936–2012) on engineering education curricular and policy reforms. I collected ethnographic data from the Engineering Change Lab (2017–2019) on contemporary educational practices. Throughout, I compare developments of the Canadian engineering education system and its couplings with Canadian nationalisms, gender hierarchies, and technoscientific change.

I narrate how: 1. Nationalisms guide the structuring of Canadian engineering education sustaining a settler colonial Canada, resisted through the inclusion of Indigenous peoples and practices. 2. Gender hierarchies guide Canadian engineering fostering a men-dominated industry where efforts to continually improve women's low representation meet some successes. 3. "Technoscientific change" gives meaning to engineering through promises of technoscientific progress and anxieties of technological change.

Considering the tensions between engineering education and engineering practices documented in this research, I use Luhmann's systems theory to examine a contradiction: engineering education is considered weakly connected with engineering practices while being leveraged as a perennial solution to problems in engineering practices. As such, engineering is a reactive discipline, one fundamentally incapable of securing its desired stability through a focus on potentialities over actualities. Occupying such a role destines one to a sense of insecurity that the present is never enough.

This dissertation advances science and technology studies by critically examining engineering education as engineering practices and the relevant sociopolitical dimensions at play, and by demonstrating nuanced approaches to understanding technoscientific education through ethnography. I argue for the utility of Luhmann's systems theory in engineering education, specifying a language with educative appeal for engineers who direct their "system" of engineering education.

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Further thanks to Pat McCormack for introducing me to the world of ethnography, and encouraging me to see engineering as a culture.

Last, thank you Marianne for hearing all of these ideas first when they were much worse ideas.

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They do not preach that their God will rouse them a little before the nuts work loose.
They do not preach that His Pity allows them to drop their job when they damn-well choose.
As in the thronged and the lighted ways, so in the dark and the desert they stand,
Wary and watchful all their days that their brethren's ways may be long in the land.

Raise ye stone or cleave the wood to make a path more fair or flat;
Lo, it is black already with the blood some Son of Martha spilled for that!
Not as a ladder from earth to Heaven, not as a witness to any creed,
But simple service simply given to his own kind in their common need.

And the Sons of Mary smile and are blessèd—they know the Angels are on their side.
They know in them is the Grace confessèd, and for them are the Mercies multiplied.
They sit at the feet—they hear the Word—they see how truly the Promise runs.
They have cast their burden upon the Lord, and—the Lord He lays it on Martha's Sons![1]

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[1] Rudyard Kipling, "The Sons of Martha," *The Kipling* Society, 2022, accessed January 17, 2022. https://www.kiplingsociety.co.uk/poem/poems_martha.htm. The poem in its entirety is included in Appendix A.

CHAPTER ONE

INTRODUCTION

1.1 Steering the technological bus

Emptied disposable coffee cups stand in groups and in stacks throughout the large lecture hall. White paper plates and napkins bear sticky traces of strawberry, cantaloupe, honeydew, and pineapple. The paperware has been pushed to the side to clear spaces for sheets of poster paper. A young man in a fitted suit stands up from the crowd, seated along the terraced rows of the lecture hall. He says, somewhat forcefully over the bustle, “In the year 2050, the engineering profession will no longer exist, and this will be a positive accomplishment.” Charles, one of the workshop facilitators, shirtsleeves rolled above the elbows, arm outstretched, palm opened towards the speaker, agrees, thanks the speaker, and warmly moves on to another raised hand. I sense a brief mixed response from the audience. The offering is a bit more extreme than previous ones—that women demand a more active role in the profession, that curriculum broadens, that entrepreneurship skills are strengthened—but the room’s attention quickly shifts elsewhere following Charles’ hand as the next speaker begins. Volunteers in matching T-shirts continue circulating with felt-tipped markers and ballpoint pens, distributing and collecting feedback forms while Charles calls on more participants to share.

A few speakers later, a woman, a dean of an applied science and engineering faculty, adds to the discussion. She says, “By the year 2050, the skills and expertise of engineers will be decentralized among other professions and trades, and that faculties of engineering will no longer exist as such.” She, too, is applauded, thanked for her contribution, and sits. A facilitator invites participants to continue sharing results from their groups’ discussions by using the Google Doc link provided on the screens at the front of the room. The lecture hall’s focus, normally front and centre, is dispersed between rows, on sheets of poster paper and feedback forms, and in barely quieted dialogue up the terraced floor towards the back of the tall room.

A man interrupts a later speaker for neglecting to share her name and role with the audience before she started sharing her group's conclusion, as per the instructions. Another woman retorts that the woman in question had already introduced herself. A third voice from the crowd kindly suggests that the man should *listen* (to women). Raucous applause follows the advice. Perspectives continue weighing in for the ten-minute exercise. But my attention stays with one thought in particular for being surprisingly radical in its forecasts: the dissolution of the engineering profession.

It is the final day of the Canadian Engineering Education Association's conference. This year's theme is "Innovation and Diversity in Engineering Education." The Engineering Change Lab (ECL) has the keynote slot this morning and is facilitating a workshop with, I guess, over 200 engineering educators from across the country. We fill the university lecture hall and subvert, subtly, its function in the Bahen Centre for Information Technology. This building is primarily used by the University of Toronto's Faculty of Applied Science & Engineering downtown, across the street from what will become the new Myhal Centre. Our prompt, on Google Slides display at the front of the hall, are two questions: "What will society require from engineers in 2050 that is different from today?" and "What are the most important changes for engineering education?"

Introducing the workshop theme at the beginning of the session, Charles recited an example from Daniel and Richard Susskind's book *The Future of the Professions: How technology will transform the work of human experts*. In the example, employees of a tool manufacturer were shown an image of a drill and asked if this was the product they sold. The employees, somewhat confused, agreed that that was indeed the case. The image changed to that of a hole recently drilled into a piece of wood, shavings surrounding the hole and a drill bit lying next to it. The employees were corrected: holes, not drills, were what their customers actually wanted. Their job was to find cheaper, better, and more efficient ways to give them what they want: the end results the tools provided rather than the tools themselves. This anecdote framed how we were intended to "zoom out" and think about engineering education in today's workshop: that systems, and professions in particular, have a tendency to "focus in on the drill and forget about the hole." Business operations valued optimizing different parts of the drill to improve their products, losing sight of the hole. Likewise, engineering educators have attempted to optimize engineering education, and may have lost sight of the whole.

"What is engineering, *as a system,* outputting into the world?" Charles asks the group. "What is it contributing to the world? And how do all the different components fit together to serve that? Including engineering education, regulation, the way we work as engineers, the k-12 system that's feeding students into engineering."

I was expecting to be rubbing my temples by now as engineers suggest increasingly instrumentalized methods of training their students, of imparting social values, of facilitating skill development, of learning financial literacy. Instead, I am surprised by the audacity that esteemed engineers could confidently proclaim the end of engineering in front of their peers. This is the first time I have witnessed the Engineering Change Lab in action, although I have been following their work for a few months, and now I am impressed. The willingness and openness with which experts, with entire careers at stake, are entertaining a deep reimagining of engineering to the point that it no longer exists is beyond what I could have expected. Maybe something will come of this after all, I think to myself.

“The technology bus is accelerating,” Charles explains in front of a photograph of a man in a suit, arm waving for attention, chasing after a red bus. Governments, workplaces, workers, and parents are struggling to keep up with the pace of contemporary technological changes, we learn.

“The interesting thing about engineering in particular is engineers, more so than any other group, are the ones accelerating this bus,” Charles continues. “So I think it would be a great irony if engineers who are controlling the bus let it run away from us, right?” He pauses. “As opposed to keeping up with it and playing a role in helping to steer it.”

1.2 Simple service

This introductory vignette illustrates some distinguishing features I will follow through this dissertation. My primary focus is on the “system” of Canadian engineering education; a designation that comes directly from my research participants. I am further interested in other systems that guide and give meaning to the system of engineering education, systems that both sustain and exceed sociocultural megatrends that are likewise apparent in the above scenario. Canadian nationalisms, and the associated professional organizations, regulations, and accreditations, structure how Canadian engineering functions: engineering education is a *national* concern, deeply tied to confederation and its associated promises and limitations. As Canadian society changes so too must Canadian engineering, and the structuring of Canadian engineering likewise engineers Canada.

The gender hierarchy system is uniquely influential in guiding engineering cultures as sexism and gender imbalances are pervasive yet often resisted—by some—within engineering. It is worth emphasizing that women's current meagre representation in Canadian engineering is simultaneously a disappointment yet an impressive accomplishment that many women fought to realize over decades. And while it would be a great disservice of this research to investigate engineering cultures and not specifically consider women as a group, other emerging social concerns regarding sex and gender continually alter the register of these issues in engineering. Here, education plays a dual role: first, as a site of gender imbalance; and second, as a means of educating engineers about women's low representation in the profession.

Further, "technological change" gives meaning to engineering education: as long as technology continues to evolve so too must engineers' training be reformed. And part of this training is the promotion of technoscientific progress and innovation themselves, reinforcing the need for future educational reforms (to facilitate greater innovation, or greater awareness of the social consequences of technological development). Thus technological change, as a rhetorical strategy, makes engineering education reforms meaningful in both promoting technoscientific progress while indicating a reigning-in of unruly innovations for society's benefit.

Back at the conference, once the audience contributions ebb and the session approaches its ending time, one of the facilitators explains why these conversations are so important. "I like to think about it like this," he says, stretching an elastic band between his hands. "The elastic is technology, and my fingers," he pinches the elastic, "are engineering. As technology develops," he pulls his left hand away from his right, stretching the elastic in front of his chest, "the distance increases until…" He lets go and the elastic flies across the front of the lecture hall. "We can no longer catch up." He walks to collect the elastic from the floor. "Another alternative," he explains, "is that the elastic breaks."

1.3 Research questions

This research project concerns the system of Canadian engineering education. In particular, this project focuses on engineers that have endeavoured to change this system, to engineer the futures of Canadian engineering education, the profession itself, and Canadian society. These efforts are nothing new, of course, the history of the Canadian engineering profession is one of subsequent groups inheriting a system they wished were different and implementing initiatives to change its trajectory. The lynchpin of this line of thinking, however, is education. Control over what students learn today has long been synonymous with control over what they will know and do tomorrow. And while the future will always be uncertain, education promises a narrowing of what it *could* be.

The purpose of this ethnographic study is to elucidate certain values and ideals of engineering culture through descriptions of engineering education reforms. Instances of judgement where engineers have identified education as being insufficient or have recognized social changes worthy of proportionate educational reforms are informative in uncovering intentions in engineering education and the fundamental selections of the system of engineering education. I take a comprehensive perspective of engineering education that includes both formal and informal activities that determine the training of current and future engineers. Sociologist Niklas Luhmann posited education as a subsystem of society, and I take up his analysis in this research, in particular his focus on education reforms. I study this system of engineering education by analyzing engineering education reforms: the cultures that desire to make engineering education, and thus the engineering profession and Canadian society, different.

My central research question throughout this dissertation is: Which systems guide and give meaning to engineering cultures?

Subquestions to my study include: In which ways are these systems implicated in sustaining sociocultural megatrends? And, how do these systems exceed these trends?

In reckoning with their education, engineers locate their profession and society within a system whereby education provides means to manage both their profession and society concomitantly. How exactly do these relationships play out in the education contexts I study? And, which types of reformations does this framing enable?

This dissertation tells a comparative story of two different perspectives in Canadian engineering education: education (the past) and practice (the future). I study these perspectives by looking to two engineering organizations interested in Canadian engineering education: Engineers Canada and the Engineering Change Lab. These accounts are further distinguished by their time periods and the data sources, although the questions I pose are similar. Studying archival materials from Engineers Canada—namely meeting minutes of the Board of Directors and the Executive Committee among other reports, memoranda, appendices, and electronic documents—stretching back to 1936, I follow the development of the Canadian Accreditation Board (CAB, now the Canadian Engineering Accreditation Board (CEAB)) from 1962 through the mid-1970s. Beginning as a trepidatious maneuver to standardize education, and thus professional licensure, nationally, what was then the Canadian Council of Professional Engineers (CCPE) formed a working group called the Canadian Accreditation Board. I theorize the formation of the CAB and its subsequent functions beginning around 1965 as "operational closure" of the Canadian engineering education system, operational closure being a condition of system *autopoiesis* as outlined by Niklas Luhmann. It is during these foundational years of operation that the CAB is able to secure authority to act over its eventual territory, assessing outputs of engineering education (graduates) to generate future inputs (students). And it is during these foundational years that evidence of a systemization of Canadian engineering education begins to appear on record through other Luhmannian concepts like organization and functional differentiation which produce fundamental selections of the system of engineering education. Why might engineers approach systematizing and reforming engineering education in the ways that they do?

I later follow the introduction, in this archival record, of women's representation in engineering and engineering education, beginning after 1989, the year of the École Polytechnique massacre. In this section I follow the policy discussions following the terrorist attack that killed 14 women in a Montréal engineering school. In the years that followed, the Canadian Committee on Women in Engineering completed a series of regional workshops across Canada and hosted a national conference, prompting the formation of the National Action Plan on Gender Equity. They commissioned a study on the future labour force of the profession that forecasted a labour shortage by the year 2000. This increased demand for workers was used as an urgent justification to expand recruitment into engineering by making it more inviting and accessible to women. I once again use Luhmann's systems theory to understand these events, applying Luhmann's concepts of "system," "environment," "selection," and "perturbation" to approach theories of systemic change. One might understand the pressure to improve the representation and experiences of women in Canadian engineering, and thus engineering education, as a perturbation, an exterior provocation or irritant from the environment outside of engineering (such as feminism, for example) to either be accommodated by the system or to destroy the system identity altogether. However, tracing women's representation in Canadian engineering to the Montréal Massacre reveals some of its origins as a national policy concern. The selection of women *out* of Canadian engineering might be better understood as the locus of the perturbation. This initial selections made possible by the gender hierarchy system—one aspect of the engineering system that has changed remarkably slowly—produces a system whereby gendered violence is possible. This analysis further elucidates why increases in the representation of women in Canadian engineering remain gradual. What are the system characteristics that make these gender reforms seemingly intractable?

The second organization I study is more recently active. I collected data through participant observation, interviews, and document analysis over the period of roughly two years of operation of the Engineering Change Lab (ECL). The ECL is likewise interested in Canadian engineering education, hosting workshops and training programs across the country for their membership and other supporters, centering education around their concept of "technological stewardship." They too, like the CAB before them, are worried about what future engineers might look like. Contemporary social concerns about technological change and responsibility for technology animate the lab environment, with a strong impetus that engineers ought to be (more) responsible for the ongoing groundswell of technological innovation. A mix of professional and activist, the ECL is seeking places within engineering to execute their vision. Are they operating as a provocation to the engineering profession? Or are they too a response to a different provocation, one determined by the content and fundamental selections of engineering education itself? Or is the impetus of the ECL better understood as a stabilizing force within engineering to protect it from potential threats? Leveraging the yet undetermined future of the ECL, I try to reconcile the impetus of disruption in contemporary engineering cultures—or provocation—with Luhmann's perturbation, concluding the esteemed object of disruptive innovation does not fit neatly within Luhmann's framework. Indeed, "disruptions" may be better understood as a type of system redundancy rather than the "revolutionary" or "transformational" monikers with which they are ascribed.

1.4 Why systems?

I was first introduced to systems thinking 15 years ago as an undergraduate student involved in my campus chapter of Engineers Without Borders Canada (EWB), an organization that prided itself on its "systems approach" to international development work. EWB began to turn some of its attention away from sub-Saharan Africa towards Canadian engineering itself during this time, a result of its own systemic analysis. Over a decade later, the Engineering Change Lab would eventually be created under the aegis of EWB.

I later encountered systems thinking academically in a resource planning and management course in graduate school. Here I used system dynamics modeling and causal loop diagrams—techniques to represent systems computationally that stem from Jay Forrester's work at MIT—in my water resources engineering research. Thinking the system in this capacity had me grappling with the complexities of federal policies and Indigenous governance in water infrastructure management. Once again, I was drawn to questions about the engineering system in Canada, how it operates, and its fundamental selections. To say that systems thinking led to my current research project is an understatement. I have been gravitating towards this topic for many years.

By the time I started to study Canadian engineering education ethnographically, I was critical of the "systems thinking" approach and how engineers were using "system" to describe engineering and engineering education. I was then delighted to first read and appreciate the work of German sociologist Niklas Luhmann. Luhmann's systems theory not only appeared to provide language to describe systems at a variety of scales, ranging from individual cognitive systems to large social systems, but could also describe the system ideologies used by other systems theorists with whom I was familiar. Luhmann's sociological systems theory accounted for how systems operate while showcasing the ontological limitations of systems themselves. It appeared to be an apt framework with which to critique the systems approach in engineering education. Luhmann's detailed treatment of the education system using his systems theory further ingratiated his concepts to my study. While other theories from other thinkers would have likewise made generous use of the data presented in this dissertation, Luhmann's systems theory provides important leverage considering education generally, and education reform specifically.

By taking seriously the "system" metaphor engineers use to describe engineering education, I analyze the educational reforms of the Engineering Change Lab and Engineers Canada in attempting to improve or innovate Canadian engineering education and, thus, society. Using Luhmann's system theory, I hold historical and contemporary engineering education reforms together to highlight some reforms that have occurred and identify system repetitions where changes seem to meet greater resistance. This juxtaposition may itself be a Luhmannian perturbation of sorts: a challenge to how engineers have conceptualized their system of engineering education. Luhmann's systems theory provides a framework to think through education reforms, and theorize why they may not be possible. Further, given that engineers already describe engineering education as a "system," Luhmann's theory specifies a language with educative appeal for those in engineering to think through. I believe that the conceptual and linguistic positioning of systems theory grants a multifaceted and robust way to illuminate (il-Luhmann-ate?) the system. And, this empirical analysis provides opportunities to challenge and perhaps refine Luhmann's theory.

Disciplinarily, Niklas Luhmann does not share much in common with science and technology scholars—something I address in the following chapter—however, focusing on engineering education as a system, and reforms to the system of education, are essential to this research project. The role education plays in how engineers understand the current state of their profession and imagine how its future might be, as explored in my research, will reveal how critical education is to engineering. Because the education system links the present to the future, it gives engineers access to engineering the future through education: opportunities to enact how they would like the world to be.

1.5 Engineering reforms

The engineering professions of Canada and the United States have navigated a number of historical social challenges. Engineers in early 20th-century America struggled to organize their profession through technical societies, and then further failed to see their technocratic visions successfully applied in politics.[2] Contemporaneously, engineers in early 1900s Canada pushed to unify their own technical societies and close the profession across the country, partly due to competition from American engineers.[3] In post-war America, engineers debated their ethical obligations to society, and sought to better meet the challenge of "technological change."[4] More recently, an explosion of engineering disciplines risk unraveling the profession altogether as more and more specializations overlap less and less.[5] These challenges link consistently to concepts of technological

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[2] Edwin T. Layton, *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession* (Baltimore: Johns Hopkins University Press, 1986).
[3] J. Rodney Millard, *The Master Spirit of the Age: Canadian engineering and the politics of professionalism 1887–1922* (Toronto: University of Toronto Press, 1988).
[4] Matthew Wisnioski, Engineers for Change: Competing Visions of Technology in 1960s America (Cambridge, MA: MIT Press, 2012).
[5] Rosalind Williams, *Retooling: A Historian Confronts Technological Change* (Cambridge, MA: MIT Press, 2002).

progress, public welfare, advanced knowledge, and the future of the engineering profession. Questions about the identity of the engineering profession are not only addressed by scholars, they are asked by engineering professionals themselves in their unique times and contexts. And yet, for some of the most significant challenges the engineering profession faces, very little progress has seemingly been made. Technological advancement continues to outpace curricular changes. Women's representation in engineering remains staggeringly low. Engineering graduates seem to always be lacking in sufficient business acumen, legal knowledge, ethical responsibility, and social awareness. But regardless the deficiency, engineering education remains an omnipresent corrective. Or at least it has appeared to be so.

Why might education not be the panacea engineers expect it to be? Why have improvements to engineering education failed to address some of its most pressing issues? Applying Luhmann's theory to the context of Canadian engineering education reveals a dynamic stability of the system, one traditionally structured by its functional differentiation and organization and subsequently beset by perturbations that seek to disrupt system identity. Where others may see opportunity in conceptualizing engineering differently as an avenue for radical changes, Luhmann's approach instead observes an obdurate discipline, incapable of self-reform unless it confronts its foundational selection processes.

This study's focus on engineering culture through engineering education contributes to the discipline of science and technology studies (STS) by emphasizing the importance of technoscientific education as technoscientific practice. Arguing for greater attention to the educational concerns of modern scientific professions, David Kaiser makes the point: "Practices, after all, have to be *practiced*—and are thereby necessarily thrust into questions of scientists' training and learning."[6] Education, then, is undeniably fundamental to the sciences and scientific practices, and yet scientific education remains understudied and undertheorized within STS. Further still, the practices of scientific education—pedagogy, teaching, training, learning, curricula, and education policies—are scientific practices themselves, ones worthy of the cultural interrogations STS brings to other fields.

The implications of national engineering education policies present obvious structural and organizational links to engineering training and learning whereby engineering curricula are accredited based on the policies in place. Policies, in part, determine what engineering students are expected to learn. Less clear, however, is how these educational activities—curriculum policies, accreditation procedures, inclusion initiatives, professional development—might be considered engineering practices themselves and what an analysis of these practices as engineering might reveal about the culture of engineering in a Canadian context.

Borrowed elements of design thinking from engineering, like failure and iteration, are becoming more common heuristics in education practices. Henry Petroski, in his text *To Engineer is Human*, presented to popular audiences engineering and engineering failures as natural processes of learning, or of learning *from mistakes*. Although similar, what I suggest in this dissertation is a somewhat inverted relationship. Rather than examining how engineering practices are learning opportunities, I investigate how engineering education reforms may be engineering practices themselves. When engineers mobilize education to address present and future states of the profession, which conditions of possibility are enabled? Which future worlds are being engineered through education?

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[6] David Kaiser, "Introduction: Moving Pedagogy from the Periphery to the Center," in *Pedagogy and the Practice of Science: Historical and Contemporary Perspectives*, ed. David Kaiser (Cambridge, MA: MIT Press, 2005), 3.

Kaiser further asks education research to consider what an education lens might clarify about scientific change.[7] Professional scientists and engineers reflecting on training and scientific roles can illuminate transformations in these professions over time. In certain circumstances, they may also distinctly show what has not changed very much at all.

My research makes further contributions to STS by arguing for the use of ethnographic methods in the study of scientific and technological disciplines. While interviews and document analysis are rather common methods of data collection and presentation, ethnographic vignettes or narratives remain underutilized within science and technology studies, despite their accepted significance in studying and writing cultures. I use narrative here to provide context to my research, to situate my writing within particular times, places, and people, and to disrupt the strong determinism inherent in a systems analysis of organizations.

1.6 My system, a narrative

> Its very presence suggests that systems theory needs narrative as a supplement, just as much, perhaps, as narrative needs at least an implicit system to generate itself. Narrative reveals what systems theory occludes; system theory articulates what narrative struggles to see.[8]

Following Hayles' prompt above, I narrativize my systems study of engineering education. The narrative complement to systems theory serves to amplify contingencies, to destabilize the rather forceful inevitability of system operations. These narratives include interview data from Engineering Change Lab members, and vignettes from some of my experiences in ECL workshops. They also include

[7] Kaiser, "Introduction," 1.
[8] N. Katherine Hayles, "Making the Cut," in *Observing Complexity: Systems Theory and Postmodernity*, eds. William Rasch and Cary Wolfe (Minneapolis, MN: University of Minnesota Press, 2000): 138.

the ruminations and actions of engineers in what was then the Canadian Council of Professional Engineers and other engineering organizations. As uncertain as the future successes and failures of the ECL are currently, so too were the initiatives of the Canadian Accreditation Board and the Canadian Committee on Women in Engineering. Yet from these data, it remains possible to surmise the ideals and values that make such ambitions possible: which elements are selected for inclusion within the system engineering education, and which elements are selected out of the system. And while Luhmann's systems theory provides a dynamic understanding of systems, narrative showcases what might be possible based on engineers' contemporaneous attempts to direct system behaviour. "With its chronological thrust, polymorphous digressions, located actions, and personified agents, narrative is a more *embodied* form of discourse than is analytically driven systems theory."[9] To try and balance these tensions between systems theory and narrative, I review Luhmann's systems theory in sufficient detail prior to narrating the data.

And, of course, in these narratives I have made cuts. They have endings and beginnings, omissions and elisions. There are other narratives about engineering education. My education and career in the Canadian engineering community, while apart from my methodology in this dissertation research, significantly influences my approach. My positionality or subjectivity as a white settler man engineer and scholar cannot be escaped, although I do attempt to provide some objective accounts and analysis in this dissertation.

My guiding intent in this work is to take up the challenge as set forth by the Engineering Change Lab, to think about the system of Canadian engineering

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[9] N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics* (Chicago: University of Chicago Press, 1999): 22.

education. What is the state of this system? How does it constitute itself? What is engineering likely to look like in the future, and what could it look like instead? I am earnestly interested in these questions. But my approach to answering them diverges from the ECL here. I think there is more to understand about Canadian engineering education that can inform strategies to improve or change the profession. And I believe that a critical perspective on the system of engineering education in Canada will further clarify why some rather glaring professional shortcomings remain so doggedly resistant to change or intervention, and why the register of some concerns has changed more dramatically.

My interest in studying engineering education emerged from a couple of different locales when conceiving this project. First, I learned of Engineers Canada's historical records of meeting minutes and other documents that, as far as they knew, had not been studied thoroughly. Not only was this reportedly an un(der)studied site, but as someone with two engineering degrees, I understood a central importance of Engineers Canada's work. Reading through their archive, I was able to piece together interesting narratives surrounding developments in Canadian engineering education that I believe are fundamental to understanding the system of *Canadian* engineering.

Second, from a Luhmannian perspective, the social system accesses subsystems through education due to state administration of schooling. So an analysis on engineering education would further explicate engineering's social functions: a topic that greatly interests me as someone interested in engineering cultures.

Third, Engineers Canada and the Canadian Engineering Accreditation Board hold a great deal of authority over engineering education. As engineering education is in myriad ways considered the entry point into engineering practice, many will identify engineering education as an appropriate site of cultural intervention.

And finally, the Engineering Change Lab and Engineers Canada, as organizations interested in engineering education, both hold to two somewhat contradictory beliefs that I will explore: 1. There is a weak link between engineering education and engineering practice—education is perpetually insufficient to the needs of the profession and society and needs reformation ("What will society require from engineers in 2050 that is different from today?" from the introductory vignette); and 2. There is a strong link between engineering education and engineering practice—education determines how pupils will act in the future, and changing engineering education will change professional engineering practice ("What are the most important changes for engineering education?" from the introductory vignette). I want to see how these beliefs might play out in detail, if they are indeed at odds, and I believe Luhmann's framework provides valuable concepts and language to make sense of this tension.

My policy focus here takes on a more reflexive angle on education than studies that focus on classrooms, teaching techniques, student participation, and faculty experiences. Presidents, vice-presidents, CEOs, chairs, directors, and deans of various engineering institutions implementing national policy decisions about engineering education—curricula, qualifications, accreditations, enrolments, scholarships—represent sincere endeavours to change the course of engineering education. And analyzing the engineering education practices of the Engineering Change Lab shows broader engineering membership perspectives on the system of engineering education. If these engineering education activities are taken as types of engineering practices themselves—as I argue how all engineering education should be understood—engineering practices take on much more explicitly political and social dimensions, dimensions obfuscated by more conventional accounts of engineering education and engineering work, and sometimes by engineers themselves.

My aim to contribute in some meaningful way to the work of the Engineering Change Lab and Engineers Canada, I hope, is appreciated by their teams, other engineers, and those interested in engineering education and engineering cultures.

Accessing the insights of the observations presented in this research constitutes a system operation itself, according to Luhmann. These reflections on the engineering system emerge as system operations, even when they deliberately may attempt to eschew or subvert more dominant structures, to cohere the multiplicity as a unity.

With that said, let us begin.

1.7 Outline

CHAPTER TWO is my literature review. I provide an overview of relevant literature from science and technology studies, including literature concerning engineering studies and education studies. I then summarize Luhmann's systems theory generally—and his analysis of the education system specifically—and examine its relationships, or lack thereof, with science and technology studies. Here I explore details of systems theory and hypothesize what it might bring to STS.

CHAPTER THREE is my methodology and an introduction to the educational contexts I study. I detail both my ethnographic fieldwork and historical research, leading into contextual examples from Engineers Canada and the Engineering Change Lab. I narrate educational events from each organization to introduce their work and outline some contours of the Canadian engineering education system and reforms to this system.

CHAPTER FOUR tells the story of the formation and function of the Canadian Accreditation Board and plans to standardize Canadian engineering education. I use Luhmann's operational closure to propose that the formation of the CAB by the Canadian Council of Professional Engineers is when the Canadian engineering system achieved *autopoiesis* through operational closure. This chapter further narrates policy interventions to Canadian engineering education from a national perspective.

CHAPTER FIVE studies women's representation in Canadian engineering, focusing on engineering education. I use Luhmann's concepts of selection and perturbation to theorize how pressure to improve women's representation in engineering affects the system, beginning with the Polytechnique massacre. What exactly stimulates a response within engineering to include women? Which system selections create the conditions for gender-based perturbations to emerge?

CHAPTER SIX presents ethnographic data of the Engineering Change Lab to explore the role of provocation and disruptive innovation within contemporary engineering education cultures. How well do contemporary understandings of system disruption agree with Luhmann's perturbations? How are these distinctions meaningful in engineering education reform?

CHAPTER SEVEN concludes this research project and makes recommendations for future study.

CHAPTER TWO

LITERATURE REVIEW

In this chapter, I draw primarily from the disciplines of science and technology studies, engineering studies, and education studies to summarize both theoretical arguments and related subject matter research that I expand upon throughout this dissertation. My major focus is on the sociopolitical dimensions of technoscience (including technoscience education), dimensions that may range from avowedly transparent sociopolitical influence (scientific government policy, for example) to ones where such influences are more deliberately obscured or ignored (sex/gender issues in engineering, for example). My research project contributes to nuanced and contextual understandings of how science and society continually refashion each other, and how scientific practices are also cultural practices.

I then provide a more detailed summary of Niklas Luhmann's systems theory, and his writings, along with Karl Schorr, on the system of education. This explanation of some useful systems theory terms—system, environment, *autopoiesis*, operational closure, observation, reflection, selection, and perturbation—will be beneficial in the data chapters that follow. I further explore why Luhmann's systems theory may not have had much purchase in science and technology studies, and how it might find some as demonstrated in my research.

2.1 Science and technology studies

According to Bruno Latour, to understand the world one must begin with studying quasi-objects, the perverse mingling of nature and culture, which will lead to understanding both nature and society rather than the modern approach of attempting an impossible bifurcation from the start.[10] Science and technology studies scholars draw from an interdisciplinary cadre of methods in attempts to showcase these sociopolitical dimensions of technoscience, examining the relationships between science, technology, and society without presumption of nature's unfettered existence. These sorts of critical examinations of technoscience demonstrate what those with authority through technoscience fear most: we have never been modern.[11] There was never a separation, a clear cutting, between nature (what can be explained by science) and society (what can be explained by social science). Thus, studying forces of power or oppression to elucidate socio-cultural phenomena are likewise applied to technoscientific ones.

The ethnographic reasoning for these approaches in STS is two-fold: first, there are studies of the social construction of scientific knowledge (most prominent during the 1980s); and second, there are studies that attend to power and politics in scientific and technological disciplines (popularized during the 1990s).[12]

Through the study of wide-ranging topics like expertise, knowledge production, technological development, and policy, STS scholars have emphasized sociocultural dynamics in technoscientific disciplines, couching "science" and "technology" within broader conceptions of society or culture.

Reflecting on the earlier work of the field of science and technology studies in an interview, Bruno Latour remarked "I think we were so happy to develop all this critique because we were so *sure* of the authority of science […] and that the

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[10] Bruno Latour, *We Have Never Been Modern*, trans. Catherine Porter (Cambridge, MA: Harvard University Press, 1993), 55.
[11] Latour, *Neven Been Modern*, 47.
[12] David J. Hess, "Ethnography and the Development of Science and Technology Studies," in *Handbook of Ethnography*, eds. Paul Atkinson, Amanda Coffey, Sarah Delamont, John Lofland, and Lyn Lofland (Thousand Oaks, Ca.: SAGE Publications, 2001), 234–245.

authority of science would be shared because there was a common world."[13] And although this sentiment has softened somewhat, a critical analysis of science and technology still focuses on challenging or unsettling any presumed epistemological, ontological, or methodological authority of technoscience. Latour elaborated on this idea in his article "Why Has Critique run out of Steam?" in which he lamented the somewhat disingenuous or bad faith use of "social constructivism" to undermine important matters of concern, like climate change.[14] Despite these reservations, critique remains an essential feature in science and technology studies, especially critique that concerns itself with power, justice, and emancipation. Engineering education, in this regard, is a quasi-object, an imbroglio of technoscience and society, worthy of critical appraisal of the ways in which it has shifted and stalled alongside Canadian society.

Donna Haraway likewise advanced a critical perspective in "A Cyborg Manifesto," encouraging readers to consider which differences are made significant in distinguishing between contrasting categories in scientific and technological fields—nature/culture, human/animal, human/machine—and to reimagine what political alliances could look like between different groups in this reconfiguration.[15] These critical deliberations on the social complexities of knowledge and power deployed through science and technology remain an important through-line of the discipline for my research.

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[13] Bruno Latour, "Bruno Latour, the Post-Truth Philosopher, Mounts a Defense of Science," interview by Ava Kofman, New York Times, October 25, 2018, https://www.nytimes.com/2018/10/25/magazine/bruno-latour-post-truth-philosopher-science.html.
[14] Bruno Latour, "Why has critique run out of steam? From matters of fact to matters of concern," *Critical Inquiry*, 30, no. 2 (2004): 225–248.
[15] Donna Haraway, "A Cyborg Manifesto," in *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York: Routledge, 1990).

Both of these tendencies within science and technology studies—investigations into the (social) construction of technoscience, and power and politics in technoscience—emphasize science as a cultural practice whereby the identities, institutions, discourses, and representations produced through technoscience likewise produce society. As per Sheila Jasanoff, these relationships between technoscience and society can be understood through the framework of co-production whereby science and society dynamically influence each other.[16]

But what of education? My research project follows closely in the STS traditions that interrogate power in scientific and technological fields, specifically through the themes of nationalisms, sex/gender, and technoscientific progress. Yet, STS has not comprehensively investigated education to answer questions of (social) construction in technoscience, nor questions of power in technoscience. The politics that animate the deliberate social structuring of engineering education and its complex relationships with society are a significant focus in the research project that follows. Positioning engineering education as practice makes clear some of its sociopolitical dimensions as engineers actively shape society. And following Haraway, education and practice appear in this research as contrasting engineering categories; categories whose boundaries I attempt to soften. How might engineering education reforms appear if the distinctions drawn between engineering education and engineering practice were not so firm? What is at stake in maintaining such distinctions?

Science and technology scholars have further provided nuanced understandings of how science, technology, and society interact to shape nationalist ideologies, narratives, and practices. Interconnected networks of infrastructures that emanate

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[16] Sheila Jasanoff, "Ordering Knowledge, Ordering Society," in *States of Knowledge: The Co-production of Science and the Social Order*, ed. Sheila Jasanoff (New York: Routledge, 2004): 13–45.

from centres of power to unite peoples have long connected individuals to conceptions of the nation. Power generation, electrical grids, and transportation networks have been designed to both provide vital infrastructures to citizens, and showcase technological advancements made possible by national authorities.[17] And while certain national projects explicitly function to celebrate or sublimate the nation, many more function with less visibility.[18] As such, these infrastructures may be considered forms of banal nationalism, symbols that function subliminally in the formation of national identities.[19]

Edward Jones-Imhotep argues that technological failure, caused by a hostile or indifferent nature, is a foil against which conceptions of the Canadian nation-state emerged.[20] This analysis of disrupted radio communications in Canada's north during the Cold War encourages consideration that even failures, technological and political, can work to bolster conceptions of nationhood despite interrupted functioning.

My research leverages similar rhetoric and policies concerning national infrastructures or technological concerns to showcase other sites of nationalisms produced through Canadian engineering. Educational policies—national

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[17] Chandra Mukerji, *Impossible Engineering: Technology and territoriality on the Canal du Midi* (Princeton, NJ: Princeton University Press, 2009). Gabrielle Hecht, *The Radiance of France: Nuclear Power and National Identity after World War II* (Cambridge, MA: MIT Press, 1998). Thomas P. Hughes, *Networks of Power: Electriciation in Western Society, 1880–1930* (Baltimore, MD: JHU Press, 1993). Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton, NJ: Princeton University Press, 1995). David E. Nye, *American Technological Sublime* (Cambridge, MA: MIT Press, 1996).
[18] Martha Lampland and Susan Leigh Star, "Reckoning with Standards," in *Standards and Their Stories: How Quantifying, Classifying, and Formalizing Practices Shape Everyday Life*, eds. Martha Lampland and Susan Leigh Star (Ithaca, NY: Cornell University Press, 2009): 3–24.
[19] Michael Billig, *Banal Nationalism* (Thousand Oaks, CA: SAGE Publications, 1995): 8. Peter Merriman and Rhys Jones, "Nations, materialities and affects," *Progress in Human Geography* 41, no. 5 (2017): 600–617.
[20] Edward Jones-Imhotep, *The Unreliable Nation: Hostile Nature and Technological Failure in the Cold War* (Cambridge, MA: MIT Press, 2017).

infrastructures in their own rights[21]—that are developed and deployed in more explicitly political environments motivate my analysis. Scientific and technological policies are but one lens through which statecraft may be understood. Extending technoscientific infrastructural analyses to technoscientific education provides additional nuance to understandings of state power and authority, revealing other invisible infrastructures constructed or subverted through nationalisms.

I leverage imaginaries in this research to question the roles of nationalisms in engineering education. Benedict Anderson posited "imagined communities" as a way to comprehend citizens' enrolment in the modern nation state—a confluence of shared language, calendrical time, and print capitalism—uniting people who may never meet under shared identities. Imaginaries, in this regard, have been leveraged by STS scholars in their specific contexts. Atsushi Akera notes that many anthropologists have embraced "imaginaries" over "identities" in analyzing engineering, preferring the greater "fluid and non-essential character of identities" expressed through imaginaries. Jasanoff and Kim, in their edited volume, explored how sociotechnical imaginaries elucidate how social futures are conceptualized through science and technology.[22] Further, Adams, Murphy, and Clarke critiqued the contemporary role of "anticipation," of capitulation to the omnipotence of "the future," in justifying present-day actions whereby anticipated futures play out in the present.[23] This analysis leads one to reconsider how closely bound together technoscience, nationalisms, and individual lives may be. In

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[21] James Elwick, *Making A Grade: Victorian Examinations and the Rise of Standardized Testing* (Toronto: University of Toronto Press, 2021).
[22] Sheila Jasanoff and Sang-Hyun Kim, eds. *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power* (Chicago: University of Chicago Press, 2015).
[23] Vincanne Adams, Michelle Murphy, and Adele E. Clarke, "Anticipation: Technoscience, life, affect, temporality," *Subjectivity* 28 (2009): 247.

assessing contemporary challenges and wishing to exceed the present, a focus shifts from actualities to potentialities. National securities, then, can enter unexpected places where the future is up for grabs. I employ both imaginaries and banal nationalisms to interrogate engineering education in the contexts of Canadian (and Québécois) nationalisms, and the future-looking approaches of systems thinking.

Philosopher Sandra Harding incorporated standpoint feminism in her epistemological analysis of science, arguing that women, from their oppressed positions from the margins or the periphery, provide different perspectives on scientific knowledge than those occupying the centre.[24] Feminist studies scholar Donna Haraway similarly advocated for a feminist objectivity in science, one predicated on the responsibility that accompanies scientific knowledge creation. Haraway argued for scientists to embrace the partial perspectives from which they make observations, to situate their knowledges within the embodied and social contexts from which they are constructed.[25]

Importantly, from this literature, it is necessary to consider the standpoint from the margins to capture a fulsome account of science. In the case of Canadian engineering, women occupy the margins, and their perspectives are illuminating to the profession. I attempt to highlight women's perspectives in this dissertation, while also giving attention to gender work reified through the engineering education. I explore issues of sex/gender in engineering more specifically later in the engineering studies section of the literature review below.

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[24] Sandra Harding, *Sciences From Below: Feminisms, Postcolonialities, and Modernities* (Durham, NC: Duke University Press, 2008).
[25] Donna Haraway, "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective," *Feminist Studies* 14, no. 3 (1988): 575–599.

Conventional tales of invention or innovation centre on the contributions of the individual to usher in change, whether by genius, entrepreneurship, or sheer luck. Conversely, laboratory studies played a crucial role in the early decades of science and technology studies in opening up the "black box" of scientific discovery, following the socio-material practices of professional knowledge generation—the experiments, the workers, the papers—revealing how deeply scientific facts are (socially) constructed.[26] At the same time, actor-network theory's methodological framework was similarly useful for exploring the social construction of technology.[27] Following human and non-human actants through their various operations can reveal the complexity and contingency of obscure, or perhaps neglected, human organization, while also emphasizing the agency of non-humans within the network.

Edwin Hutchins explored how cognition, a seemingly singular psychic process, may be distributed between subjects and objects.[28] Hélène Mialet went a step further in showing how the human subject itself may be distributed in, or assembled by, a network.[29] These authors raise important questions about individual and collective cognition, and how thoughts produce action that lead to further thoughts and actions: the promise of innovation. Mialet has further investigated innovation in industrial practices, detailing how new ideas are created. Importantly, the stronger the links between an individual and their organization, peers, and subject matter the more "inventive" they become.[30] In

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[26] Bruno Latour & Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton, NJ: Princeton University Press, 1979).
[27] Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch, eds. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, MA: MIT Press, 1987).
[28] Edwin Hutchins, *Cognition in the Wild* (Cambridge, MA: MIT Press, 1995).
[29] Hélène Mialet, *Hawking Incorporated* (Chicago: University of Chicago Press, 2012).
[30] Hélène Mialet, "Making a Difference by Becoming the Same," *International Journal of Entrepreneurship and Innovation* 10, no. 4 (2009): 257.

other words, the more they assimilate within a network, the more they stand out as a singularity.

David Edgerton's critical scholarship of innovation highlighted the ubiquity of technological use, elevating quotidian technological applications and repurposing above the rather tired view of inventors being "ahead of their time."[31] From this vantage point, it becomes possible to imagine how commonplace innovation might actually be, practiced by any number of individuals throughout their lifetimes in a variety of contexts. Innovation, purportedly, makes individuals and organizations successful, although greater economic activity can be attributed to maintenance than innovation.[32] The earth-moving potential of Silicon Valley unicorns likewise relies more on the innovations of earlier technologies (open source software, digital platforms, and cloud computing) and winner-take-all dynamics of venture capital investment than it does on the novelty of artifacts and services produced by start-ups.[33] My research project builds upon these critical perspectives on innovation to challenge how innovation may be deliberately facilitated, and to question the value of innovation in engineering education.

While the above literature deeply informs my approach and analysis in this research project, missing from these critical perspectives on science and technology is education. Technoscientific education remains undertheorized in STS and undervalued within the discipline. Much attention has been given to the obscured or denied social dimensions of technoscience, yet similarly critical study

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[31] David Edgerton, *The Shock of the Old: Technology and Global History Since 1900* (London: Profile Books, 2006): ix.
[32] Andrew L. Russel and Lee Vinsel, "Make Maintainers: Engineering Education and an Ethics of Care," in *Does America Need More Innovators?*, eds. Matthew Wisnioski, Eric S. Hintz, and Marie Stettler Kleine (Cambridge, MA: MIT Press, 2019): 249–269.
[33] Martin Kenney and John Zysman, "Unicorns, Cheshire cats, and the new dilemmas of entrepreneurial finance," *Venture Capital* 21, no. 1 (2019): 35.

of technoscience education has evaded many STS scholars' inquiry even when they may recognize learning and training as foundational to the technoscientific practices they do examine.

David Kaiser's edited volume *Pedagogy and the Practice of Science* makes a significant contribution to STS, theorizing how education, through pedagogy, training, learning, and research, should be included in studies of science.[34] Graeme Gooday's chapter in this volume captures the tensions between "analytical" and "practical" theories in the development of the discipline of electrical engineering, showcasing how analytical or theoretical approaches to problem solving are practices of their own and have their own types of practical applications.[35] Yet, Kaiser's volume still divides the texts along the "practice-practitioner dyad" whereby training (practices) and practitioner roles, norms, and values (practitioners) are considered apart.[36] My research attempts to centre engineering education in all its forms (policies, curricula, professional development, training, pedagogy, learning) as engineering practices.

Other scholars have argued that "science and technology studies should strive to change society by contributing to the design of learning environments that form future generations of producers and consumers of scientific and technological knowledge" by using STS research findings to design "alternative learning environments."[37] Through science and technology studies' critical perspectives on

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34 Kaiser, "Introduction," 1.
35 Graeme Gooday, "Fear, Shunning, and Valuelessness: Controversy over the Use of 'Cambridge' Mathematics in Late Victorian Electro-Technology," in *Pedagogy and the Practice of Science: Historical and Contemporary Perspectives*, ed. David Kaiser (Cambridge, MA: MIT Press, 2005), 111–150.
36 Kaiser, "Introduction," 4.
37 Wolff-Michael Roth, Michelle K. McGinn, and G. Michael Bowen, "Applications of Science and Technology Studies: Effecting change in science education," *Science, Technology, & Human Values* 21, no. 4 (1996): 454.

nature, culture, agency, experiment, climate change, race, and gender/sex, authors of a special collection of Education Studies argued that STS may be leveraged to provide these alternative approaches in teaching science, technology, engineering, and mathematics.[38] Although others caution against trying to instrumentalize humanities research interventions into clear educational lessons, specifically identifying attempts to leverage STS research as convenient ways of improving engineering education.[39] Further, recent policy initiatives for interdisciplinarity within STEM are driven by "corporate interest in the entrepreneurial potential of postsecondary students" rather than a commitment to diversified learning.[40]

Gary Downey explicitly addressed an STS perspective on the demarcation problem in engineering education between technical knowledge and social knowledge. Downey argued that the cultural problem of engineering education that devalues social knowledge in favour of technical knowledge lies "precisely within the technical core of engineering practices and, hence, the curriculum" rather than as the broader culture surrounding this technical core.[41] Characterizing the curricular infrastructure that demarcates technical and social knowledge, Downey elaborated:

> All social knowledge of engineering work and its consequences is beyond and supplemental to engineering. For students passing through these infrastructures, acceptance of these powerful definitions and expectations is supposed to be a given. Resistance produces all the effects of an ontological and ethical violation.[42]

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[38] Roth, McGinn, and Bowen, "Applications of Science and Technology Studies": 454–84.
[39] Wisnioski, *Engineers for Change*.
[40] Elizabeth de Freitas, John Lupinacci, and Alexandre Pais, "Science and Technology Studies × Educational Studies: Critical and creative perspectives on the future of STEM education," *Educational Studies* 53, no. 6 (2017): 551–559.
[41] Gary Lee Downey, "Critical Participation: Inflecting dominant knowledge practices through STS," in *Making & Doing: Activating STS through Knowledge Expression and Travel*, eds. Gary Lee Downey and Teun Zuiderent-Jerak (Cambridge, MA: MIT Press, 2021), 220.
[42] Downey, "Critical Participation", 227.

Noting myriad challenges from engineering educators that recognize these cultural deficiencies and attempt to address them, Downey further cautioned that the demarcation between technical and social knowledge is so pervasive and resilient that “even engineering educators who seek to reframe core learning in ways that might help students reflect critically on that learning can find themselves defaulting to that demarcation.”[43]

Downey’s point is a strong one, attempting to position engineering knowledges and skills within a cultural frame—so that activist educators can draw attention to barriers to cultural changes in engineering education—risks reifying that the technical curricular core of engineering education is extra-cultural. Instead, one must emphasize that “the self-limiting cultural problem in engineering lives in practices at the infrastructural center.”[44] This research project will provide some glimpses into this infrastructural centre of engineering education, while questioning which types of practices are enabled by which types of education.

2.2 Engineering studies

While considered a subfield of science and technology studies, engineering studies provides some unique perspectives specific to the critical examination of engineering as a culture and its relationships with technology and society. I use three landmark texts from engineering studies to guide my dissertation: Millard’s *The Master Spirit of the Age*, Layton’s *The Revolt of the Engineers*, and Wisnioski’s *Engineers for Change*.

J. Rodney Millard, in the *The Master Spirit of the Age: Canadian engineering and the politics of professionalism 1887–1922*, presented a history of engineering

[43] Downey, “Critical Participation”, 236.
[44] Downey, “Critical Participation”, 237.

organizations in Canada. In the early 20th century, engineers in Canada argued that they had contributed greatly to the industrialization of Canadian society, warranting the prestige and remuneration that accompany professionalization.[45] They succeeded in their professionalization, further arguing that their expertise exceeded the abilities of the public, and that they alone could vouchsafe public welfare in modern industrialized life.[46] The highly regarded engineer earned their respect through service. Rudyard Kipling's poem "The Sons of Martha," extols the virtues of this industrial service (and is referenced in the title and opening of this dissertation). Originally written in 1907, Kipling adapted the poem for the Ritual of the Calling of an Engineer in 1922, commonly called the "Iron Ring Ceremony" where Canadian engineering graduates are welcomed to the profession. Kipling's esteem of engineers' services to society were echoed by other writers at the time. One wrote:

> It is the engineer who harnesses the Niagaras of the world to transform the night of our cities into noonday, and to turn the wheels of commerce. It is the engineer who develops the mining and furnishes the metal with which he builds machines that by their ingenuity compel us to stand in awe and admiration. It is the engineer who produces the steel to form a network of highways over our continents and that makes possible the myriads of floated palaces on our oceans. It is the engineer who has abolished famine and pestilence. It is the engineer who has annihilated distance with his telegraph and his telephone. It is the engineer who has made possible the conquest of the air.[47]

It is from these beginnings in the early 20th century that engineering emerges as a profession, distinguishing itself from, while acting responsibly for, the Canadian public. Millard argues that this structure of professionalization effectively conferred "monopoly powers on a private interest group, as a public service."[48] The Engineering Institute of Canada initiated the provincial licencing legislation

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[45] Millard, *Master Spirit*, 122.
[46] Millard, *Master Spirit*, 133.
[47] Millard, *Master Spirit*, 20.
[48] Millard, *Master Spirit*, 133.

for engineers in 1918 through bills that would create licensing bodies separate from the technical groups.[49] Making licensure mandatory assured membership in the new provincial associations. At the time, some engineers predicted that compulsory registration with provincial regulators would cause members to drop their memberships with EIC.[50] Certainly, in the decades that followed, the EIC suffered from decreased influence while the provincial associations took control of the profession. This is where Millard's account ends. However, questions about how engineering organizations seek to control the profession and Canadian society remain. This dissertation research tracks the developments of national engineering programs directed by these provincial associations through the Canadian Council of Professional Engineers/Engineers Canada, where the EIC, the CCPE, universities, and provincial associations will continue to jockey for control of the future of the Canadian engineering profession. The stakes are not limited to the engineering profession, as one engineer remarked at the time: "Statecraft is merely national engineering."[51]

Edwin Layton's *The Revolt of the Engineers: Social responsibility and the American engineering profession* detailed American engineers' technocratic political aspirations. Following Taylorites, disciples of one Frederick Taylor, through their roles in industrial research, engineering technical societies, utility companies, and city manager offices, Layton's history explored the successes and failures of scientific management as a political project. So too did engineers in this context view society's future as whatever "the engineering profession willed it to be."[52] Layton characterized this time in 1920s and 1930s America as a crisis

[49] Millard, *Master Spirit*, 135.
[50] Millard, *Master Spirit*, 136.
[51] Millard, *Master Spirit*, 20.
[52] Layton, *Revolt Engineers*, 57.

of professional identity for engineers as they seemingly disappeared within the large public and private organizations that emerged with the formation of their profession.[53] Some engineers sought for engineers to control organizations that directed engineering, some engineers wanted a comprehensive body to unite all engineers, and some business-oriented engineers devoted their interest to technical societies of specific industries over organizing a unified profession.[54] Layton was interested in the transformational endeavours of these engineers, but he highlighted they were not revolutionaries, simply bureaucrats.[55] I wonder how Layton's concerns play out in a Canadian context. What political ambitions to engineering educators have for their profession and for society? How do they organize to accomplish these explicitly political goals of directing their profession?

Matthew Wisnioski's *Engineers for Change: Competing visions of technology in 1960s America* examined similar internal technological debates among engineers, although in this history it focuses on engineers' complacency in the military-industrial complex less than a half-century later than Layton. Wisnioski problematized the concept of "technological change," arguing that "an ideology of technological change provided a solution to the crisis of technology while undercutting the identity of the engineer."[56] Proponents of technological change "asserted that technology was an inevitable force in society, that its control necessitate their expertise, and that with an assertion of social responsibility engineers might attain a role as policy makers."[57] Engineering as a profession has deep ties with policy, and Wisnioski explored this relationship while remaining

[53] Layton, *Revolt Engineers*, 5.
[54] Layton, *Revolt Engineers*, 25.
[55] Layton, *Revolt Engineers*, 1.
[56] Wisnioski, *Engineers for Change*, 197.
[57] Wisnioski, *Engineers for Change*, 196.

critical of engineers' reliance on "technological change" and "social service" as discursive tactics for political control.

This dissertation contributes to these sociopolitical concerns within engineering by presenting unique data from a historical and contemporary Canadian context. I further apply Wisnioski's troubling of "technological change" to present a contradiction in engineering education where technological change is simultaneously valued as a social good provided by engineers while being leveraged as social threat to justify power and control of the profession.

While I previously identified technoscientific education as being undertheorized and undervalued within science and technology studies, engineering education is a ubiquitous subject within engineering studies. The focus of much of this literature on engineering education remains limited to post-secondary institutions, studying undergraduate student, graduate students, and faculty, with little attention given to other organizations or systems implicated in engineering education.[58] In some respects, there is a presumed importance of engineering education as a way to study engineers or engineering. But the synergies available

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[58] Karen L. Tonso, "'Plotting Something Dastardly': Hiding a Gender Curriculum in Engineering," in *The Hidden Curriculum in Higher Education*, ed. Eric Margolis (New York: Routledge, 2001), 155–74. Gary Downey and Juan Lucena, "When students resist: Ethnography of a senior design experience in engineering education," *International Journal of Engineering Education* 19, no. 1 (2003): 168–76. Karen L. Tonso, "Teams that Work: Campus Culture, Engineer Identity, and Social Interaction," *Journal of Engineering Education* 95, no. 1 (2006): 25–37. Alice L. Pawley, "Universalized Narratives: Patterns in How Faculty Members Define 'Engineering,'" *Journal of Engineering Education* 98, no. 4 (2009): 309–19. Amy E. Slaton, *Race, Rigor, and Selectivity in U.S. Engineering: The History of an Occupational Color Line* (Cambridge, MA: Harvard University Press, 2010). Amy Sue Bix, *Girls Coming to Tech!: A History of American Engineering Education for Women* (Cambridge, MA: MIT Press, 2014). Cecilia Moloney, Janna Rosales, and Cecile Badenhorst, "A methodological evaluation of an integrative pedagogy for engineering education," (presentation, 2016 IEEE Frontiers in Education Conference (FIE), Erie, PA, October 12–15, 2016). Jennifer Long, Amin Reza Rajabzadeh, and Allan MacKenzie, "Teaching Teamwork to Engineering Technology Students: The Importance of Self-Reflection and Acknowledging Diversity in Teams," (presentation, 2017 Canadian Engineering Education Association (CEEA), Toronto, ON, June 4–7, 2017).

between studying engineering education critically and using these types of studies to adjust engineering educational programs (curricula, classroom practices, diversity initiatives) make humanistic research in engineering schools fairly common.

Lionel Claris and Donna Riley studied the application of critical theory and critical thinking in engineering education, noting a recent interest in critical thinking in post-secondary engineering education to improve engineering education.[59] Other scholars remarked about their embeddedness as science and technology studies academics in engineering faculties, clarifying their roles as engaging in what Gary Downey calls "Big STS."[60] These authors further outlined what they call Canadian engineering education's "constitutional moment" in the Canadian Engineering Accreditation Board's (CEAB) 2014 adoption of graduate attributes. The authors identified opportunities for social sciences and humanities scholars through the rollout of the educational outcomes as nine of the twelve attributes provide roles for humanistic disciplines.[61]

Elizabeth Reddy, Stephen Rea, and Qin Zhu examined the roles of medical metaphors concerning ethics in engineering education ("doses," "microdosing," "infusions," "micro-insertions"), arguing that framing engineering students as "ethically problematic symptoms" overlooks cultural or institutional determinants of ethical behaviour.[62] Further, Reddy et al. warn that ethics pedagogies may have

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[59] Lionel Claris and Donna Riley, "Situation Critical: Critical Theory and Critical Thinking in Engineering Education," *Engineering Studies* 7, no. 1 (2012): 1.
[60] Brandiff Caron et al., "Navigating a Constitutional Moment: Reflections on Implementing Graduate Attributes in Canadian Engineering Education," *Engineering Studies* 6, no. 1 (2014): 44. Gary Downey, "What is engineering studies for? Dominant practices and scalable scholarship," *Engineering Studies* 1, no. 1 (2009): 73.
[61] Caron et al., "Navigating a Constitutional Moment," 47.
[62] Elizabeth A. Reddy, Stephen C. Rea, and Qin Zhu, "Ethics by the Dose: Medical Treatment Metaphor for Ethics in Engineering," (presentation, 2020 ASEE Virtual Annual Conference Content Access, Virtual Online, June 22–26, 2020): 8.

educational "side effects" even when they meet the "treatment goals" of educational reform.[63] Caron et al. noted that despite the opportunities presented by the Canadian engineering graduate attributes, and similar interest in incorporating science and technology studies themes in engineering programs, these reforms were still met with resistance as engineering faculty privileged traditional "technical knowledge" over "soft skills."[64] Relatedly, Erin Cech concluded that engineering "students' public welfare concerns *decline* significantly over the course of their engineering education," suggesting a "culture of disengagement" as their education progresses.[65] My research builds on these ideas to show the explicitly social concerns engineering educators have historically and contemporarily shared about engineering education curricula, and how education is leveraged to attempt to produce specific social outcomes.

Andrew L. Russell and Lee Vinsel argued that many of the social consequences of technology are obscured through an overwhelming focus on innovation and a recent flourishing of "innovation-speak." With their goal of offering more holistic understandings of human relationships with technology, Russell and Vinsel turned to engineering education specifically because "innovation-speak is particularly rampant in that domain." They further argued for a reorientation of engineering education around an ethics of care, that emphasizing "maintenance, repair, upkeep, and mundane labour" can liberate engineering education from the limitations imposed by undue attention on innovation as an assumed social good.

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[63] Reddy et al., "Ethics by the Dose," 8.
[64] Caron et al., "Navigating a Constitutional Moment," 46.
[65] Erin A. Cench, "Culture of Disengagement in Engineering Education?" *Science, Technology, and Human Values* 39, no. 1 (2013): 42.

Another common theme of study in engineering education is that of gender identity.[66] Pawley and Slaton dissect the persistent inequities in engineering education related to race, gender, and ability.[67] They argued for small, qualitative studies of engineering education that draw from intersectional, Queer, and Disabilities studies theories to interrogate engineering education inequities, as opposed to 'large-n' quantitative studies that may prevent incisive analysis.[68]

These concerns of gender inequities have also been studied among engineering faculty. Kacey Beddoes interviewed engineering professors and studied their contributions to the social construction of ignorance surrounding gender in engineering, remarking the ways that they (un)willingly promote a culture that avoids addressing gender issues.[69] In another study, Beddoes, Schimpf, and Pawley interviewed science, technology, engineering, and mathematics (STEM) faculty and found that choice discourse was used often to frame challenges experienced by women faculty, a double standard in which women "choose"

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[66] Amy Sue Bix, "From 'Engineeresses' to 'Girl Engineers' to 'Good Engineers': A History of Women's U.S. Engineering Education," *National Women's Studies Association Journal* 16, no. 1 (2004): 27–49. Kerry L. Meyers et al., "Factors relating to engineering identity," *Global Journal of Engineering Education* 14, no. 1 (2012): 119–31. Amy Sue Bix, *Girls Coming to Tech!*. Keith J. Bowman and Lynnette D. Madsen, "Queer identities in materials science and engineering," *MRS Bulletin* 43, no. 4 (2018): 303–7. Anna T. Danielsson et al., "The Pride and Joy of Engineering?: The Identity Work of Male Working-Class Engineering Students," *Engineering Studies* 11, no. 3 (2019): 172–95. Stephen Secules, "Making the Familiar Strange: An Ethnographic Scholarship of Integration Contextualizing Engineering Educational Culture as Masculine and Competitive," *Engineering Studies* 11, no. 3 (2019): 196–216. Ryan A. Miller et al., "'It's dude culture': Students with minoritized identities of sexuality and/or gender navigating STEM majors," *Journal of Diversity in Higher Education* 14, no. 3 (2020): 340–52. Jacqueline Rohde et al., "Anyone, but not Everyone: Undergraduate Engineering Students' Claims of Who Can Do Engineering," *Engineering Studies* 12, no. 2 (2020): 82–103.
[67] Amy E. Slaton and Alice L. Pawley, "The Power and Politics of Engineering Education Research Design: Saving the 'Small N,'" *Engineering Studies* 10, no. 2–3 (2018): 133–57.
[68] Slaton and Pawley, "The Power and Politics," 133.
[69] Kacey Beddoes, "Agnotology, Gender, and Engineering: An Emergent Typology," *Social Epistemology* 33, no. 2 (2019): 125.

academic careers and the associated difficulties of work-life balance rather than "better" industry workplaces.[70]

As with engineering education research summarized earlier, academic studies of engineering practice, the profession, or culture consistently find gender to be a major determinant in engineering social structures.[71] Wendy Faulkner examined gender paradoxes in engineering using ethnographic methods to study gender (in)authenticity in engineering workplaces,[72] concluding that women were largely understood as either not real engineers (they were engineers to secure a romantic heterosexual partner in men engineers) or not real women (they were desexualized by coworkers as lesbians, or "one of the lads").[73] More recently, Miriam Schmitt studied the rarity of women engineers in higher management positions, finding that women rely on gender-specific support to introduce them to engineering work culture.[74] In a study of Australian engineers, researchers found that gender equity had become an "accepted demand," and that "resources are allocated and efforts made to improve the proportion and standing of women engineers."[75] Conversely, they further concluded that both men and women engineers meet these efforts with resistance, hostility, and indifference, frequently

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[70] Kacey Beddoes, Corey T. Schimpf, and Alice L. Pawley, "Engaging Foucault to Better Understand Underrepresentation of Female STEM Faculty," (presentation, 2013 ASEE Annual Conference, Atlanta, GA, June 23–26, 2013): 9.
[71] Karen L. Tonso, *On the Outskirts of Engineering: Learning Identity, Gender, and Power via Engineering Practice* (Rotterdam: Sense Publishers, 2007).
[72] Wendy Faulkner, "Doing gender in engineering workplace cultures. I. Observations from the field." *Engineering Studies* 1, no. 1 (2009a): 3–18. Wendy Faulkner, "Doing gender in engineering workplace cultures. II. Gender in/authenticity and the in/visibility paradox." *Engineering Studies* 1, no. 3 (2009b): 169–89.
[73] Faulkner, "Doing gender in engineering II," 169.
[74] Miriam Schmitt, "Women Engineers on Their Way to Leadership: The Role of Social Support Within Engineering Work Cultures," *Engineering Studies* 13, no. 1 (2021): 30.
[75] Suzanne Franzway et al., "Engineering Ignorance: The Problem of Gender Equity in Engineering," *Frontiers: A Journal of Women Studies* 30, no. 1 (2009): 95.

denying that gender has any relevance to engineering work or culture.[76] These studies emphasize the importance of attending to gender within engineering culture, even when it may be ignored or denied by engineers being studied.

In the Canadian context, Marcia Friesen researched career development in professional engineering by immigrants to Canada finding that engineers have a tacit understanding that "engineering knowledge, identity and practice are heuristic, context-specific and culturally dependent."[77] Friesen argued that these cultural practices, or, following Bourdieu, *habitus*, much more subtly inform professional integration than the more explicit requirements and qualifications, or cultural capital, of engineering.[78] This conclusion suggests an omnipresent culture within engineering that, in some ways, supersedes the more explicit roles of engineering organizations and regulations that dominate the Canadian landscape. This culture, no matter how objective, regimented, or regulated, is still practiced, after all, by humans. My research project represents some of these ineffable characteristics of engineering culture through situated narratives.

2.3 Education studies

"What is education for?" asks Gert Biesta in his work The Beautiful Risk of Education.[79] Since the purpose of education is multidimensional, with potential synergies and trade-offs between different purposes, judgement about what is educationally desirable is a crucial element of education. Biesta identifies three domains of educational purpose: qualification, socialization, and

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[76] Franzway et al., "Engineering Ignorance," 95.
[77] Marcia R. Friesen, "Immigrants' integration and career development in the professional engineering workplace in the context of social and cultural capital," *Engineering Studies* 3, no. 2 (2011): 98.
[78] Friesen, "Immigrants' integration," 98.
[79] Gert J. J. Biesta, *The Beautiful Risk of Education* (New York: Routledge, 2016), 127–128.

subjectification.[80] Briefly, qualification considers how education qualifies people with knowledge, skills, and dispositions. Socialization includes how people become parts of social, cultural, and political practices and traditions through identity formation. Subjectification, in contrast, deals with how people exist outside these orders, a question of human freedom. Subjectification in this regard, the process by which individuals confront themselves as subjects through education, is overlooked in educational reforms which focus instead on qualification and socialization.

Niklas Luhmann was interested in education from a systems theory perspective specifically because of how education was used by other subsystems to access state administration and the social system.[81] The system of education is unique in this regard as it became foundational to many other systems' functions. It is through couplings with the education system that subsystems are further coupled with the social system. In this fashion, education provides both social purpose and professional security to a system through which training is required. A distinct social role is protected, awaiting the trainee to finish their education and fulfill a social obligation. These systems have become so tightly coupled that participation in the education programs is compulsory to the ranks of certain professions.

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[80] Biesta, *Risk of Education*, 17–18.

[81] Niklas Luhmann authored two major works concerning education. The first, published in 1978, applied his systems theory to education as a subsystem: Niklas Luhmann, *Das Erziehungssystem der Gesellschaft* (The Education System of Society) (Berlin: Suhrkamp, 2002). The second, *Reflexionsprobleme im Erziehungssystem*, was co-authored with education scholar Karl Eberhard Schorr in 1979: Niklas Luhmann and Karl-Eberhard Schorr, *Problems of Reflection in the System of Education*, trans. Rebecca A. Neuwirth (New York: Waxmann Münster, 2000). Only the latter is available in English, thanks to a translation by Rebecca A. Neuwirth.
Claudio Baraldi and Giancarlo Corsi compiled their 2017 English-language text Niklas Luhmann: Education as a Social System using Luhmann's German-language works in addition to his numerous other writings: Claudio Baraldi and Giancarlo Corsi, *Niklas Luhmann: Education as a Social System* (Cham, Switzerland: Springer, 2017).

Luhmann proposed four aspects of education that contribute to its structuring: 1) Conveyance (of skills and knowledge), 2) Intention to educate (reflection on education determines the contents and materials of education and what is excluded from them), 3) Trivialisation (of pupils socially to produce desired outputs), and 4) Socialisation effects (or unintended effects produced by the 'hidden agenda' or the 'implicit' and 'nul' 'curricula').[82]

My research brings Biesta's domain of "subjectification" into conversation with Luhmann's "intention to educate." Educational intentions produce fundamental selections in the system of education.[83] These selections are geared toward conveyance, qualification, trivialization, and socialization (Luhamnn; Biesta), yet overlook how education might be practiced outside of these intentions or selections.

These intentions select elements as parts of the education system while selecting others as outside of the system, or as parts of "the environment." As such, education reforms directly address educational intentions where proposed changes must align with some conception of educational outcomes. Ruminating on what makes certain changes in education desirable invites the question: What is the purpose of education? While this research project does not attempt to answer this question, it does provide a nuanced description of some of the purposes and intentions demonstrated through reforms to Canadian engineering education. However, front and centre is a concern of the fundamental selection processes in engineering education.

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[82] Baraldi and Corsi, *Niklas Luhmann*, 50–54, 74.
[83] Raf Vanderstaeten, "An Observation of Luhmann's Observation of Education," *European Journal of Social Theory* 6, no. 1 (2003): 139.

Kieran Egan discusses the foundations of education through educational intention, explaining a Rousseauian or Deweyan view that sees that "the means and ends of education are tied together."[84] The purpose of education can be made clear through examination of the processes of education. Egan provides an illustrative example, "we feel a bit uncomfortable about compelling attendance at institutions that try to teach the values of liberty and democracy."[85] Here, Egan might agree with Luhmann that the supposed content of curriculum is not as important to the purpose of education as is the development of the ability to learn.

For Luhmann, the pupil's present is the point of tension between past and future, two opposing worlds rather than a linear trajectory.[86] They are marked as students, in need of (re)learning from a corrigible history, to imminently become improved versions of their current selves. Education reforms pupils as it reforms itself. This research project tracks reforms in this light where students become a focus of reform in order to improve society.

2.4 What might Niklas Luhmann's systems theory offer STS?

This dissertation relies substantially on the work of Niklas Luhmann. But I must address a significant discontinuity: I am in a science and technology studies program yet I have chosen a theorist who seemingly has no relationship with the discipline. This section provides an overview of Luhmann's systems theory as it will be applied to the research project, primarily using his writings on the education system. I further deliberate about potential synergies between Luhmann's systems theory and science and technology studies.

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[84] Kieran Egan, *The Educated Mind: How Cognitive Tools Shape Our Understanding* (Chicago: University of Chicago Press, 1997), 19.
[85] Egan, *Educated Mind*, 19.
[86] Baraldi and Corsi, *Niklas Luhmann*, 94.

Many have written theories of systems. Jay Forrester's *Industrial Dynamics*, *Urban Dynamics*, and *World Dynamics* lionized the potential of system dynamics computational modeling.[87] Later, Peter Senge's *The Fifth Discipline* and Arie de Geus's *The Living Company* further explored nonlinear, counterintuitive, and complex system management, and brought "systems thinking" to popular audiences.[88] Sociologist Niklas Luhmann was also interested in systems during the latter quarter of the 20th century and offered his own systems theory.

In Luhmann's *Introduction to Systems Theory*, he accounts others' theoretical frames of understanding systems—explaining systems in even broader philosophical terms—but also critiques this systems theory through its epistemological and ontological limitations.[89]

Niklas Luhmann's systems theory, sometimes called second-order cybernetics, begins first with an understanding of cybernetics.

2.4.1 Classical cybernetics

Luhmann constructs an understanding of systems based on the rather simple process of communication found in Norbert Wiener's classical cybernetics.[90] In Wiener's cybernetic model, the communication of information is necessary for

[87] Jay W. Forrester, *Industrial Dynamics* (Cambridge, MA: MIT Press, 1961). Jay W. Forrester, *Urban Dynamics* (Cambridge, MA: MIT Press, 1969). Jay W. Forrester, *World Dynamics* (Cambridge, MA: MIT Press, 1971).
[88] Peter M. Senge, *The Fifth Discipline: The Art and Practice of the Learning Organization* (New York: Currency, 1990). Arie De Geus, *The Living Company* (Cambridge, MA: Harvard Business Press, 1997).
[89] Niklas Luhmann, *Introduction to Systems Theory*, trans. Peter Gilgen (Malden, MA: Polity Press, 2013).
[90] Norbert Wiener, *Cybernetics: Or Control and Communication in the Animal and the Machine* (Cambridge, MA: MIT Press, 1948).

the foundational feedback mechanism that guides machine targeting.[91] Information, in this case, originates from two variables: the current measured position of the enemy target, and the previously predicted position of the enemy target. These two variables, these two pieces of information, are subsequently communicated as inputs in a calculative relationship to "steer" the targeting system. A negative feedback loop is established via this calculation, continuously recalculating one of the inputs (forecast) while the other input changes somewhat independently (target position). The feedback is called negative feedback because the calculation is a subtraction, a *difference*, between the current position of the enemy target—observation—and the previously predicted position of the enemy target for the same time—forecast. This difference, between which location was anticipated one time step earlier and the current location of the target, is used to calculate the new forecast of the enemy's location for the next time step. The calculation's output becomes its input in the next iteration.

In the more ubiquitous example of negative feedback, the thermostat, the programmed or desired temperature set at the thermostat is compared to the actual measured temperature of the room by the thermostat. Mechanically and electronically, the thermostat's components hold the two inputs in a calculable relationship that determines the state of the heating apparatus. A stability, albeit a dynamic one, is reached through the *reduction of difference* between the observed state and the desired one. When the room temperature is lower than the programmed temperature, the heating mechanism activates. As the room heats, it reaches the desired temperature at the thermostat and the heating mechanism switches off. However, the room continues increasing in temperature as

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[91] Peter Galison, "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision" *Critical Inquiry* 21, no. 1 (1994): 228–66.

convection distributes heat more evenly through the room, and the heating mechanism residually heats the room as it too continues to cool. The desired temperature is overshot somewhat. Eventually, with the heat off, the room loses sufficient heat until the temperature at the thermostat falls below the desired temperature. The heating mechanism is once again engaged, and the room temperature continues to fall as the heating mechanism and, thus, the room, begin warming once again.

N. Katherine Hayles summarizes this cybernetic perspective.

> Wiener's assumptions, as we have seen, were rooted in a probabilistic worldview. He realized that one of the subtle implications of this view is that messages are constituted, measured, and communicated not as things-in-themselves but as relational differences between elements in a field. Communication is about relation, not essence.[92]

This negative feedback model is what made Wiener's cybernetics so powerful, and ushered in a new perspective on system stability. Stability is fundamentally a dynamic process predicated on the communication of negative feedback. Negative feedback is a stabilizing, corrective force. Room temperature is not the static holding of a consistent temperature, but a dynamic relationship between measured and desired states.

2.4.2 Luhmann's Systems Theory

Luhmann expands on this way of thinking, asking: What makes this cybernetic model comprehensible? How is it observed? Systems theory approaches these questions "starting with structures of meaning that are more deeply seated—structures which make Cybernetics possible in the first place."[93]

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[92] Hayles, *Posthuman*, 91.
[93] Luhmann and Schorr, *System of Education*, 45.

Using Luhmann's framework, the process of observation becomes central to understanding the system. Observing or measuring the room temperature is necessary for the functioning thermostat, as explored above, as it is information needed to target the desired temperature. But there is more to observation than simply providing a dataset for calculation. Because although the thermostat is indeed initiating a real effect on temperature, the understanding that holds the thermostat within this feedback network exists in the mind of an observer. Someone designed, manufactured, installed, programmed, and used the thermostat to engage its function. The "system" taken semiotically, then, enables cognition. The thermostat materially functions, but ones explanatory framework for understanding its function is psychic. A question changes from: "How does the thermostat obtain information about its environment?" to: "How does it happen that the thermostat has the structure that permits it to operate adequately in the medium in which it exists?" The system of the thermostat, then, grows to include an observer who witnesses the functioning of the thermostat, and, perhaps, intervenes in or contemplates its function. In this model, there are no inputs or outputs per se—nothing enters or leaves the system—as a system functions autopoietically; the system contains the means for its own reproduction. So what were once considered inputs or outputs in cybernetics are now understood to be part of the system. "No system can operate outside its own boundaries."[94] Systems have attained *operational closure*. A system is stable because it makes and remakes itself out of itself. And while the components of a system may change, expand, or shrink, this flexibility and dynamism enables a system to endure. So what is the thermostat's system? It is the negative feedback that

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[94] Niklas Luhmann, "On the Scientific Context of the Concept of Communication" *Social Science Information* 35, no. 2 (1996): 265.

undergirds the thermostat's function, yes, but it is also the embodied sensations of an observer in the room who feels the temperature of the air and their skin, who reads and adjusts the dial to achieve a thermal goal, and who sustains the functioning thermostat through these interactions. Further, the system, depending on the thermostat in question, likewise contains the household wiring, the power grid or fuel distribution networks, the laws of thermodynamics, the clothing and textile industries, building codes, and so forth. As advancements and setbacks occur in thermostat technology, energy policy, and construction practices, the system of thermostats likewise changes to continue enabling a world in which one can adjust the room temperature to one's desire via the thermostat.

2.4.3 Observation: distinction and indication

The observed observer denotes the "second-order" element of second-order cybernetics. Observation, due to its cognitive nature, produces the system. The system is observable because it is comprehensible to the observer. Further, "no observer can avoid being observed" themselves.[95] Observation is an empirical operation that changes the system from which it arises. So each and every observation is also an observable operation and comprises some aspect of the system it observes. The system requires an observer to exist, and, in turn, this observer is observed (sometimes by themselves, sometimes by another).

How does observation occur? For Luhmann, observation is a paradoxical operation.[96] Observation simultaneously requires distinguishing (one thing from another) and indicating (one thing over another). When an observer observes, they

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[95] Niklas Luhmann, "The Cognitive Program of Constructivism and a Reality that Remains Unknown," in *Selforganization: Portrait of a Scientific Revolution*, eds. Wolfgang Krohn, Günter Kuüppers, and Helga Nowotny (Dordrecht: Springer Science and Business Media, 1990): 77.
[96] Luhmann, "Scientific Context Communication," 257.

not only semiotically distinguish the object of observation from other potential objects, but they also indicate or determine the focus of this distinction. In other words, the distinction implies a selection. To isolate *A* from not-*A*, is to choose *A* over not-*A* as the focus of observation. One cannot indicate not-*A* over *A* since it is *A* that is distinguished. Conversely, one can, in theory, distinguish not-*A* from *A* (since the distinction functions diametrically) but no observation of not-*A* is possible as *A* is indicated over not-*A*. Observing something requires both distinguishing something *from* not-something and indicating something *over* not-something. In systems theory, it is the system that is indicated over the environment. Reflection chooses a system reference, assuming that things that are not part of the environment can be managed.[97] These "things" construe the system: a unity of operations under control. Thus, observation is a duality that functions as unity: both distinguishing and indicating. But, and herein lies the paradox, observation necessitates a further distinction, one between distinguishing and indicating themselves, a distinction that repeats in itself. "One has to postulate instead: Everything issuing from this process of a transformation of limitations into conditions for the increase of complexity is, for the system in question, knowledge."[98] An analysis in this vein may appear trivial or redundant, but it enables a nuanced epistemological and ontological approach. Centering the observer as the source of observation, and thus knowledge, in such a fashion manages both the inherent limits of epistemological claims arising from a system, and the conditions of possibility generated by the system.

[97] Luhmann and Schorr, *System of Education*, 378.
[98] Luhmann, "Cognitive Program," 77.

2.4.4 Functional differentiation

Luhmann and Schorr introduce the history of the system of education through its functional differentiation. In the context of 18th-century Germany, they explain how education became a subsystem of society and how society made use of the education system. “It became increasingly plausible to imagine the future as being open to the influence of progress and, therefore, to think of that it is possible to improve upon or even eliminate the things that [exist] in the present.”[99] The existence of this education system brought with it potential for social transformation along with its concepts of learning and improvement. Education became functionally differentiated from the system of society. The functional differentiation of subsystems within the social system is the mechanism by which subsystems gain sensitivity to particular happenings.

> Through its differentiation (from other systems), the system of education becomes more dependent on ideas and more dependent on organization than it previously was in regard to areas that it has chosen as being sensitive and their relation to the social environment; at the same time, it becomes much more independent in regards to much of what happens otherwise.[100]

Random events in the environment are increasingly met with indifference by the differentiated subsystem.[101] A functionally differentiated system does not care what happens outside of itself.

The “function” part of functional differentiation merely concerns a subsystem’s function in relation to the social system as a whole.[102] The education system can play a pivotal role in functional differentiation, as it is used by other subsystems of society for their orientation. If a subsystem gives its primary function to

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[99] Luhmann and Schorr, *System of Education*, 68.
[100] Luhmann and Schorr, *System of Education*, 20.
[101] Luhmann and Schorr, *System of Education*, 20.
[102] Luhmann and Schorr, *System of Education*, 42.

education, then the subsystem emerges as connected to and under the influence of larger society.[103] The subsystem's own functional differentiation is recognized by the system of society through its orientation via the education subsystem. Education is one way society is granted access to subsystems, to induce change to society or to that subsystem itself. In turn, subsystems secure their function.

The system of education carries with it a historic-temporal understanding of perfection, "the perfection or completion of human being can be proclaimed as a guiding formula for the differentiation of the system of education (from other systems)."[104] Education facilitates the perfection of humans as well as other functionally differentiated subsystems, including itself. And since the education system is likewise under improvement, it recognizes that learning in the future will be different. The all-around education idea (*Bildungsidee*) "anticipates the learning for future learning."[105]

The ability to change society is assumed to proceed from its current structure. Any process of restructuring the social system toward functional differentiation relies on the connections between proceeding structures; society cannot be "started from scratch."[106] Improvement, however, toward an idealized perfection is possible. Public education in democratic societies is conventionally understood as a poverty reduction measure. Access to education, independent of context, can enable any individual to change the circumstances of their existence. Public education's counterpart, education in the home, is unfavourable as it reinforces class structure.[107] Presumably, parents can only teach what they know to their

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[103] Luhmann and Schorr, *System of Education*, 42.
[104] Luhmann and Schorr, *System of Education*, 71–72.
[105] Luhmann and Schorr, *System of Education*, 70.
[106] Luhmann and Schorr, *System of Education*, 115–16.
[107] Luhmann and Schorr, *System of Education*, 271.

children. All-around education (*Bildung*), which became a dominant force within education in the 18th century, is geared toward individuality and individual improvement rather than scholarship.[108] However, education limits potential improvements, both socially and individually, through its own organization whereby dogma and rigidity supersede responses to the needs of society.[109]

This willingness to change determines one's ability to learn.[110] And the ability to learn is necessary for education to happen, so education depends on students' willingness to change. Framed as such, pupils' abilities to learn are not simply the output of education, providing society with individuals who know how to learn, but are rather the very premise of education itself.[111] The ability to learn, through continual use in the performance of education, intensifies. "In this way, the function is not a present that will be in effect in the future, but [a] future that is always present. Learning learns itself."[112] Educators are responsible for assuming and generating the ability of students to exert themselves.[113] The pupil's future is the educator's present.[114] The educator has already demonstrated an ability to learn by learning the material—the future state of the pupil if they too put effort into engaging with the material.

2.4.5 System and environment

"Reality is what one does not perceive when one perceives it."[115] A contradiction, no? With this rather simple statement, Luhmann brings together both the major

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[108] Luhmann and Schorr, *System of Education*, 271.
[109] Luhmann and Schorr, *System of Education*, 239–40.
[110] Luhmann and Schorr, *System of Education*, 98.
[111] Luhmann and Schorr, *System of Education*, 98.
[112] Luhmann and Schorr, *System of Education*, 98.
[113] Luhmann and Schorr, *System of Education*, 172–73.
[114] Luhmann and Schorr, *System of Education*, 247.
[115] Luhmann, "Cognitive Program," 76.

thesis of his systems theory, and the inherent limitations to systems thinking generally. When systems are used to explain phenomena from a perspective of holism or complexity, they are used to capture or represent reality. They reduce reality. Reflection produces self-simplification.[116] Only a misunderstanding of complexity would attempt to capture all elements and relations of a system. "The dynamics of an arbitrary complex system will result in a simplified structuring of that complexity."[117]

The advent of systems thinking has typically been understood as an antidote to modernity, as a way to truly (or more truly) understand reality. However, thinking the system still relies on the paradoxical duality-as-unity operation of observation. The distinction that repeats in itself—the distinction between distinguishing and indicating—is apparent when one designates a system from everything outside of the system, what Luhmann calls "the environment." So when one outlines a system to explain some phenomenon, some aspect of reality, one simultaneously enrols oneself into the system. If a system must contain all the components to reproduce itself, it then contains the observer who observes the system, who connects all of the pieces to mentally hold the system together. Distinguishing the system from the environment and indicating the system over the environment in the same unitary operation constitutes the cognitive process of observing the system and, therefore, fails to perceive reality as it is. One "perceives" reality through the system, but has left aspects of it behind, imperceptible in the environment.

Distinctions are instruments of cognition.[118] And each observation, which requires a distinction, likewise distinguishes a "blind spot": the environment within which

[116] Luhmann and Schorr, *System of Education*, 378–79.
[117] Luhmann and Schorr, *System of Education*, 378–79.
[118] Luhmann, "Cognitive Program," 76.

a system is contained, the imperceptible reality described above. This distinction employed in the moment of observation, this blind spot of observation, is a guarantee of a world.[119] How is it, then, that a cognitive function of attempting to observe reality determines reality? Because the blind spot of cognition establishes a connection with the reality of the external world.[120] It may prove impossible for one to truly perceive reality, but, through observation, by distinguishing and indicating a cognitive system from and above the environment in which it is contained, a relationship with reality is constructed. Precisely because it remains unobserved or unobservable, reality continues. But that which is cognitively enrolled into the system, including the observed observer, likewise continues autopoietically. In tandem and in perpetuity, then, two worlds—the system and the environment, or an internal reality and an external reality—are dynamically reshaped through observation. Only one, though, enables knowledge for and action from those who observe: the system.

Although Luhmann is critical of where the system in systems theory is located, centering its ontology in ones subjective mind rather than as an out-there perceptible reality, he does concede that “highly developed cognitive systems can [...] make prognoses.”[121] This epistemological strength is in turn limited by an imagined distinction within the system: that between past and future. While the time-step, the incremental flux from current to future state, is essential for the iterative calculus of cybernetics, the computational models of system dynamics, and Luhmann’s systems theory, it necessitates an unobservable future and a knowable past. Systems bypass the impossibility of seeing the future by

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[119] Luhmann, “Cognitive Program,” 70.
[120] Luhmann, “Cognitive Program,” 76.
[121] Luhmann, “Cognitive Program,” 71.

imagining it. One may make forecasts, which is not analogous to perceiving the future.

> Presumably, prognosis has to be understood as a product of our own imagination that can be evaluated by the memory, that is, as the creation of an excess of individual possibilities that is then offered up for selection according to self-constructed criteria of "suitability."[122]

But, of course, this characteristic makes systems resilient as their prognoses mitigate risks, risks that originate from, and give back to, the system. And because of this moment-like existence, caught between past and present, the events that anchor cognitive systems do not repeat but are rather replaced by other events in time.[123] Events communicate to other events. So the effects of an event may still be perceptible, or an event may appear cyclical, even stable or predictable. But there is no repetition, only substitution, a perpetual deferral. The autopoietic reproduction of the system, adjusting to its own perturbations, its own observations, attains a dynamic stability through time.[124]

2.4.6 ST + STS

Luhmann's systems theory is largely uncited in science and technology studies. Outside of the collection *Selforganization*, where Luhmann appears alongside the likes of Katherine Hayles and Helga Nowotny, I have only found one paper that deliberately attempts to reconcile Luhmann's systems theory with science and technology studies, summarized below.[125] While it is difficult to say whether the discipline has deliberately remained ignorant of Luhamnn's work, the citational

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[122] Luhmann, "Cognitive Program," 71.
[123] Luhmann, "Cognitive Program," 70.
[124] Luhmann, "Cognitive Program," 71.
[125] Klaus Taschwer, "Science as system vs. science as practice: Luhmann's sociology of science and recent approaches in science and technology studies (STS)—a fragmentary confrontation," *Social Science Information* 35, no. 2 (1996): 215–232.

politics go both ways as Luhmann fails to mention STS scholars who contemporaneously theorized paradigm shifts, large technological systems, actor-networks, and cyborgs during a similar time period.

Luhmann did write about science, albeit, briefly, identifying it as a subsystem of society. Addressing the idea of how theoretical change within a system is itself indicative of far-reaching structural change, Luhmann and Schorr provide examples of turning points that do not affect system identity.[126] The political system, they say, was significantly altered during the French Revolution. The system of economics was similarly revolutionized by Adam Smith and John Maynard Keynes. In these cases though, despite ground-breaking changes in how these systems were respectively perceived, the system identity remained consistent. Politics was still politics. Economics was still economics. Luhmann and Schorr include science here, citing Immanuel Kant and Karl Popper as such revolutionary figures in the system of science who preserved its system identity.[127] I found no other works that touched any other academic investigations adjacent to science and technology studies (i.e. Merton, Kuhn). Luhmann devoted entire works to explore the social subsystems of law, religion, and art,[128] but rarely explored science or technology with any depth.

Despite these aversions, when Luhmann does address some specifics of the scientific discipline, his thinking is not too far afield from STS scholarship.

> A society that increasingly differentiates its most important sub-systems in relation to specific functions intensifies to a highly improbable degree its cognitive output in the area of science. If one then reflects on this situation, one arrives at theories that

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[126] Luhmann and Schorr, *System of Education*, 366.
[127] Luhmann and Schorr, *System of Education*, 366.
[128] Niklas Luhmann, *Law as a Social System*, trans. Klaus A. Ziegert (Oxford: Oxford University Press, 2004). Niklas Luhmann, *A Systems Theory of Religion*, trans. David A. Brenner and Adrian Hermann (Stanford, CA: Stanford University Press, 2013). Niklas Luhmann, *Art as a Social System*, trans. Eva M. Knodt (Stanford, CA: Stanford University Press, 2000).

> themselves seem improbable. For this reason, epistemology cannot provide a foundation for the sciences. It cannot offer basic principles, arguments or even certainty. It can no longer be understood as a theory of the founding of knowledge. The opposite is true: it analyzes the uncertainty of knowledge and gives reasons for it. It therefore should come as no surprise that no theory of knowledge today can attain the degree of certainty to be found in quantum physics or biochemistry. It is perhaps not the least important function of constructivist epistemology to make society irritatingly aware of the fact that it produces science.[129]

Certainly his framing is more simplified than many in STS would have it, but Luhmann does reach a similar conclusion that many in the field have: society produces science.

2.4.6.1 "Science as a system vs. science as practice"

Klaus Taschwer directly compared Luhmann's systems theory to general STS approaches, and noted three major similarities. First, both Luhmann and STS scholars abandon scientists as the basic units of analysis via a semiotic or linguistic turn, although Luhmann focuses on communication and STS scholars decenter the social.[130] Second, both approaches are constructivist in nature: Luhmann is a cognitive constructivist while STS scholars are empirical constructivists.[131] And third, both deal with integrated reflexive loops: Luhmann focuses on the paradox of observation and unavoidable blind spots while STS scholars document inconsistencies of "science in action."[132]

Despite these similar ambits, there are some fundamental distinctions between Luhmann's analysis of science and that of established STS. Taschwer highlights two key differences. First, Luhmann frames science as a closed autopoietic system whereas science in STS is framed as a "seamless web."[133] Luhmann

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[129] Luhmann, "Cognitive Program," 81.
[130] Taschwer, "Science as system," 221.
[131] Taschwer, "Science as system," 221.
[132] Taschwer, "Science as system," 222.
[133] Taschwer, "Science as system," 223.

argues for a clear distinction between science and non-science, cognitively and institutionally, whereas STS has made this boundary fluid. Luhmann's systems theory requires this demarcation otherwise science could not be conceived as an autopoietic system.[134] So while Luhmann's approach to science may appear less open, flexible, or contingent about what science *is* or what science *may be*, the boundary between the system and environment is a necessary precondition for a systems analysis.

The second difference noted by Taschwer is that, for Luhmann, theory is central to science as it anchors the cognitive system. In STS, scientific theory is usually subordinate to scientific practice, to the material-semiotic network of actions that comprise knowledge construction.[135] Luhmann's systems theory relies on the resilience of cognitive systems to respond to perturbations, to achieve dynamic stability and operational closure. Since Thomas Kuhn's *The Structure of Scientific Revolutions*, STS has generally accepted that theories are limited and slowly replaced through paradigm shifts after sufficient evidence suggests that new theoretical foundations are required.[136] A Luhmannian approach to these paradigm shifts would ask how these "outside" perturbations are either subsumed within the cognitive theoretical frame of science, or simply ignored. Luhmann's systems theory presumes, from the outset, that the field of play is flexible, that what appears to constitute the system will invariably change. There are no epistemological controversies in science, simply a cognitive system that adjusts to new information.

[134] Taschwer, "Science as system," 223.
[135] Taschwer, "Science as system," 225.
[136] Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962).

Here, I would inject another distinction worth exploring in detail. Taschwer identified Luhmann's systems theory as cognitive constructivist where STS is empirical constructivist, but did not elaborate on the significance of this difference. Luhmann relies on a type of sociological reductionism that builds social systems from individual cognitive systems; systems emerge from the observed observer and the process of observation. And while Luhmann's own analysis of the system of education begins within the context of 18^{th}-century German education, his analysis still relies on the specific observations of individual cognitive systems, to say nothing of other relevant actants. My question is: Why not begin with collective systems? STS scholars have shown the value in conceptualizing cognition and human subjectivity as distributed and relational processes. If systems are indeed as resistant to reform as Luhmann and others explain and if cybernetics and systems theory are supposed to emphasize relationality between elements within a field, then perhaps there is more to understanding the system than simply how it is cognized at an individual level. I attempt to balance Luhmann's systems theory in the research that follows with the predilections of my STS training, narrating a cultural system of engineering education that is practiced with express sociopolitical goals.

CHAPTER THREE

METHODS, METHODOLOGIES, AND ENGINEERING EDUCATION CONTEXTS

In this chapter, I detail the methods I used to collect data and the methodologies that supported these methods. Pulling from ethnographic theories and qualitative research methods, I describe my process in developing this research project, its questions, data collection, and the analysis and discussion of the results. I introduce the two organizations I study through the data collection process: Engineers Canada (and their Canadian Engineering Accreditation Board), and the Engineering Change Lab. These introductions serve both as demonstrations of my methods—how field-level data and observations become narratives about systems—and to provide some salient background to these organizations and their contexts before the more detailed analysis in the chapters that follow.

Through these descriptions I foreground engineering education reforms as being driven by diverse interests in what the future of engineering could look like. The approaches used by engineers in these accounts promote transformation, disruption, maybe even revolution. But from a systems theory perspective, they may be better understood as system redundancies, repetitions of system operations echoing down new corridors.

3.1 Engineering cultures

As indicated by the research questions, this research is interested in systems that guide and give meaning to engineering education. And while the institutions and people I study have been separated by time and place, I bring them together in this dissertation ethnographically as a culture-sharing group.[137] "If culture […] is

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[137] John W. Creswell and Cheryl N. Poth, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*, (Thousand Oaks, CA: SAGE Publications, 2018), 276.

mostly caught rather than taught,"[138] what might one learn about culture when studying practices of those who teach or facilitate others to learn? Set on achieving certain policy or social outcomes, engineers envision an improved future where the next generation of engineers will learn and do differently. Which systems influence what is practically and conceptually possible for these desires? Which systems make these desires meaningful and aspirational for engineers? Here, education reforms provides one angle from which to observe education policies and practices from a cultural perspective. Kaiser elaborates: "the problem of generational reproduction—how one generation of scientists and engineers brings up its successors—is always shot through with decision about norms, values, roles, and personae."[139] Engineering education reforms, explored through policies and practices in this dissertation, is one way to examine engineering cultures and their values.

Thematic narrative, organized from a variety of data sources, is used in this dissertation to provide an understanding of this culture-sharing group.[140] My interpretive framework is simultaneously critical and constructivist.

Of course, others have applied this type of systems, or cybernetic, approach to studying culture. Clifford Geertz's credited his cultural turn to cybernetics. Operationalizing a systems approach in anthropology, Geertz posited culture as a system of "control mechanisms."[141] Gregory Bateson likewise shared a cybernetic view of culture, famously coining information as "a difference that makes a

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[138] Creswell and Poth, *Qualitative Inquiry*, 145.
[139] Kaiser, "Introduction," 3.
[140] Creswell and Poth, *Qualitative Inquiry*, 323.
[141] Poornima Paidipaty, "'Tortoises all the way down': Geertz, cybernetics and 'culture' at the end of the Cold War," *Anthropological Theory* 20, no. 1 (2020): 104.

difference."[142] Explaining how this approach can be used in describing culture, Bateson wrote "the subject matter of cybernetics is not events and objects but the information "carried" by events and objects."[143] Luhmann too was inspired by cybernetics, occasionally referring to his systems theory as second-order cybernetics.

Raf Vanderstraeten, a former student of Luhmann, observed potential future directions for Luhmann's theoretical insights in ethnographic education research. Vanderstraeten argues that in the interaction model of education (between parent and child, and teacher and student) educational intentions produce the fundamental selections of education (acceptable and unacceptable behaviour, approval and disapproval, good and wrong).[144] Of course, education does not itself distinguish between what is correct or incorrect knowledge in any given context, but rather "between those who are able to use the distinction and those who are not."[145] Missing from Vanderstraeten's account is the consideration of forces outside of the interaction model—which privileges face-to-face interactions—as the site where education happens. Following Kaiser's prompt, pedagogy not ought to be treated solely "in the narrow sense of classroom teaching techniques" but can include the institutions of training through which recruits become working professionals.[146] Analyzing policies and practices that, from the outset, seek to establish suitable and unsuitable educational inputs and outputs for educators to follow likewise seem to provide fertile ground to

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[142] Gregory Bateson, "Form, Substance and Difference," in *Steps to an Ecology of Mind*, (Northvale, NJ: Jason Aronson, 1987).

[143] Gregory Bateson, "Cybernetic Explanation," in *Steps to an Ecology of Mind*, (Northvale, NJ: Jason Aronson, 1987), 288.

[144] Raf Vanderstaeten, "An Observation of Luhmann's Observation of Education," *European Journal of Social Theory* 6, no. 1 (2003): 139.

[145] Vanderstaeten, "Observation," 140.

[146] Kaiser, "Introduction," 4.

empirically examine Luhmann's theory beyond the classroom. Studying tensions or controversies in education can reveal "prevailing pedagogical presuppositions" as engineers debate over "what should count as "appropriate" or "effective" training."[147] I agree with Vanderstraeten that fundamental selections in the education system are produced through interactions in education. But I contend that one must further consider that educators must learn to educate. Educational policies and practices that seek to transform how pupils learn must transform how teachers learn to teach. From regulated curricula and pedagogical certification to standardized testing and program accreditation, there are many areas that shape the structures that gird the interaction model.

Initiatives that intervene in the education landscape are designed to persist through time and space, to continue to change the system. A cybernetic perspective, however, encourages an analysis of the information over its supposed transmission. Bateson elaborates on the systems perspective to culture.

> Evidently, the nature of "meaning," pattern, redundancy, information and the like depends upon where we sit. In the usual engineers' discussion of a message sent from A to B, it is customary to omit the observer and to say that B received information from A which was measurable in terms of the number of letters transmitted, reduced by such redundancy in the text as might have permitted B to do some guessing. But in a wider universe, i.e., that defined by the point of view of the observer, this no longer appears as a "transmission" of information but rather as a spreading of redundancy. The activities of A and B have combined to make the universe of the observer more predictable, more ordered, and more redundant. We may say that the rules of the "game" played by A and B explain (as "restraints") what would otherwise be a puzzling and improbably coincidence in the observer's universe, namely the conformity between what is written on the two message pads.[148]

So what was once a change or a difference to a culture, for a cultural observer, becomes a stability, or a redundancy of that culture: a repetition. The ethnographic observer, although interested in information, is not interested in the

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[147] Kaiser, "Introduction," 5.
[148] Bateson, "Cybernetic Explanation," 292.

same ways as those who transmit and receive the information. The focus on culture as a system is a focus on that stability or redundancy. The challenge is for the observer to uncover the medium of shared-culture from their own particular vantage point and to convey this understanding forward.

Exploring how engineers understand Canadian engineering education ethnographically, this research project diverges from more conventional sites like classrooms, laboratories, and student groups. Instead it tracks engineering practices in boardrooms, workshops, and policy briefs, revealing broader perspectives on what makes up engineering education beyond post-secondary education at universities. In so doing, I expose some contours of the engineering education system, how it has been segmented, projected, and managed, and how it continues to be re-envisioned. Focusing on certain themes—nationalism, gender/sex, and technological change—this research seeks to explain the systems that guide and give meaning to engineering education change cultures in a Canadian context.

3.2 Qualitative research

Creswell and Poth describe eight phases of conducting qualitative research that I applied to this research project.[149] Figure 2.1 shows these phases in sequential order that I will further describe below.

[149] Creswell and Poth, *Qualitative Inquiry*, 92.

Figure 2.1. Eight phases of qualitative research process.

I have already introduced the interpretive lens of this research project and its assumptions, along with a literature search and my research questions. Next, I will describe the data collection and analysis followed my representation of results, discussion, and validation strategies.

3.2.1 Data sources

While significant attention has been given to understanding engineering education—students learning engineering—as an important site of engineering, less frequently considered is how engineering education policies and practices are likewise practices of engineering culture. Further still, engineering education reforms that aim to orient future engineering practices make important contributions to fulsome accounts of engineering education. These considerations directed my selection of data sources towards engineering organizations and their engineering education policies and practices, including questions about technological change, social responsibilities, and professional autonomies.

The first organization that I selected to study was the Engineering Change Lab. Recently formed and currently active at the time of writing, the ECL is a social lab comprised of engineers from a variety of organizations that are working to steer the future of the engineering profession under their banner of "technological stewardship." When I first learned of the ECL, I was certain it was a group I wanted to study as I was keenly interested in engineers actively reflecting on their profession and how it relates to society. Their workshops also presented excellent opportunities to conduct participant observation and recruit lab members to interview.

While conceiving of this study, I contacted the, at the time, only staff member of the ECL to gauge their interest in my research. I explained that I was interested in engineering education cultures and was planning to conduct an ethnography of engineers. The ECL was receptive, and we communicated frequently as I developed my research proposal. When the necessary approvals were in place, they invited me to the workshops to conduct participant observation.

The second organization was Engineers Canada. As the national engineering body responsible for accrediting undergraduate engineering programs among other responsibilities—directed by the provincial regulators who have legislated authority of the engineering profession—Engineers Canada has a large volume of publicly available documentation stretching back to 1936. I contacted them to inquire about accessing their archived documents and they were encouraging that I would have access to plenty of records, including meeting minutes from their Board of Directors and the Executive Committee along with accompanying materials.

While assessing which materials were available in their archive and what information they might contain, a staff member kindly asked what *specifically* I was looking for. I had no easy answer. I admitted that I was not certain at the time but that I would look at anything they had. They explained that I would be welcome to visit their office and look through their documents in person, and that they could pull some other resources to share with me when I visited. Eventually, I booked a flight to Ottawa to visit their office.

I supplemented the physical records from Engineers Canada with relevant electronic resources like conference websites, parliamentary records, consultant reports, and white papers.

3.2.2 Data collection

I summarize my two streams of data collection in Table 2.1 below.

Table 2.1. Parallel research streams of data collection from the Engineering Change Lab and Engineers Canada

		Engineering Change Lab	Engineers Canada
2016	Fall	First contact ECL, meet to discuss research	First contact Engineers Canada about archive
2017	Summer	Canadian Engineering Education Association (CEEA) Conference	
		ECL Workshop #1	
2018	Fall	ECL Workshop #2	
2019	Spring	ECL Workshop #3, conduct interviews	Document archive, interview staff

	Engineering Change Lab	Engineers Canada
Summer	ECL Workshop #4, conduct interviews	Organize documents

3.2.2.1 Engineering Change Lab

Conducting participant observation and interviews for my dissertation research required ethics approval through my university. York University's Office of Research Ethics approved the research methods described below as they concern my research of the Engineering Change Lab.

I followed the Engineering Change Lab over the period of roughly two years. I attended four two-day workshops over this period to participate in ECL activities, and to observe other participants in the workshop spaces from October 2018 through October 2019. As a participant observer, I participated in workshop activities in good faith while simultaneously observing the interactions, conversations, and reactions of other participants. Since my interests generally aligned with the work of the ECL, I did not feel as though I equivocated in my participation. I did, however, announce my intent to observe before each workshop, which may have affected how participants chose to interact with or around me. That being said, one of the rules of the ECL announced at the beginning of each workshop is that all participants are free to share anything that happens in the workshop space. This rule is limited by the mantra "no attribution without permission" meaning that other participants' words or actions in the workshop should not be attributed to them without their consent. As such, the characters in the vignettes remain anonymous unless they have otherwise provided consent, in which case they are anonymized.

Figure 2.2. An Engineering Change Lab workshop in downtown Vancouver.[150]

I took notes of my observations throughout the workshops, filling over 50 pages of handwriting over two notebooks. At the end of each field day, I typed reflections on my experiences and thoughts of the day, ranging from two to four pages of text.

I further recruited interview participants at the workshops. My sampling was opportunistic: when having a one-on-one conversation with someone who seemed interested in the work of the ECL and my research, I asked for contact information so that we could arrange an interview. I interviewed seven

[150] Arlene Williams, "Technological Stewarship—Engineering leadership to ensure technology makes the world a better place for all," *The Voice of Ontario's Engineers*, December 2018, 16.

participants of the ECL, some were fortunate enough to be done in person and others were completed over virtual platforms. Before starting each interview, I read through a consent form with participants and discussed how I will protect and use their interview data.

For interviews conducted in person, I recorded the interviews on my phone. For interviews conducted over virtual platforms, I recorded the audio channel on my computer. Interviews generally lasted one hour, and I took about two pages of notes during each. Questions focused on their participation in the Engineering Change Lab, the organization they "represented," their relationships with engineering, and their personal careers. I also asked prepared questions about engineering and engineering education more generally.

Further ethnographic data of the Engineering Change Lab I collected included document analysis. Emails, newsletters, websites, slideshows, radio programs, printed workshop materials, and texts on systems thinking and social labs comprised the bulk of data sources for document analysis. I analyzed resources and reference materials circulated and recommended by Engineering Change Lab staff and participants in conjunction with the other ethnographic data and relevant literature.

3.2.2.2 Engineers Canada

I visited Engineers Canada's main office in Ottawa for five days. While visiting their office, I interviewed seven staff members about their different portfolios through Engineers Canada. These conversations served to guide my document selection and analysis, and to better understand how Engineers Canada operates as the unifying national body for engineering in Canada. These discussions were not recorded, although I did take roughly two pages of notes during each conversation.

Figure 2.3. Bound volumes of meeting minutes for CCPE/Engineers Canada Board of Directors and Executive Committee at the Engineers Canada office in Ottawa.

I photographed Engineers Canada's archive of Executive Committee meeting minutes and Board of Directors meeting minutes including appendices and attachments from 1936–2012. While documenting this archive, I resisted the temptation to read through the meeting minutes in any detail while photographing the documents, saving that delight for my desktop computer. I did create a list of seemingly significant diagrams, reports, and appendices that caught my attention, planning to return to them at a later time.

Figure 2.4. Screenshot of the author's computer photo library of meeting minutes.

Staff at Engineers Canada provided me with documentation they thought may be germane to my research outside of the meeting minutes, including contemporary evaluations of engineering education curriculum in Canada, and current diversity and inclusion initiatives. They provided me with electronic records of every CEAB Annual Report from 1975 to 2018. I made copies of these documents to analyze at a later time.

3.2.3 Analysis, representation, discussion, and validation

My analysis centred on themes I expected to encounter through my field notes and journaling, interviews with participants, and the various historical and contemporary documentation. These themes included diversity (gender/sex, race), education reform, ethics, professional autonomies, and social responsibilities. While engaging with the data, other salient themes became clear, notably nationalisms (the state), technological change, systems, and disruptive innovation.

Once I had coalesced the research themes around the specific topics of nationalisms, gender/sex, and technological change, I wrote vignettes of my experiences with the Engineering Change Lab that touched on these topics in interesting or enlightening ways. I reviewed my field notes of these experiences to capture direct quotations, the flow of events, and contextual details. I used my journal entries from those days to provide more fulsome accounts of my personal thoughts and feelings about what had transpired.

In cases where I was seeking information to construct a vignette, I read through my field notes directly, flagging thematic moments that could be combined and used as part of a broader narrative and then developing a vignette as described above.

I typed verbatim transcriptions of the interviews directly from the audio recordings, usually listening to them at one-half or one-quarter speed. I used my interview notes to seek out thematic elements discussed by the interviewees, or the process of transcription itself to identify worthwhile ideas or quotations for presentation and analysis. Transcription excerpts that I selected for this dissertation were edited from the verbatim transcriptions to promote ease of reading while occasionally including some verbatim details to contextualize the interviewee and the subject matter.

Data from Engineers Canada necessitated a somewhat different approach where I built quotations, policies, and motions into narratives by following themes forward and backwards chronologically, tracking specific historical developments through available documentation.

Eventually compiling a satisfying narrative from meeting minutes was not always straightforward. Rarely did speakers provide broad overviews or explanations for certain issues or actions whether directed towards other meeting attendees or in addresses for membership. The quality and type of archival material available changed over the study period, further hampering my attempts to deduce clear narrative lines. The “Report of the President,” a yearly address to membership wrapping up a president’s term that was usually attached in appendix A, typically provided an excellent source of narrative and motivation. However, these letters ceased appearing after 1978. The content of written discussion also changed over this period becoming more professional and obscure, with less frankness, personality, feeling, and humour written in the minutes. By the late 1980s and early 1990s, the appendices largely disappear from the record too. Some years’ minutes have no appendices at all. Others make reference to presentations or reports attached as appendices, but no copies of said documents were physically bound with the minutes. These variances in the archive’s richness over time made it easier for me track developments before 1990, and also provide more colour to the concerns as some characters exhibit clearer intentions and emotions.

Creswell and Poth encourage researchers to consider a deconstructive stance in coding, to note themes relating to desire and power, attending to disruptions, contradictions, and metaphors.[151] Presenting themes in such a way then enables an analysis of “larger units of abstraction.”[152] What information was surprising, conceptually interesting, or unusual? For whom? What are the dominant interpretations? What are the alternatives? These questions guided my analysis.

Here I have tried to represent truthfully the perspectives of participants in the Engineering Change Lab and engineers that sat on boards and committees of engineering organizations.

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[151] Creswell and Poth, *Qualitative Inquiry*, 261.
[152] Creswell and Poth, *Qualitative Inquiry*, 261.

Creswell and Poth emphasize the importance of validation strategies in qualitative research to establish credibility through the triangulation of data sources, methods, and investigators.[153] They explain that a credible study should have at least two forms of validation and provide a number of strategies, three of which are present in my study: reflexivity, prolonged engagement in the field, and collaborating with participants.[154] And while these are certainly important aspects of my research, in particular in the communication of this research project, I prefer Harry Wolcott's approach. Understanding, Wolcott explains, can be more important for ethnography than validation.[155]

3.3 "A flashing red light on the dash"

We have trouble. An indicator light signals that there is something, or some things, wrong with engineering education. What might they be?

I begin with Engineers Canada (then the Canadian Council of Professional Engineers) and a series of reforms of their engineering curricula over two decades. These education policy concerns are followed by a series of vignettes from the Engineering Change Lab and their workshops. Bringing these stories and organizations together reveals consistencies in the systems that guide and give meaning to engineering culture in these specific educational contexts. Regarding the sociocultural megatrends of nationalism, gender/sex, and technoscientific progress, these contexts further elucidate how these systems are sustained and exceeded by engineering cultures.

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[153] Creswell and Poth, *Qualitative Inquiry*, 336.
[154] Creswell and Poth, *Qualitative Inquiry*, 341.
[155] Creswell and Poth, *Qualitative Inquiry*, 337.

3.3.1 Standardizing education: years, accreditation units, and graduate attributes

Ronald C. Biggs, on his way out the door as Chair of the Canadian Engineering Accreditation Board (CEAB), listed his concerns facing the Board in their annual report. He warned of an uncertain future looming over engineering leadership. The year previous had instigated a critical reappraisal of the engineering profession with the publication of "The Future of Engineering Education in Canada," a joint report by the Canadian Council of Professional Engineers (CCPE) and the National Committee of Deans of Engineering and Applied Science (NCDEAS).[156] The world had changed, and engineers needed to take action to catch up. Education would get them there. Ronald Biggs elaborated:

> As during the industrial revolution, it is clear something big is happening, but no one can forecast the nature of the new order that will follow the present chaos. It is clear, however, that the engineering graduates of today must be poised to take an appropriate leadership role in a future likely to be dominated by information and technology. As a consequence, the accreditation process and criteria must be maintained and applied so as to ensure that engineering programs provide academic preparation for these future challenges.[157]

The year was 1993. The information revolution was happening, and engineers wanted to revolutionize their accreditation criteria alongside.

Axel Meisen, of the NCDEAS, and K. F. Williams, of the CCPE, co-chaired the task force that authored "The Future of Engineering Education in Canada." Devised to describe and assess "the current system of engineering education in Canada" this document "identifies the principal issues and problems in Canadian engineering education and the means of addressing them" and recommends actions "so that Canadian engineering education meets Canada's present and

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[156] "The Future of Engineering Education in Canada," Canadian Council of Professional Engineers and National Committee of Deans of Engineering and Applied Science (1992).
[157] "CEAB 1993 Annual Report," Canadian Council of Professional Engineers (1993), 3.

future engineering needs."[158] The context justifying the report hinged on six "major forces" at play in engineering practice: knowledge explosion, competition, globalization, impact of technology, environmental concerns, and infrastructure renewal.

"Never before has knowledge been generated as rapidly as now. New discoveries and ideas are reported and widely disseminated at an unprecedented pace," warned one paragraph.[159] "The time between initial discovery and commercialization is decreased with the result that well-established products are at constant risk of being rapidly replaced by new and superior products," read another.[160] Further, "Canadian engineers must be *leaders* in the generation and use of engineering knowledge for without such leadership the economy will be unable to cope with the rapidly increasing international competition."[161]

These engineers in the early 1990s did not limit their concerns to the knowledge or skill sets of engineers described above. They extended their interests to the unintended impacts of technology saying, "technological changes can not only quickly create new high-quality jobs but also render entire industries obsolete with ensuing severe unemployment."[162] And, "environmental degradation is widely viewed as an example of the injudicious application of technology."[163] This outlook set up the report findings and recommendations to future proof the profession.

> Large sectors of Canada's engineering infrastructure such as roads, bridges, ports, water supply and waste water treatment systems, buildings, electricity transmission, and communications systems were built many years ago and have outlived their design life.

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[158] "Future Engineering Education," 1.
[159] "Future Engineering Education," 2.
[160] "Future Engineering Education," 2.
[161] "Future Engineering Education," 2.
[162] "Future Engineering Education," 3.
[163] "Future Engineering Education," 4.

> Even with regular maintenance, the structures reach a point of major renewal. Such renewal may involve extensive repair or complete reconstruction. In either case, remedial action is costly and, when multiplied by the number of structures in the country, represents a huge financial outlay. The technical, managerial and financial ingenuity required to solve the infrastructure renewal problem will place engineers in leading roles.[164]

The task force chaired by Meisen and Williams appeared as a direct response to a report sent from NCDEAS to the Canadian Engineering Accreditation Board the year previous recommending to "consider alternatives for determining the absolute amount of instruction in a program."[165] What had been used up until that point in the accreditation criteria, what NCDEAS wanted alternatives for, was how engineering education curricula were measured, and thus assessed.

In his annual message, H.A. Rod de Paiva, CEAB Chair for 1992, said: "this will be an important change and the CEAB will have to be assured that the benefits of such a change result in an improvement to both the accreditation process and engineering education."[166] Before closing, de Paiva acknowledged "the recent report of the CCPE/NCDEAS on the Future of Engineering Education in Canada has some important implications for accreditation."[167] Further, the CEAB policies and procedures committee wrote in the same annual report that "the current *method of analyzing curriculum content* for accreditation purposes measures relative amounts of instruction, not absolute amounts."[168] The committee had conducted a study on "the length of year" at engineering schools across the country, sharing their results with NCDEAS and agreeing to "establish a task force to examine alternatives to the current measuring system."[169]

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[164] "Future Engineering Education," 4
[165] "CEAB 1990/1991 Annual Report," CCPE (1992), 10.
[166] "CEAB 1992 Annual Report," CCPE (1992), 5.
[167] "CEAB 1992 Annual Report," CCPE (1992), 6.
[168] "CEAB 1992 Annual Report," CCPE (1992), 7.
[169] "CEAB 1992 Annual Report," CCPE (1992), 7.

The “current measuring system” in 1992, as written under section “2.2 Curriculum Content,” included “relative amounts of instruction.” as such:

> 2.2.1 **Mathematics**: A minimum of one half year of mathematics including appropriate elements of matrix algebra, differential and integral calculus, differential equations, probability, statistics and numerical analysis.
>
> 2.2.2 **Basic Science**: A minimum of one half year of basic (natural) sciences, defined as appropriate elements of physics and chemistry and, where appropriate, elements of life sciences and earth sciences. These subjects are intended to impart an understanding of natural phenomena and relationships through the use of analytical and/or experimental techniques.
>
> 2.2.3 **Engineering Sciences and Engineering Design**: A minimum of two years of a combination of engineering sciences and engineering design. Within this two-year combination, engineering sciences and engineering design must be not less than one half year each. This leaves one year for any combination of engineering sciences and engineering design that may be deemed desirable.[170]

This system of measurement using years, or “half years”—semesters, roughly—to assess the “amount” of curriculum content dates back two decades to 1975, the year of what was then the Canadian Acceditation Board’s (CAB) first annual report. Detailing the components that would help conceptualize the fulsome education of engineering students, the CAB “Terms of Reference” from 1975 included what would eventually become a ubiquitous image in Canadian engineering education: a pie chart representing four years of undergraduate engineering programing divided into curricular slices comprising engineering education: mathematics, basic science, engineering sciences, design and synthesis, humanities and social sciences, and “slack.”

[170] “CEAB 1992 Annual Report,” CCPE (1992), 12–13.

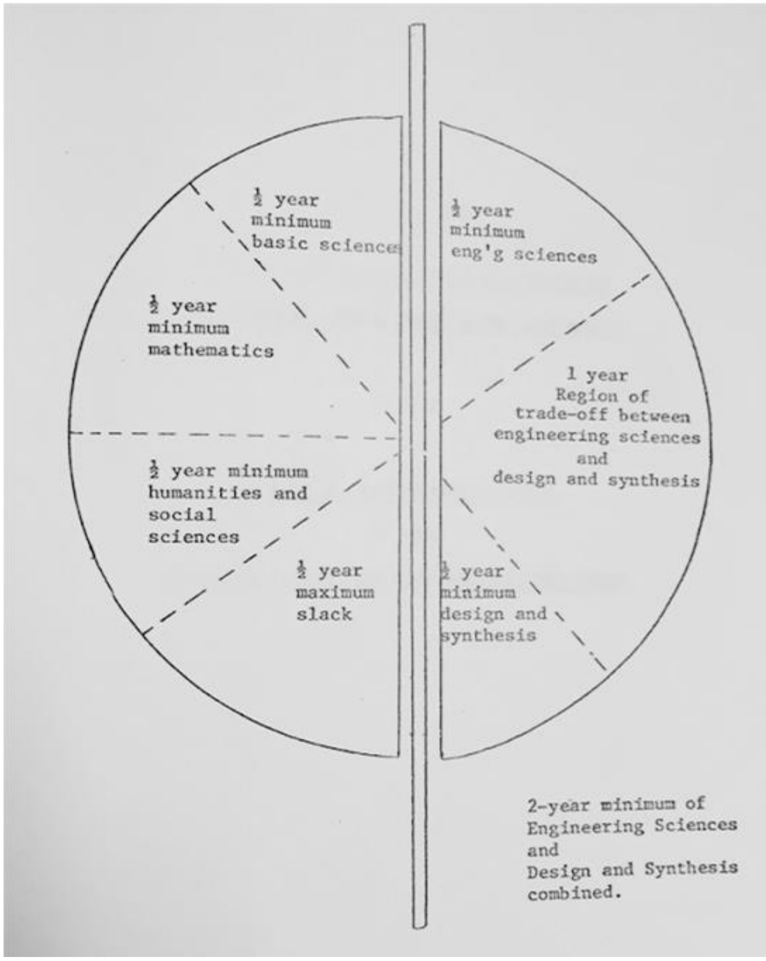

Figure 3.1. "Interpretation of C.A.B. Criteria (Article 5.2.8)."[171]

3.3.1.1 Accreditation units

It was not until 1995 that the new engineering curriculum measurement system was decided. The Task Force on Curriculum Content Analysis presented their proposal to the CEAB, CCPE, and NCDEAS, all of who approved the method to

[171] "Terms of Reference," Appendix 'A,' Minutes of a Regular Meeting of the Board of Directors, November 1975, Appendix I, Engineers Canada Office, Ottawa.

analyze curriculum using absolute amounts of instruction. The new method was implemented for the 1996 accreditation visits the following year.[172]

The method for measuring absolute amounts of instruction developed by the task force was based on units of measurement helpfully titled "accreditation units," adapted from the Carnegie Unit. Section 2.2.1 of the CEAB annual report provides the definition of the newly accepted accreditation units.

2.2.1 **Definition of Accreditation Units (AU)**

a) Accreditation Units (AU) are defined as follows (*hourly basis*) for an activity which is granted academic credit and for which the associated number of hours corresponds to the actual contact time of that activity :

- one hour of lecture (corresponding to 50 minutes of activity) = 1 AU
- one hour of laboratory or tutorial work = 0.5 AU

This definition is applicable to most lectures and periods of laboratory or tutorial work. Classes of other than the nominal 50-minute duration are treated proportionally.

2.2.1 **Définition des Unités d'Accréditation (UA)**

a) On définit comme suit les Unités d'Accréditation (UA) (*base horaire*) pour toute activité menant à des crédits académiques et pour laquelle le nombre associé d'heures correspond au temps réel de contact pour cette activité:

- une heure d'enseignement (correspondant à 50 minutes d'activité) = 1 UA
- une heure de laboratoire ou de travail dirigé ("tutorial") = 0,5 UA

Cette définition s'applique à la plupart des cours et des périodes de laboratoire ou de travail dirigé. Les cours d'une durée autre que 50 minutes sont considérés au prorata de cette durée.

Figure 3.2. CEAB's definition of accreditation units.[173]

The accreditation units were designed to be measured on an hourly basis of "contact time" for students completing academic credit activities: lectures, labs, and tutorials. One hour of lecture represented one accreditation unit, and one hour of laboratory or tutorial time represented half of an accreditation unit. Design or research projects that were degree requirements of the university but were not effectively measured using "contact time" were to use an equivalent measure of accreditation units that was "consistent with the above definition."[174] CEAB

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[172] "CEAB 1995 Annual Report," CCPE (1995), 7.
[173] "CEAB 1995 Annual Report," CCPE (1995), 14.
[174] "CEAB 1995 Annual Report," CCPE (1995), 14.

provided an equation to determine this equivalence using a proportionality basis. A factor, *K*, could be calculated for these activities which would then be multiplied by the units defined by the institution for that course to determine the number of accreditation units for that course.[175]

$$K = \frac{\Sigma \text{ AU for all common core and program compulsory courses for which the computation was carried out on an hourly basis}}{\Sigma \text{ units defined by the institution for the same courses}}$$

Figure 3.3. Calculating factor *K* using a proportionality basis for accreditation units.[176]

The analysis then quantified the accreditation units required by each part of the engineering curriculum, abandoning the curricular slices for an absolute metric.

On these changes, CEAB Chair Louise Quesnel wrote:

> CEAB Members are well aware of the dynamic nature of this environment as they work together with the National Council of Deans of Engineering and Applied Sciences to ensure that engineering students reap the benefits of a solid knowledge base, adapted to the needs of the society of which the engineer is a part. The method used to analyze the quantitative data reflecting the contents of teaching programs has been finalized with this in mind.

Quesnel further noted that updating these criteria would require other changes to “raise the profile” of environmental studies and sustainable development.[177] The CCPE Board of Directors similarly registered positive feelings about the new system while acknowledging a desire for another: “the recently adopted

[175] “CEAB 1995 Annual Report,” CCPE (1995), 14–15.
[176] “CEAB 1995 Annual Report,” CCPE (1995), 15.
[177] “CEAB 1995 Annual Report,” CCPE (1995), 4.

Accreditation Unit system introduced by CEAB to analyze the curriculum content is a good example of allowing greater flexibility in the accreditation process" and that "a gradual move to an output measurement system be considered."[178] To assist, the CCPE established a committee to review both the CEAB criteria and the prerequisites for practicing engineering.[179] Their first task as part of their review of engineering education accreditation and professional requirements was to imagine their desired outcome. So they developed their profile of "the engineer of the 21st century."[180]

3.3.1.2 Graduate attributes

More than a decade later, an output measurement system was implemented. In 2008, Engineers Canada added "graduate attributes" to the accreditation process. These 12 attributes became the measurable outcomes of engineering graduates for the CEAB, supplementing the input measures of absolute instruction of curriculum content provided by the earlier accreditation units. At the October 2008 Board of Directors meeting, Dave Ennis presented the "Framework for the Implementation of Outcomes Assessment" and responded to questions and comments from the Board of Directors.[181] The presentation included a schedule for implementing the criteria adopted in May and outlined the outcomes-based assessment system that the Board of Directors had requested. The graduate attributes are listed in the 2008 Accreditation Criteria and Procedures, noting that

> engineering programs are expected to continually improve. There must be processes in place that demonstrate that program outcomes are being assessed in the context of these attributes, and that the results are applied to the further development of the program.[182]

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[178] Minutes Board of Directors' Meeting, November 1996, Engineers Canada Office, Ottawa, 16.
[179] "CEAB 1995 Annual Report," CCPE (1995), 7.
[180] "CEAB 1995 Annual Report," CCPE (1995), 7.
[181] Board of Directors Meeting, October 2008, Engineers Canada Office, Ottawa, 12.
[182] "CEAB Accreditation Criteria and Procedures 2008," Engineers Canada (2008), 12.

A brief description of each attribute then followed:

1. A knowledge base for engineering
2. Problem analysis
3. Investigation
4. Design
5. Use of engineering tools
6. Individual and team work
7. Communication skills
8. Professionalism
9. Impact of engineering on society and the environment
10. Ethics and equity
11. Economics and project management
12. Life-long learning[183]

3.3.1.3 Professional education

Whether in 1992, with the accreditation units, or in 2008, with the graduate attributes, widespread reformation of how engineering education was to be measured, assessed, and redirected across Canada flowed through CCPE/Engineers Canada, from the provincial regulators who make up its Board of Directors toward the universities. Not only did these changes more strictly determine the metrics used by the Canadian Engineering Accreditation Board in approving Canadian university engineering programs, they further outlined how universities should evaluate their own programs internally as they experiment with their unique curricula.

These "constitutional moments" in engineering education had a basis for implementation, a presumed authority and capability to enact desired change.[184] To more fully appreciate the significance of the evolving metrics by which CEAB, and thus CCPE/Engineers Canada, prescribed the curricular content of

183 "CEAB 2008," 12–13.
184 Caron et al., "Navigating a Constitutional Moment."

engineering education in Canada, it is necessary to investigate how the CAB and CCPE secured the authority to do so in the first place.

J. Rodney Millard's history of engineering professionalization in Canada notes the early 1920s as when the profession became closed across the country. By 1920, all provinces except Ontario, Saskatchewan, and Prince Edward Island had engineering licensing laws.[185] Prior to these developments, the engineering profession had already begun to shift towards greater professionalization, and thus prestige, with the development of university degrees during the late 1800s and early 1900s.[186] University education in engineering altered the register of what had been, up to that point, an apprenticeship-based discipline. Legislation was simply the next step for the engineering profession as engineers had received "neither the renumeration, nor the respect" that they deserved for having developed the natural resources and industries of the country.[187] Eventually all provinces adopted licensing laws and the profession became "closed" across Canada when provinces made registration compulsory.[188]

Applying Luhmann's systems theory to this context, I argue that with the formation and operation of the CAB, Canadian engineering attained *autopoiesis* securing *operational closure* as a functionally differentiated subsystem through accreditation control of engineering education. While, in Millard's account, engineering had been a closed profession in Canada since the 1920s, this fact rests on engineering legislation having been passed in each province. *Canadian* engineering, I argue, only comes into existence as a system with the creation and successful operation of the Canadian Accreditation Board as the first nationally

[185] Millard, *Master Spirit*, 140.
[186] Millard, *Master Spirit*, 8–9.
[187] Millard, *Master Spirit*, 122.
[188] Millard, *Master Spirit*, 143–44.

unifying initiative of Canadian engineering and continued through their reevaluations of engineering curricula. The CAB made Canadian engineering through standardizing Canadian engineering education. And this standardization, this accreditation of engineering education programs, represented the beginning of *autopoiesis* for the Canadian engineering system as the system generates itself by producing future Canadian engineers through its education programs. I will return to the history of the Canadian Engineering Accreditation Board (and the Canadian Accreditation Board) in greater detail in the next chapter.

But first, what do more contemporary concerns on Canadian engineering education look like?

3.3.2 Another workshop

Picture yourself in downtown Vancouver. You are in a large second-floor conference room with windows overlooking the busy rain-darkened street. Pedestrians, cyclists, and cars complete their morning commutes, kicking up the odd brown leaf from the concrete and asphalt below you. Engines rev, accelerating politely around corners. The low rumble of buses and trucks permeates the glass wall. The city hums awake. Adjacent office buildings reflect sunbeams into your eyes. Autumn is emerging in the Pacific Northwest: yellowing trees, rain bursts, and shadowy, dappled light. But if you stand next to a palm tree on the shore in the full afternoon sun, your skin stretches easily back to summer: beach volleyball bumps, gull cries, and ocean air. Instead, you taste the HVAC atmosphere, paper cup coffee, and fruit plate. Fluorescent lights likewise reflect off the windows from the fixtures overhead. A slideshow glows patiently on two screens along a perpendicular wall behind you, suspending two white rectangular spectres above the streetscape. Pressing closer to the glass, you peer sideways down the street trying to glimpse the mountains or the ocean, seeing neither. In business casual attire you turn and join the others milling about the catering, waiting for the workshop to begin.

Participants have flown in from across Canada, and hosts welcome them as they enter the room, directing them to refreshments and their name tag, and encouraging them to mingle. It's just past 8 a.m. on a Thursday morning, yet nearly all of the 40 people happily chat, introducing themselves to new acquaintances or continuing earlier conversations with colleagues. Facilitators play matchmaker, bringing stragglers and introverts into the fold. The group seems energized and eager for the workshop. A few have already claimed seats. The hubbub grows as the final guests make their way down the glass corridor from the elevators. Without much delay, Charles invites the crowd to take their seats. You sit amid a wide semicircle of black office chairs three rows deep, facing the screens.

In rolled shirtsleeves, a black sweater, and slacks, Charles stands before the screens and welcomes everyone. The slide changes, black text on a white background displays:

> We would like to begin by acknowledging that the land on which we gather is the unceded territory of the Coast Salish Peoples, including the territories of the xʷməθkwəy̓əm (Musqueam), Skwxwú7mesh (Squamish), and Səl̓ílwətaʔ/Selilwitulh (Tsleil-Waututh) Nations.

Charles reads the territory acknowledgement. An aerial photo of downtown Vancouver appears on the screens: a blue-green gradient, the peninsula of office towers and condos pushes into the background surrounded by ocean and the dark mountains silhouetted along the top. Charles casually shares his previous history living here in Vancouver, how he used to enjoy connecting with the land, hiking in the mountains and kayaking in the ocean, but asks us to consider what this land used to look like before colonization and what connecting with the land might mean today. "What would the land look like without us? What would the land look like without our technology?” he questions, delicately segueing into the outline of the workshop.

Figure 3.4 A facilitator introduces the workshop.[189]

This workshop is the Engineering Change Lab’s pilot workshop for “strategic doing.” You are attending with a cohort—an engineering faculty, an engineering company, an engineering student group—and your cohort of between three and six members will be *doing* something *strategically*. Charles explains. You are about to be introduced to a new paradigm. You are going to use this paradigm to direct some act as an organization. You are going to *do* this act, informed by a *strategy* developed within the paradigm. You learn that the process for introducing the paradigm and conceptualizing your action is grounded in the work of systems thinkers like Donella Meadows. Charles continues describing paradigms, referencing Thomas Kuhn and his work on paradigm shifts, where a new way of thinking supplants an earlier one. Charles marries paradigms with systems. A paradigm shift induces a change in the system, he says. Since systems are nested, a changed system picks up momentum and, in turn, changes other

[189] Williams, “Technological Stewarship,” 17.

systems. To illustrate the point, Charles narrates the environmental science movement of the 1960s and how Rachel Carson's *Silent Spring* created the path for others to follow, triggering a paradigm shift of environmentalism.

Over the next two days, this conference room of an engineering and earth sciences consulting firm is the space of the Engineering Change Lab. This group of people is simultaneously a result and a feed of the Lab: assembling a unique and diverse contingent of engineers to participate in the workshop setting, and providing wide-ranging input on the Lab's operation and direction from both new and seasoned participants. Here is where the majority of the ever-fluid membership interacts, and the ECL advances its agenda, at least for the time being. When social innovation types discuss change labs, this situation is what they mean: 40 people representing diverse interests and organizations gathered to work through common challenges and uncommon perspectives.

The Engineering Change Lab website recommends a compilation of two resources on systems. One text by Donella Meadows—of *The Limits to Growth* and the Club of Rome fame—contains the following list of "Places to Intervene in a System (in increasing order of effectiveness)."

12. Constants, parameters, numbers (such as subsidies, taxes, standards)
11. The sizes of buffers and other stabilizing stocks, relative to their flows
10. The structure of material stocks and flows (such as transport networks, population age structures)
9. The lengths of delays, relative to the rate of system change
8. The strength of negative feedback loops, relative to the impacts they are trying to correct against
7. The gain around driving positive feedback loops
6. The structure of information flows (who does and does not have access to what kinds of information)
5. The rules of the system (such as incentives, punishments, constraints)
4. The power to add, change, evolve, or self-organize system structure
3. The goals of the system
2. The mindset or paradigm out of which the system—its goals, structure, rules, delays

parameters—arises

1. The power to transcend paradigms[190]

Many other systems thinkers and theorists have foregrounded Meadows' point: system change depends on how one first views the system in question, and one's ability to imagine the system being otherwise. If one can escape the dominant paradigm of a particular system, then one can effectively change the system.

3.3.2.1 Technological optimism

Returning to the Vancouver conference room that Thursday morning, participants are introducing themselves by responding to a prompt: "What is the default trajectory of humanity's relationship with technology?" Charles asks us to place ourselves on a spectrum from one (technological pessimist) to ten (technological optimist). For those yet unfamiliar with how one might critically examine this sort of relationship with technology, Charles offers some cultural touchstones to elucidate. Technological pessimism is exemplified by films like *Terminator* or the series *Black Mirror*—technology run amok, beyond human control and working to the detriment of humanity—whereas optimists see technology deployed more beneficially, like in *Star Trek* or *Black Panther*. The setup is intentionally superficial, a convenient primer of the workshop theme: technological stewardship. I am a bit surprised to be the first person called on to respond, introducing myself as someone who is there to observe and research the workshop, to study them. I also had not really thought through the exercise and do not readily see myself holding a particular position on the pessimist-optimist axis; I am hung up by the word "default" as a way to describe human behaviour but before I entertain the notion of exploring that any further in front of the group, I

[190] Donella Meadows, "Leverage Points: Places to Intervene in a System," The Sustainability Institute (1999): 3.

interrupt my own thoughts. “I’m a five,” I say, neutrally eschewing the premise, and offering no further explanation. On a piece of flipchart paper taped to the wall, Charles colours a large fuchsia dot above the middle of the line and moves on to my neighbour.

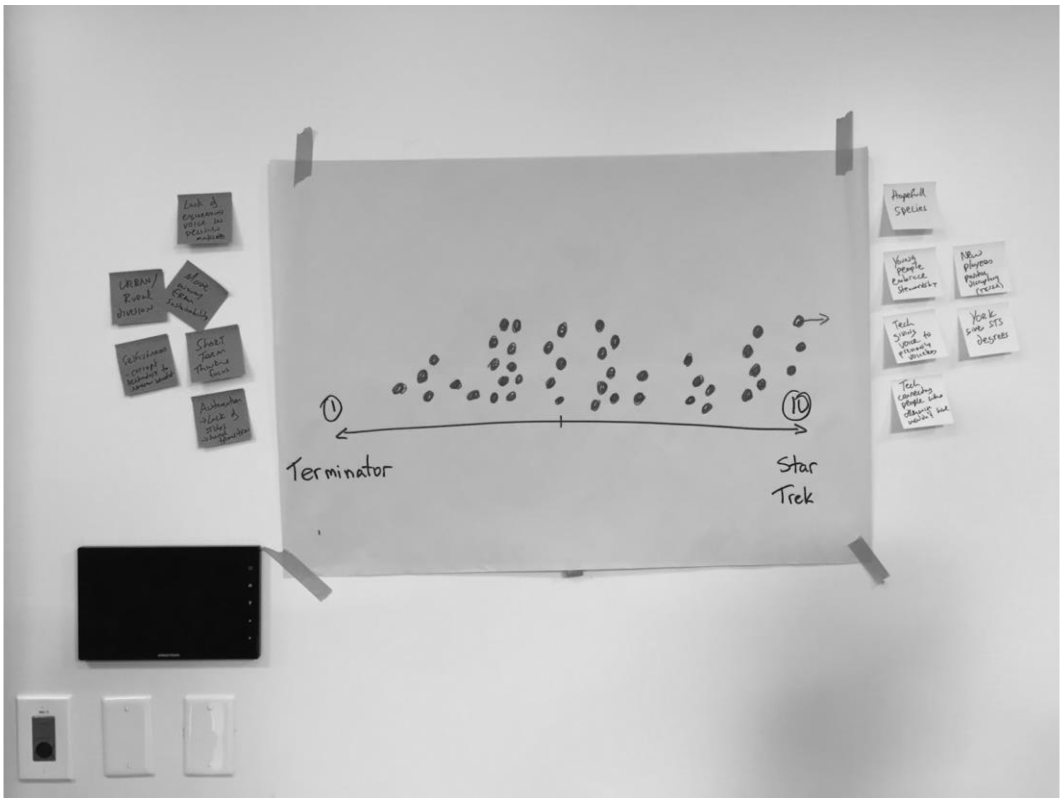

Figure 3.5. What is the default trajectory of humanity’s relationship with technology?

As our responses are added to the chart, participants quip or justify their place on the axis. “I want to be a 10, but I’m a 4.” says one. Others share this sentiment, seeing the simultaneous promise technology can offer while acknowledging some contemporary concerns about new tech. Another participant, joining from the US, smiles and remarks slyly “My trajectory moved up coming across the border. So I’m at a 3.” The joke lands and the group laughs; Donald Trump is currently President of the United States and Brett Kavanagh was just sworn in as an

Associate Justice of the Supreme Court on Monday. Introductions move through the rows. The crowd's attention is captured, they are eager to think about and discuss these technological issues.

Colleen takes over facilitation. She introduces herself as a "recovering city planner" and goes over the "group agreements" of the Lab. First, she asks all attendees to be present during the workshop. This means we are to actively listen and participate in good faith. Further, we are to leave the room to use our phone or take calls, even glancing at one's screen can be distracting. The space is to be inclusive, but will also be one that challenges our assumptions. Our interactions should be respectful, but we should be prepared to be uncomfortable or challenged. Colleen explains that we are welcome to share what happens in the workshop outside of the workshop, but that we should keep confidences. So if you want to tweet something another participant said, for example, do not identify the person who said it. "No attribution without permission," Colleen states. At her request, the audience provides a thumbs-up to these agreements.

Fantasies of transformation—for society and for the participants themselves—impend over the workshop. We are about to be changed, and we will leverage this change to improve the world. The promise is compelling, and the group appears to take it seriously. For the duration of the two days, I do not notice anyone texting or scrolling social media on their phone in the workshop. Participants certainly would leave the room to take calls and send emails, or excuse themselves for portions of the workshop. But the mood of the Lab is focused and determined. Attention concentrates on speakers, and the content of their presentation. It is a *work*shop.

Colleen prepares the room for how to think about what is going on. She introduces us to different ways of talking and listening. By carefully considering how we talk and listen in the Lab environment, we can move towards "generative dialogue." Rather than "downloading" or "debating"—ways of talking and listening that reenact past realities—we can enact emerging realities, shown in Figure 3.6.

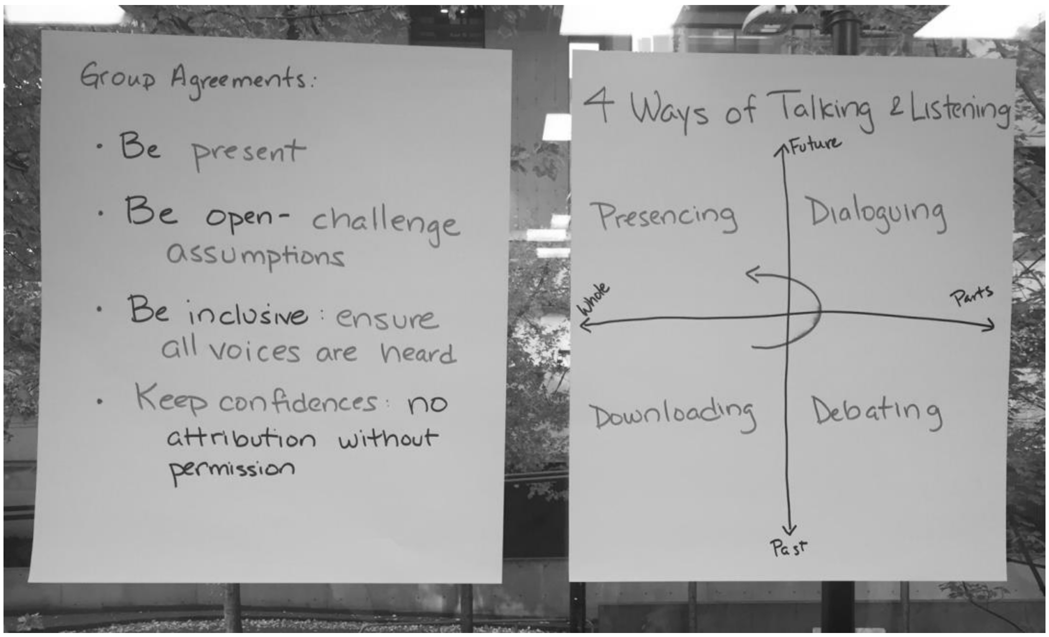

Figure 3.6. "Group Agreements" and "4 Ways of Talking & Listening."

Colleen leads us to ask ourselves "What do I need to suspend to do my best work?" One participant offers "I need to suspend my idealism," adding "That's heartbreaking." Another later affirms their need to suspend their pessimism. Yet another needs to "suspend that [they] know the answers." Colleen redirects our attention to the pessimist-optimist axis and asks to discuss compelling points on both sides. A note taker writes comments on post-its and adheres them next to the flip chart paper. They include observations like: "Tech giving voice to previously voiceless," "Tech connecting people who otherwise wouldn't have," "Lack of engineering voice in decision making," "Automation: lack of jobs, hand transition," and "Selfishness, corrupt technology to narrow benefit."

Now that they have our attention, and our willingness to participate, they say that they want to introduce us to more nuanced ways of thinking about technology so that we can "move to the next level." The facilitation changes hands once again.

3.3.2.2 A social lab

Social labs attempt to innovate on traditional problem solving approaches that feature clearly defined problems and clearly delineated responsibility. Instead the problem for a social lab can change unexpectedly and affect many different stakeholders. A graphic from the Engineering Change Lab website compares these two methods of problem solving in Figure 3.7.

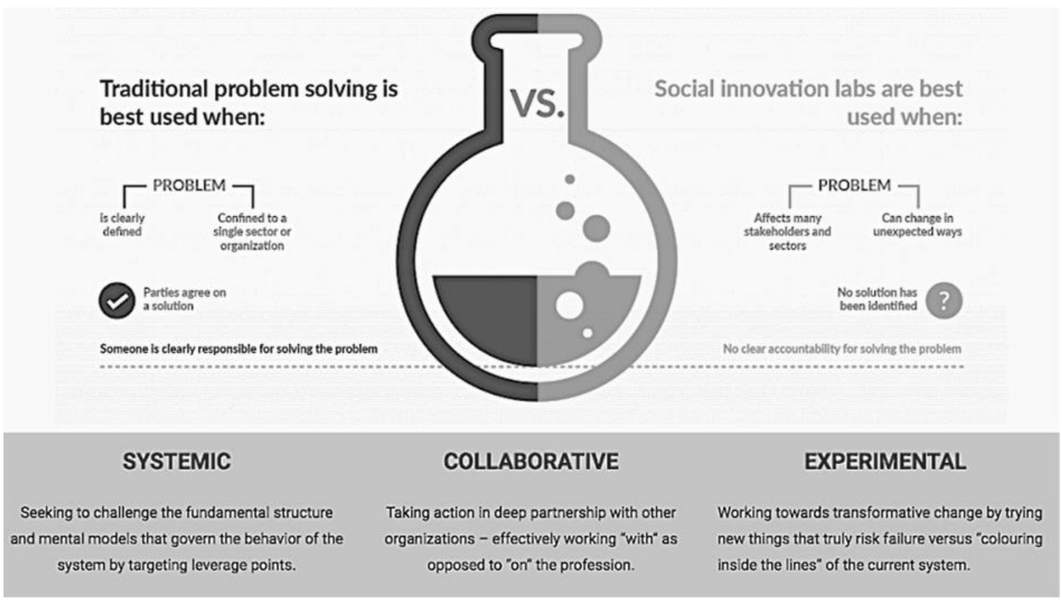

Figure 3.7. Traditional problem solving (left) compared with social innovation labs (right), taken from the Engineering Change Lab website.[191]

[191] "Engineering Change Lab," Engineering Change Lab, accessed January 17, 2022, https://www.engineeringchangelab.ca/.

Social innovation labs embrace a certain degree of adaptability and heterogeneity as conveners account for unique local conditions: their foci have varied from Alberta's energy future, Yemen's famine, and childhood poverty in India to Indigenous reconciliation in Australia, post-apartheid South Africa, and Israeli-Palestinian relationships.

Charles explained how the ECL first formed in the fall 2014.

> In the social lab process, […] you convene a microcosm of the system you're trying to change. So we sat down and said, "Well, who is the engineering system in Canada?" [...]
>
> [We] came up with lists of who are the organizations that kind of represent engineering in Canada, like, K-12, postsecondary, regulators, advocacy bodies, different types of engineering workplaces, government, you know, non-profit. So we came up with, like, a sort of master list, [a] wish list of all these organizations and then we sent out about 100, 110, 120 invitations from the CEO of Engineers Canada and the CEO of EWB to this launch event to get our 40 leaders, which we ultimately did: 40 leaders, 40 organizations at the launch event within the EWB conference of January 2015. And we made a couple of important strategic decisions in the beginning. The first was to pick the social labs process. And you know, for the reasons I've said before, I think it was a generally good fit. But in hindsight it, well in partial sight then and in clearer hindsight now, I think we picked the right process. Because I think social labs are good when, not just how to tackle a complex system level challenge, like how to solve it, but also, you know, what the problem *is* is fuzzy. So in our case, our convening question is: how do we unlock the higher potential of engineering to contribute to society?
>
> And implicit in that question was a belief that no one really had a robust way of thinking about that yet. Like, if you had asked an EWBer, if you had asked Engineers Canada, or leaders within engineering, they probably could have filled pages of an answer, but it all felt like it wasn't quite satisfactory. Like it was partially good, but not a bigger picture that everyone, kind of, agreed on. […] The social labs process I think was good because we were expecting to understand the nature of the challenge itself as a major part of the work, a deepening understanding of the challenge itself.
>
> The other sort of strategic decision we made was, in some labs they launch and only kind of focus on sharing perspectives and emerging this bigger thinking before starting initiatives, like experiments of the lab, tangible experiments. We decided to do both at the same time partially because, for two reasons, one, we felt like engineers are, you know, tend to be on the practical side and want to sort of, you know, get to action sooner rather than later. And two, because we felt like, the things that were likely to come up, which proved to be true, were probably pieces of the bigger puzzle anyway so that there wasn't a huge risk that we'd be doing something that was totally off base: so things like diversity in engineering, [claps] curriculum reform, [claps] you know, the need for a stronger voice

> in leadership in engineering leadership, things like that. And so those in fact did become a lot of the self-organized initiatives that came out of the early days of the lab.[192]

Half a dozen iterations of social change lab workshops later, the mission has now been distilled into something more specific: from "unlocking the higher potential of the engineering profession," the ECL now identifies its mission as promoting "technological stewardship" as the responsible framework for understanding engineers' social roles.

> You don't have to go too far to see the growing scepticism about the role technology is playing in society. Technology, I would argue, is the output of engineering. And I would argue we're in somewhat of a crisis about our relationship with technology as a society. So if there's a crisis in the relationship with the product of your work or the outcome of your work, i.e. technology and society writ large, I think it's pretty hard to argue as engineering […] like, "Well we got our core work down and now we can be a liberal arts degree for everyone else!" You know what I mean? It's like, that should be a flashing red light on the dash of people who care about the engineering community in the future and it isn't right now.[193]

It had taken the ECL three years to focus their concern on technology. Up until this point, the workshops and newsletters vaguely addressed their desire to "unlock the higher potential of engineering." Earlier in their exploration of the Canadian engineering system, the ECL had identified initiatives for experimentation and improvement in the profession that included diversity, innovation, ethics, and curriculum change. Now, this ambition is couched within their new catchall "technological stewardship." By redirecting their attention towards technological stewardship, the Lab dramatically simplified their messaging while maintaining their original impetus to improve the culture of engineering in Canada across the board. Further, "technological stewardship," as the emergent paradigm the ECL wishes participants to adopt and advance, easily includes their prior concerns. Borrowing examples from science and technology

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[192] "Charles" in discussion with the author, May 2019.
[193] Charles.

studies and popular techno-criticism enables conversations at the workshops about “technological stewardship” to include topics like women and other minority groups in engineering, contemporary ethical concerns in tech industries, and knowledge gaps engineers may have of their own profession. Thus, at the time of writing, “technological stewardship” is the Engineering Change Lab’s framework for both evaluating current practices and imagining future engineering.

3.3.2.3 Strategy

The second day of the Vancouver workshop changes course somewhat. While the first day was educationally-oriented—explaining to participants what the Engineering Change Lab is, facilitating critical discussion on technology, and priming them to use “technological stewardship” conceptually—the second day focuses on “strategic doing.” Each institution or cohort participating at this workshop has between three and six attendees. We are now tasked with devising a strategy to advance technological stewardship in our workplaces. Here, the facilitators encourage cohorts to find their “big easy”: the action that will have the largest impact with the least effort. Participants identify and evaluate options, select their strategy, and create timelines for execution and reporting. The intent of these strategies is to both advance the ECL’s concept of “technological stewardship” and for the participating organization to derive benefit from the workshop. Circling back to Donella Meadows’ list, the intent of the workshop is to transcend the previous paradigm, and usher in technological stewardship by reimagining our organizations’ work.

The workshop ends later that Friday afternoon in that same conference room. Each cohort has developed a “pathfinder project,” a take-to-work initiative to advance technological stewardship replete with success metrics, guideposts, deliverables, deadlines, communication strategies, and scheduled follow-up meetings. Winding down near the end of the last day while the groups finalizes their projects or programs, Charles assures the room: “If you’re worried that it’s not perfect, that’s okay. This is set-up to quickly get to the action.”

While the significance of the cognitive paradigm is downplayed here in favour of *doing*, this introduction to the ECL highlights the powerful role of the “system” in this context. While changing very little about these different organizational cohorts’ work, the result of this work is imbued with new substance. Reframing ones “big easy” under the aegis of technological stewardship is a simple strategy to avoid overloading participants with a project with which they may not succeed. More importantly though, the easier the execution of their application of technological stewardship, the more deftly the paradigm of technological stewardship ingratiates itself within existing structures. Except for the mediation with which participants engage their work, nothing has changed. Yet.

What responsibilities, if any, toward action accompany knowledge? The Engineering Change Lab posits that education should produce results. The ECL’s focus on technological stewardship as a heuristic portends an outcome. Participants will be convinced. Education has a purpose. Further, the success of the workshop does not rest solely on changing minds; the wayfinders are compelled to act differently too. Their transformations, in thought and in action, will change the world. They want a revolution. But what here is revolutionary? If the intent is to execute our “big easy,” are we not simply continuing business as usual under a new banner of “technological stewardship?” Although, following Luhmann, perhaps that is the most one could hope for in changing the system.

CHAPTER FOUR

“WE ARE INTERESTED IN EVERY ENGINEER [...] FROM THE CRADLE TO THE GRAVE.” OPERATIONAL CLOSURE AND CANADIAN ENGINEERING EDUCATION REFORMS

In this chapter, I will chronicle a few more moments in Canadian engineering education using archival data from Engineers Canada (formerly the Canadian Council for Professional Engineers) to narrate the development of the Canadian Accreditation Board (which would become the Canadian Engineering Accreditation Board). Beginning in the early 1960s, engineers representing national bodies, universities, and provincial associations began investigating engineering education as a national concern, aligning national interests with engineering education and other professional initiatives. Contemporaneously, the relationship between the CCPE and the Engineering Institute of Canada (EIC) reveals CCPE’s concerns with federally unifying the myriad Canadian engineering organizations.

The politics of Canadian confederation guide the structuring of professional engineering and further influence approaches to Canadian engineering education reforms, limiting engineering concerns within the scope of the Canadian state and state administration. The drive to accredit Canadian university engineering programs stemmed from a desire to unify the profession nationally. In Luhmannian terms, *autopoiesis* of Canadian engineering was secured by coupling professional education to state administration through the national accreditation of university engineering programs. Coupling engineering education to state administration allows for engineering education to serve the state, and vice versa.

Some focus of engineers on the international engineering community may exceed the purely internal concerns of Canadian engineering, however the few international moments of engineering present in this archive remain firmly entrenched within conceptions of Canadian nationalism, to present a unified front of *Canadian* engineering.

While this chapter does not attempt to address gender or sex in engineering culture, some of the evidence does suggest a humanistic framing of engineering culture: one where engineers are framed as classical, liberal subjects, unencumbered by gender or sex. You may notice engineers or would-be engineers referred to exclusively as “men” and “he.”

Technological change and innovation give meaning to Canadian engineering culture. Historically, technological change and the suitability of engineers to appropriately manage technological change through their education and professionalization have been omnipresent frameworks to make engineering education reforms relevant interventions for the engineering profession. Technological change can pose a threat to society, but educated and well-trained engineers can act as a corrective. That engineers position themselves as protectors of society from technological change further enables engineers to value technoscientific progress and innovation. And although technological change has historically been a threat to the suitability of Canadian engineering education, as shown in this chapter, the innovation of technologies themselves are devised and welcomed by engineers in their times.

These national policies, and discussions about national policies, serve as reimaginings of the future of Canadian engineering and society. Treating engineering education as engineering practice further reveals important cultural elements of Canadian engineering. The very concept of whether teaching and learning engineering in schools qualifies as engineering practices is contested through these records. The sometimes competing interests of provincial regulators, national bodies, technical societies, universities, educators, and international engineering organizations animate a world where what engineering should be is up for debate and influence. These policy concerns likewise demonstrate which elements are selected as parts of the system of engineering, and which are not. And while some of these historical concerns appear familiar, resembling more contemporary issues, disruption to the system of engineering in this context is altogether unwelcome.

4.1 Instituting engineering education: the Canadian Accreditation Board and the politics of confederation

Fears about the sufficiency of engineering education, and the desire for feedback about engineering curricula in Canada pre-date the standardization concerns described in the early 1990s in chapter three. At the 1964 Canadian Council of Professional Engineers Board of Directors meeting, the Committee on Future Development of the Engineering Profession presented their annual progress report, and much of the discussion focused on their findings regarding engineering practice. Their report outlined five "needs" identified by engineering educators, engineers themselves, and engineering employers:

> (a) The need to 're-educate' or to 'refresh' periodically engineers in practice.
>
> (b) The need to better acquaint engineering educators, and engineering students as to the practical problems, requirements and outlooks of the practising engineer, and of the various employers of engineers.
>
> (c) The need to better acquaint practising engineers, and employers thereof, with up-to-date design and analysis techniques - and to provide a source of such specialized service which could be available for the solution of particular problems, or the relief of certain 'peaks' in work loads.
>
> (d) The need to monitor continuously the many uses to which engineering talent is put, and to see that the engineering student is, upon graduation, equipped to do the tasks to which he will likely be exposed.

(e) The need to acquaint engineering undergraduates with the ethical, sociological and legal aspects of engineering practice.[194]

All of these needs of the profession concerned the knowledge-base and education of engineers. Evidently engineering education and engineering practice were linked, policymakers believed that different knowledges could produce different behaviours within their profession. This relationship, understood so strongly, was also ironically considered weak. Engineering professor W. M. Armstrong stated that "a growing number of educators were concerned at the growing gap between practicing engineering and the schools of engineering."[195] The current education of engineers, though necessary, was insufficient at preparing students for workplaces.

Not only did the practice of engineering seem significantly apart from the engineering education students were receiving at the time, but board members further shared concern regarding the seemingly widespread abilities of certain practicing engineers. Yvon Tasse presented on the topic and discussion followed "concerning the often marginal, and sometimes quite unacceptable, quality of workmanship, and ethics displayed by certain engineers in public practice."[196]

Preoccupied with these dual challenges of adequately preparing engineering students for professional work and addressing shortcomings of current professionals, at this meeting the CCPE made a plan. With the goal of improving their profession, the board moved and carried unanimously a motion "to bring universities and practicing engineers closer together" by re-educating professional

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[194] Committee on the Future Development of the Engineering Profession "Progress Report," CCPE Minutes of the 28th Annual Meeting, May 1964, Appendix D, Engineers Canada Office, Ottawa: 2.
[195] CCPE Minutes of the 28th Annual Meeting, May 1964, Engineers Canada Office, Ottawa: 5.
[196] "Progress Report," May 1964, 3.

engineers, educating teachers of engineering students to practical problems, and exposing engineering students to the realities of engineering practice.[197]

These mid-century challenges that shaped the conversations of engineering education bodies plagued other attempts to coordinate the Canadian engineering profession. A combination of technological progress and a lack of political will and resources were blamed for not resolving some of the profession's more glaring shortcomings. In his 1964 address, CCPE President Gilles Sarault elaborated:

> This is the past, but what of the future? How can Canadian Council best serve its Constituent Bodies and their over 45,000 members. We have agreed to give it more strength, to expand its activities and it is therefore all the more important that our direction be the right one. One of my predecessors, Mr. L. Wardrop, remarked in his presidential report that the Provincial bodies did not show adequate interest in Council matters and often related them to the end of their agendas. To ensure proper consideration of the Confederation issue, he organized a one-day meeting of Provincial Presidents. This apathy is our basic weakness: it exists because the Provincial Bodies consider Canadian Council as an independent organization rather than an extension of themselves. They are not taking the initiative of bringing problems and questions of common interest to this body and their attitude is passive rather than active. If I understand correctly the viewpoint of the C.P.E.Q. with respect to our proposed Charter, it is based on this very fear that Council is evolving gradually to a position of independence with power of its own. We must therefore take a hard look at our guiding philosophy and chart our course after sound analysis and serene deductions.
>
> The engineering profession is faced with problems of major importance which result from the extremely rapid social changes of our era. Salaried engineers are looking for a key to their search for status commensurate to their contributions to society and some are considering unionism as a possible answer; consulting engineers are struggling to retain the professional character of their practice against the pressure to evolve towards a straight business operation; the engineering field is being invaded by so-called experts in a large number of domains; and finally the public image of the engineer is far too much that of a calculating machine to which you throw problems and then relegate in the corner after the answers have been produced.[198]

Gilles Serault concluded:

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[197] CCPE Minutes, May 1964, 5.
[198] Gilles Sarault, "President's Report," CCPE Minutes of the 28th Annual Meeting, May 1964, Appendix A, Engineers Canada Office, Ottawa: 2.

> The enthusiasm of the Provincial Bodies for Canadian Council can only be kindled by the benefits which they will derive from it. Unfortunately, I have no recipe to offer, but I sincerely believe that a committee of Council could spend useful time struggling with these questions.[199]

Chairs of the CCPE had been feeling the pressure to address widespread challenges faced by Canadian engineers and the educational needs of the profession. However, the ability to coordinate action nationally depended on the cooperation of representatives from the various provincial engineering associations that made up the CCPE Board of Directors.

Some of these tensions are more evident in the Committee on Future Development of the Engineering Profession "Progress Report" where the committee shared unanimity in "deploring the fact that the [Provincial] Associations did not appear to have the means for dealing with such cases [of marginal workmanship], particularly those involving various levels of public administration."[200] The authors note that some of the provincial associations were formulating "minimum standards of engineering services" and that the CCPE should offer "any assistance or encouragement that would lead the Associations to accelerate this work."[201] They move carefully, however, only to launch an investigation into engineers working federally, keeping language regarding engineering services for provincial or municipal governments limited to "encouragement" to standardize service. The provincial associations had cooperated inasmuch as they had formed the CCPE. However, any initiative undertaken by the CCPE had to expressly avoid encroaching on provincial jurisdictions lest any of the regulatory bodies cease their participation.

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[199] Gilles Sarault, "President's Report," 2.
[200] Gilles Sarault, "President's Report," 3.
[201] Gilles Sarault, "President's Report," 3.

Contemporaneously, there were other nationally active engineering organizations that likewise faced challenges coordinating their efforts.

In 1963, CCPE President D.S. Simmons took responsibility for the failure of securing confederation between the CCPE and the Engineering Institute of Canada, a body representing the various technical societies within engineering. He explained his frustration:

> It has been my privilege this spring to attend the annual meetings of five of our members. One cannot help being impressed with the number of problems that are common to the members. Many of these problems could be solved more satisfactorily on a national basis, and many of them are receiving national attention as is apparent from the agenda of this meeting. It is also apparent that many provincial problems are peculiar to the province itself and can only be solved on a provincial basis, thus meeting the needs of the province at this particular time. This, of course, requires strong and skilful provincial leadership. This can only be provided by capable councils. I do not feel the Association or the Corporation can afford to have the council powers fall into the hands of those most diligently seeking them. We must go out and seek the men we want and persuade them to seek election to offices. The men we need most for future developments are not, generally, the men who will relish a long and controversial campaign to be elected. We must provide a means whereby "the office seeks the man" rather than the reverse.
>
> Public relations is probably the second most important concern of a national president. I would like to report my great pride in seeing what I believe to be a continuing improvement in the public image of our profession. The average person outside our profession holds us in high regard and looks on us very favourably as the people who are doing most to bring him his present high standard of living. I also believe that he looks on our profession as holding in its hands the keys to the future which looks so promising. As long as the average citizen looks on us in this light I would say we have an excellent public image. I would like to remind you, however, that every time we do something which appears to the public to be an effort to collectively raise our relative economic status in the community, we begin to resemble a trade union and our public image as a profession takes on a little tarnish.[202]

The consistent and shared concerns that affected the engineering profession in all provinces covered a gamut of organizational, political, and technical issues. One domain that appears frequently in the archived minutes, and appears to progress and develop over time, is a focus on engineering curriculum. Spurring the creation

[202] D.S. Simmons, "President's Report," CCPE Minutes of the 27th Annual Meeting, May 1963, Appendix A, Engineers Canada Office, Ottawa: 2.

of a new course for engineering undergraduate students in “The Practice of Professional Engineering,” the Committee on Future Development said:

> It is observed that engineering graduates are generally very poorly informed as to the social, ethical and legal implications of engineering practice. Current engineering curricula usually omit these topics in favour of increased technical course content, a procedure which is perpetuated due to two difficulties - lack of interest on the part of students and their teachers.[203]

In these early years of the 1960s, meetings between different engineering organizations and working group committees frequently referenced both national challenges for the engineering profession and a desire for more nationally uniform engineering education. A 1962 report to the Committee on Acceptable Canadian Engineering Curricula noted that “one of the major difficulties in reaching uniformity in the recognition of engineering curricula might have been the fact that we did not have a recognized uniform basis for accreditation.”[204] Simply put, the Committee was urging for agreement between the provincial associations regarding broad accreditation policy. Even if differences in detail remained, “great progress will have been made toward uniformity in academic requirements for registration across Canada.”[205]

Creating the basis for accreditation thus became a priority for the Committee. In justifying the need to accredit, and thus identify, the curricula that satisfy provincial licensing bodies’ academic requirements, the Committee drew attention to its own limitations in intent and, perhaps, authority.

> It recognizes that a broad basis for recognizing acceptable curricula should be formulated to avoid over-specialization and narrowness of purpose and sufficient freedom should be retained to allow differing details in curricula due to regional and other factors and to

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[203] “Report of Committee on Future Development of the Engineering Profession,” CCPE Minutes of the 27th Annual Meeting, May 1963, Appendix D, Engineers Canada Office, Ottawa: 2–3.
[204] “Report of the Committee on Acceptable Canadian Engineering Curricula,” CCPE Minutes of the 28th Annual Meeting, May 1964, Appendix E, Engineers Canada Office, Ottawa: 2.
[205] “Acceptable Canadian Engineering Curricula,” May 1964, 2.

> permit well-founded and reasonable experimentation in curricula without immediate loss of acceptable status.[206]

The goal was to provide a standardized education so that professional practice itself could follow suit. However, the requirements for "uniformity in the recognition of engineering curricula" hinged on a "uniform basis for accreditation." In turn, a "uniform basis for accreditation" necessitated a national body to oversee the accreditation of engineering programs at universities that did not infringe on the responsibilities of either provincial regulators or universities themselves.

This concern regarding an accreditation process that was too strict or too narrow, with nearly identical wording, in fact, emerged over a decade later in 1975 with the publication of the first annual report of the Canadian Accreditation Board. It read:

> The criteria provide a broad basis of recognizing acceptable degree programmes and are formulated to avoid over-specialization and narrowness. Sufficient freedom must be maintained to allow differing details in curricula related to different regional and academic factors and to permit a short-run experimentation in curriculum development without long-run loss of accreditation status.[207]

Even after a "uniform basis for accreditation" had been established in the CAB, they reiterated their restraint in their conceptualization of acceptability of engineering school curricula.

Returning to 1964, the final recommendation from the Committee on Acceptable Canadian Engineering Curricula suggested "that a central accrediting committee be set up by Canadian Council with sufficient power and finances to implement the above recommendations."[208]

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[206] "Acceptable Canadian Engineering Curricula," May 1964, 3.
[207] "CAB 1st Annual Report," CCPE (1975): 11–12.
[208] "Acceptable Canadian Engineering Curricula," May 1964, 4.

These pushes for uniformity touched a nerve similar to many discussions concerning confederation in Canada. A year later, in 1964, the Board of Directors received the report detailing the proposed Canadian Accreditation Board. All but four provincial associations had approved the proposal as submitted. British Columbia and Saskatchewan had approved the proposal but each listed three reservations they had with details of the text. Representatives from British Columbia and Saskatchewan indicated that their respective provincial associations' comments on record concerned details that could be "ironed out" later by the proposed Board itself. W.M. Armstrong clarified that "the British Columbia Council was very anxious [sic] to see this Board organized as soon as possible."[209] E.J. Cole echoed that "the Saskatchewan Association was wholeheartedly in favour of establishing the Canadian Accreditation Board without delay."[210] T.B. McLennan apologized that the Council of the Prince Edward Island Association had failed to consider the proposal "through an oversight and that this would be done very shortly."[211] However, P. Demers had more to say regarding Québec's participation. While the CPEQ felt that an accreditation board could be "quite useful, […] the proposal as submitted could not be approved in its present form."[212] The CPEQ Council felt "very strongly that the authority for accreditation of engineering curricula must remain with the Provincial Associations."[213] Fearing that the proposal would cede too much power to the national board, the CPEQ felt that they could not delegate powers as such. Demers added further that "the overall tone of the proposal was objectionable to

[209] CCPE Minutes, May 1964, 13.
[210] CCPE Minutes, May 1964, 13.
[211] CCPE Minutes, May 1964, 13.
[212] CCPE Minutes, May 1964, 13.
[213] CCPE Minutes, May 1964, 13.

his Council, but that he felt that the proposal could be revised in such a way as to become acceptable to the Quebec Corporation."[214]

E.J. Cole, the representative for Saskatchewan, stated that as far as he knew "the Canadian Council of Professional Engineers has never attempted to dictate to the Provincial Associations nor to usurp their functions."[215] P. Demers countered that "it is the duty of Canadian Council to establish policies for the Council and to ascertain that provincial prerogatives are not usurped by CCPE."[216]

At the following year's meeting in May 1965, the Canadian Council of Professional Engineers (unincorporated) formally dissolved after its 29 year history, only to be immediately reformed as an incorporated entity.[217] Ushering in the welcome changes, President John F. McDougall boasted that CCPE was granted "the first bi-lingual charter ever issued by the Secretary of State for Canada."[218] McDougall expressed his sincere desire that "incorporation will increase the influence of the Council and enhance the respect it already commands."[219] He continued:

> If the Council is to become the highly respected and influential organization, which most of the constituent bodies would like it to be, it must be granted a higher degree of autonomy in the management of its internal affairs and greater freedom to express opinions on matters of National concern to the engineering profession.[220]

In discussing his vision for Canadian engineering, the President gradually shifted focus to engineering education.

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[214] CCPE Minutes, May 1964, 13.
[215] CCPE Minutes, May 1964, 13.
[216] CCPE Minutes, May 1964, 13.
[217] CCPE Minutes of the 29th Annual Meeting, May 1965, Engineers Canada Office, Ottawa: 3–4.
[218] John F. McDougall, "President's Report," CCPE Minutes of the 29th Annual Meeting, May 1965, Appendix A, Engineers Canada Office, Ottawa: 1.
[219] McDougall, "President's Report," 1.
[220] McDougall, "President's Report," 1.

> Public Relations is a perennial topic of discussion at the Annual Meetings of C.C.P.E. and of the Provincial Associations. Public Relations programs may have their place, but can only project the image the profession itself creates. Too often what seems to be lacking is a coherent sense of direction, values, responsibility and dedication which is so necessary if we are to cope with the great tides of change that are sweeping over the profession, the nation and the world.
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> To some degree this inconstancy stems from the narrowness of engineering education and its emphasis on utilitarianism. This is reflected in a statement once made by the late Sir Winston Churchill. "We want a lot of engineers in the modern world, but we do not want a world of engineers." He went on to say - "A university education ought to be a guide to the reading of a lifetime and looked upon as a key to open many doors of thought and knowledge."[221]

McDougall announced that engineering education in Canada was in need of reappraisal, that failure to educate "the whole man" would be an "irreparable loss" for the profession.[222] Engineering education, for McDougall, "should not be confined to learning for learning's sake," but rather should "train the mind" to educate itself further.[223] "If the values of civilized life are to endure they must be buttressed by education that will guard and shape our future, and give us the sense of perspective we need for broad and distant views."[224] This challenge was further complicated by "the climate of bigness and diversity" that "pervaded North America" at the time.[225] The growth and complexity of Canadian society "make it ever more difficult to reinforce in the minds and purposes of the multiplying numbers of persons and groups in our society the values which should motivate the whole."[226]

> If the engineering student is to be provided with a foundation upon which he may build a career of professional stature, his education must help him to seek his fullest development as an individual. This requires for its achievement adequate attention to subjects in the humanistic and social fields- A Liberal Education.

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221 McDougall, "President's Report," 2.
222 McDougall, "President's Report," 2.
223 McDougall, "President's Report," 2.
224 McDougall, "President's Report," 2.
225 McDougall, "President's Report," 2.
226 McDougall, "President's Report," 2.

> A Liberal Education is not the mere ghostly shadow of things that some persons imagine it to be. It is real and substantial. No matter how glorified the science may be or how practical the technology, it needs an arterial connection with basic education if it is to live. A Liberal Education is practical, because it provides experience in formulating judgments about concrete contemporary problems.
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> It is not claimed that a Liberal Education will do a complete job of preparing a young man for life, but it initiates the sort of personal growth that leads to maturity. It helps to liberate him from provincialisms, whether geographical, historical or occupational. It develops his capacity to make sound qualitative judgements so that he may distinguish that which is good, from that which is mediocre. It encourages wisdom, judgment and perspective; qualities needed in facing the daily decisions of life. […]
>
> We are misguided if we think of one curriculum as being suitable to prepare men to be leaders, and of another as being suitable for specialists in techniques who are to be the servants of the policy makers. The course of our technological development is such that increasingly grave social responsibilities are falling upon the shoulders of technically trained men.
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> Business is reaching out more and more for people whose training is broad, deeply infused with the ideas that come from a sound Liberal Education programme, and ideals that arise out of the association of great minds. In the August 1964 Imperial Oil Review, W.O. Twaits states - "The biggest deficiency in potential management candidates today is their lack of knowledge of political, social and economic affairs."[227]

McDougall continued to pontificate the virtues of liberal education. "A Liberal Education is tailored to free men from ignorance, superstition, prejudice, arrogance, hatred, tyranny, greed, insensitivity and cynicism," and to strengthen "man's" dedication to the dignity of "his fellowmen."[228] This type of education imagined by McDougall produces "responsible leaders" in all activities of society.[229] McDougall characterized the difficulties in directing education to bring order to a world of "exploding knowledge."[230] What this expanding knowledge base produces in engineering in particular is, what McDougall considers, over-specialization.

> With increasing specialization there comes an easy assumption of arrogance and intolerance among the competing areas of learning. Not only do areas of specialization

[227] McDougall, "President's Report," 2–3.
[228] McDougall, "President's Report," 3.
[229] McDougall, "President's Report," 3.
[230] McDougall, "President's Report," 3.

> lose valuable contact, but they also lose reasonable proportion. Knowing more and more about less and less, is not an empty quip.[231]

Professionalism, despite these fears of over-specialization, is necessary for "enlightened and responsible citizenship."[232] The "learned professions," in McDougall's view, are in the "vanguard as the watch-dogs of freedom."[233] "[D]emocratic freedom is neither a God given right, nor a natural law, but a political condition which can be kept only by vigilance, use and practice."[234] Freedom can only be safeguarded by "informed, educated, sound and vigilant public opinion" from the forces that seek to destroy freedom: "selfishness, greed, hate, amoralism, venality and the lust for power."[235] Professionals, through "impeccable conduct in [their] daily lives will confine government to its only justifiable role: that of protector of the rights and freedom of the individual."[236] McDougall concluded with a warning, that the greater the personal and social burdens assumed by the government, "the closer we bring the day when the rulers will be stronger than the rules, and self-government will disappear."[237]

It certainly seemed that the goals of greater control of engineering Canada-wide followed incorporation of CCPE and the establishment of the Canadian Accreditation Board. By 1966, the concerns of confederation with the Engineering Institute of Canada and its constituent technical societies were all but gone. Instead, CCPE had established amicable relationships with engineering technical societies and they were successfully collaborating where their interests

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[231] McDougall, "President's Report," 3.
[232] McDougall, "President's Report," 3.
[233] McDougall, "President's Report," 3.
[234] McDougall, "President's Report," 3.
[235] McDougall, "President's Report," 4.
[236] McDougall, "President's Report," 4.
[237] McDougall, "President's Report," 4.

and authorities overlapped. The Canadian Accreditation Board was likewise incredibly active during this time.

In their update to the Board of Directors in May 1966, the CAB confirmed that they had accredited all Canadian engineering curricula which had previously been accredited by their constituent associations: the provincial regulatory bodies.[238] As a starting point, the CAB sought first to accredit programs that had already been provincially accredited, hardly an imposition on jurisdiction. The authority to perform the accreditation in any regard was a sufficient enough goal at the time. The 1965 accreditation gave the Board information to determine other files in which they might intervene while maintaining their subservience to the provincial associations. They quickly identified the incongruence of acceptable engineering curricula between different provincial associations. The Board agreed to investigate curricula that were not unanimously accepted by provincial boards and to determine the reasons for non-acceptance.[239] Providing uniform and consistent acceptability of engineering education between the provinces remained the impetus in the early days of the Board. The CAB likewise extended this accreditation to foreign engineering curricula and qualifications that "were acceptable for registration purposes to all the constituent associations of C.C.P.E. as of October 1st, 1965."[240]

Although the nascent activities of the Canadian Accreditation Board had thus far been rather intentionally restrained, even suppressed, their, at this point, semi-annual reports continued to gesture towards larger ambits. In their May 1967 report, they clarify some functions of the CAB: The Board accredits programs as

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[238] "Annual Report of the Canadian Accreditation Board," CCPE Minutes of the 2nd Annual Meeting of Members, May 1966, Appendix D, Engineers Canada Office, Ottawa: 1.
[239] "Annual Report CAB," May 1966, 1.
[240] "Annual Report CAB," May 1966, 2.

providing an engineering curriculum adequate for subsequent registration with provincial associations. The Board does not accredit programs regarding their disciplinary acceptability, i.e. whether it is an acceptable civil, mechanical, electrical or other engineering program.[241] The Board examines all options and accredits the curriculum if all options are acceptable. The Board does not separately accredit options of a curriculum.[242] Most of these statements appear rather straightforward distinctions of the CAB functions regarding engineering curricula. However, detailed in this policy statement lies a consideration in accreditation that extends beyond post-secondary course acceptability, introducing new focus on pupils.

> In determining the adequacy of curriculum content in relation to the development of the ability to solve practical engineering problems the Board will exercise its own judgment taking into consideration "that there be a minimum level of competence of graduates equal to that represented by the professional examinations in the Uniform Syllabus", the current views generally accepted throughout the country, the various types of functions for which engineers are required and the broad needs of the nation.[243]

Here "a minimum level of competence of graduates," shifts attention away from other elements of engineering programs. The previous accreditation criteria still remained important—the curricula, the facilities, the professors—but now the CAB interested itself in educational outcomes: graduates. The impetus for the standing committee on engineering curricula in 1962 was the challenge for a uniform basis for accreditation: accrediting individuals as professional engineers based on their engineering knowledge and skill base. Four years later and accreditation now concerned the programs that educated these individuals, and engineers making up these accreditation processes identified the engineering graduates as potential sites of analysis and, thus, reform.

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[241] "Semi-annual Report of the Canadian Accreditation Board," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1967, Appendix D, Engineers Canada Office, Ottawa: 3.
[242] "Semi-annual Report CAB," May 1967, 3.
[243] "Semi-annual Report CAB," May 1967, 3.

The following year, the Board began work devising a new examination on ethics, economic factors in engineering, and professional practice that was expected to be included in the branch examinations which, at that point, included electrical, civil, mechanical, and chemical engineering.[244] While gradually progressing on their goals to unify the Canadian engineering profession, the CAB and the CPPE practiced caution about impinging too strongly on the provincial associations. A note in CCPE's June 1968 minutes read: "whenever possible avoid duplication of accreditation visits with any provincial Accreditation Board."[245] The CAB's semi-annual report spelled out how accrediting procedures were initiated "only at the request of the applicable provincial association and with the consent of the educational institution concerned, or at the invitation of a particular educational institution with the consent of the provincial association concerned."[246] The report further assigned a role to the provincial accreditation boards stating that when an assessment had been requested of the CAB: "every effort will be made to obtain as much data as possible from such a Provincial Accrediting Committee."[247] The successful function of the CCPE and the CAB relied on cooperation of everyone involved, rather than the dictates of a singular authority.

Difficulties managing and coordinating the disparate practices of the provincial organizations, of course, extended to other CCPE committees. Addressing a roadblock stalling the work of the National Program on Continuing Education, CCPE President R.J. Genereux addressed the national Canadian interest in

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[244] "Semi-annual Report of the Canadian Accreditation Board," CCPE Minutes of a Regular Meeting of the Board of Directors, November 1967, Appendix B, Engineers Canada Office, Ottawa: 2.
[245] CCPE Minutes of a Regular Meeting of the Board of Directors, June 1968, Engineers Canada Office, Ottawa: 5.
[246] "Semi Annual Report of the Canadian Accreditation Board," CCPE Minutes of a Regular Meeting of the Board of Directors, June 1968, Appendix D, Engineers Canada Office, Ottawa: 4.
[247] "Semi Annual Report CAB," June 1968, 4.

centrally coordinating continuing education for professional engineers in his annual report.

> I would like to turn my attention to some of the problem I see. We are all aware of the explosive growth of new knowledge and new technologies. The rate of growth of new knowledge is such that in one generation there has been more new developments than in the prior past history of man. This raises two problems. Continuing education, or re-education, and re-examination. A degree in an Engineering discipline received 20 years ago does not ensure that an individual is qualified to practice today, or will be qualified a decade from now. I believe that if the engineer is to continue to perform his function in society, and to do this for the maximum good of society, some rather formalized opportunities must be developed for continuing education and re-education. I also believe we must critically examine the need for re-examination, especially for those in private practice or for those changing vocations.
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> This leads me directly to the work of the Canadian Accreditation Board. I personally feel the activities of the Board must be accelerated. Every Canadian Engineering curriculum must be evaluated in depth, and they should be evaluated in depth before the graduates of the course enter the work of the profession. It must be disconcerting to say the least for a young graduate to find his Canadian Engineering Degree has insufficient engineering content to meet the registration requirements of one or more Provincial Associations.
>
> If we are to do these things, we need to know the educational needs of the profession. What things should a member entering the profession be taught? What knowledges, skills and abilities will he need in his career? If we had the answers to these questions, many of our problems would be simplified. [...]
>
> To accomplish some of these things is going to require the best of the imagination and effort of the profession. It is going to require a stronger, more adequately financed central organization. I make no apology when I say central organization. The needs of the country and of the profession demand a strong central organization. When we are exporters of services, or products of engineers, we cannot live behind a wall. The maximum mobility of our profession is necessary if we are to play our role, and uniform rules and practices must prevail to ensure the ease of that mobility. As the practice of any profession is controlled provincially, a strong central organization acting with the full support of all provincial associations, is a necessity to ensure that mobility.
>
> This finally brings me to internal government of the Canadian Council of Professional Engineers. You are all aware of the present constitutional organization. I can think of no better place to start our re-examination. The safeguards of that constitution are no longer necessary, if indeed they ever were. Surely a majority of members, representing a majority of individual members of the profession, is a consensus. At most a 60% majority should be required. The power of the veto in the hand of one provincial association is not a realistic safeguard to-day.[248]

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[248] R.J. Genereux, "President's Report," CCPE Minutes of a Regular Meeting of the Board of Directors, June 1968, Appendix A, Engineers Canada Office, Ottawa: 1–3.

Unabashedly and unequivocally, R.J. Genereux argued for centralization and increased power to CCPE, calling to remove a veto option available to any provincial association.

CCPE President D.B. Redfern picked up the thread in his 1969 annual report the following year. Redfern identified major challenges facing the Canadian engineering profession: a small population for the technological demands of society, the scattering of professionals across the vastness of the country, and "the knowledge that we have a great human resource which has not been utilized to the best advantage of a more unified voice."[249] Redfern emphasized the singular importance of coordinated action for the engineering profession across Canada, assuaging fears of impinging too strongly on provincial authority

> The Canadian Council of Professional Engineers being essentially a co-ordinating body of the Provincial and Territorial Associations and Corporation by its very nature has power to act only when its constituent members authorize it to so do. It is easy to see historically why this is as it is. Legal authority for the government of our profession comes from provincial statutes and it was possible to create a national co-ordinating body only with severe restrictions to its authority and area of influence.
>
> These restrictions were not excessively onerous to Canadian Council's operations in its formative unstructured years. However, today, certain of these restrictions imposed appear to be unduly burdensome particularly in the areas of internal management and other matters not impinging directly on a provincial association's own legal jurisdiction.
>
> Certain recommendations will be placed before this meeting which it is felt will effect [sic] a more rational, effective and economical means by which Canadian Council can operate without removing from the constituent associations their control over matters which by provincial law is their exclusive right. [...]
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> Over many years there have been suggestions, discussions and recommendations attempting to create some greater degree of centralization of efforts of the engineering profession in Canada in the professional and technical areas.[250]

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[249] D.B. Redfern, "Report of the President," CCPE Minutes of a Regular Meeting of the Board of Directors, June 1969, Appendix A, Engineers Canada Office, Ottawa: 1.
[250] Redfern, "Report of the President," 1–2.

At this time, provincial associations also had difficulties accomplishing their more limited goals concerning engineering education and the engineering profession. Despite their occasional resistance to overarching goals of "Canadian engineering," the provincial bodies did not uniformly control the profession within their jurisdictions. In 1969, the New Brunswick Association had drafted and submitted an amendment to their Professional Engineers Act, including a clause that "would have made it compulsory for professors teaching engineering subjects in the engineering school of the province, to become registered as professional engineers."[251] Both the University of Moncton and the University of New Brunswick opposed the clause, leading to withdrawal of the Bill. However the Director from New Brunswick indicated "the intention of the Association to re-submit an amended Bill, which would again incorporate a clause making it compulsory for the above-mentioned professors to become registered."[252] Universities' opposition stemmed from an argument "that many of their professors had received their training overseas and would be unable to qualify for registration at this time."[253] The Department of Labour of the New Brunswick Government had also strongly registered opposition to the proposed amendment that, in addition to compulsory engineering professor registration, further included a problematic bargaining agent clause.[254]

Interestingly, the New Brunswick association "was anxious to find out, [sic] if any other Association had the same type of thing in mind,"[255] turning to CCPE to hopefully resolve this issue with reference to similar provincial policies. Despite

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[251] CCPE Minutes of a Regular Meeting of the Board of Directors, November 1969, Engineers Canada Office, Ottawa: 8–9.
[252] CCPE Minutes, November 1969, 14.
[253] CCPE Minutes, November 1969, 14.
[254] CCPE Minutes, November 1969, 14.
[255] CCPE Minutes, November 1969, 8–9.

any misgivings the provincial associations had regarding potential overreach of CCPE, they were not necessarily reluctant to engage with CCPE on matters that laid firmly within their respective jurisdictions. The Directors of the other provincial associations responded to New Brunswick's inquiry, confirming that the teaching of engineering was not considered as the practice of engineering under any of the acts in any of the provinces, and that no other provinces intended to make teaching engineering subject to compulsory registration.[256]

The 1969 "Report of Committee on Admission Standards" presented some related judgments concerning the acceptability of engineering experience at post-secondary institutions for the engineering profession. While none of the provinces had yet to consider the teaching of engineering at engineering schools "as the practice of engineering," the Committee on Admission Standards recommended that credit for registration as an engineer should be given for teaching experience but "only for time spent teaching engineering science subjects and professional engineering practice subjects."[257] Other occupational experience recommended by the Committee as being acceptable towards a professional designation included a wide range of activities: sales engineering, administration, management, supervision of production, supervision of inspection or construction, start-up of commissioning of plant, surveying, orientation programs, patent examination and filing, engineering work in military service, feasibility or economic studies, computers or data processing, drafting, construction estimating, and quantity surveying.[258] Learning or studying engineering at the master's or doctorate level, however, did not fully meet the Committee's expectations for suitable

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[256] CCPE Minutes, November 1969, 8–9.
[257] "Report of Committee on Admission Standards," CCPE Minutes of a Regular Meeting of the Board of Directors, November 1969, Appendix C, Engineers Canada Office, Ottawa: 3.
[258] "Report Admission Standards," November 1969, 2–3.

occupational experience. They recommended that "a candidate be awarded credit for 50% of the time spent in post-graduate instruction with a maximum of one year being given for all post-graduate work."[259] Further, it was recommended that no credit be granted for post-graduate work in non-engineering subjects: business administration, health sciences, behavioural science, and social sciences.[260] Since they were also recommending a minimum of two years, or 24 months, of acceptable engineering occupational experience to register as a professional, engineering graduates with only academic post-graduate experience would be essentially barred from registration with any provincial association. Engineering education, while seen as an essential feature of engineering and a useful forum through which to explore unifying the profession nationally, stood apart from what was considered the practice of engineering. Teaching engineering was not practicing engineering, but would soon count as relevant occupational experience. Learning engineering and receiving a bachelor's degree was required to eventually register as an engineer, but advanced engineering education and study counted for half of the credit of other comparable experience and, for registration purposes, was redundant beyond two years of study which would yield the maximum one year of credit. Any expectation for engineering professors to thus register as professional engineers appears to unfairly target those whose only experience of engineering was limited to academia, disadvantaging those with relevant experience in master's or doctorate programs, i.e. future engineering professors. As much as the provincial associations might perceive conflict with CCPE's attempt to centrally coordinate the Canadian engineering profession, both the CCPE and the constituent associations appear unified in diminishing the influence universities teaching engineering may have had over engineering, using

[259] "Report Admission Standards," November 1969, 3.
[260] "Report Admission Standards," November 1969, 3.

both curricula and professionalization to these ends. Engineering education needed improvement on a variety of fronts, but more time studying engineering at universities was not necessarily one of them. Perhaps unifying nationally would give provincial regulators greater control of engineering education within their own provinces as they could more effectively coordinate their interests.

Of course, the confederation problem was still at play. A proposal to amend CCPE by-laws in principle and remove veto power for constituent associations became a sticking point for the Corporation of Engineers of Québec. A series of proposed amendments to the CCPE by-laws requiring the larger associations, namely Québec and Ontario, to relinquish their veto rights had been ratified by all constituent association except for the Corporation of Engineers of Québec. During the ensuing discussion, the Director from Québec conceded that certain associations having veto power due to their membership size had not provided the best method for CCPE's operation. His personal opinion was that the Council of the Corporation might consider surrendering this power when "the aims and objects of CCPE are more clearly defined."[261] The motion carried, with the director from Québec abstaining.

At this point, we will take a slight detour away from the development of engineering accreditation to examine one issue facing attempts to nationally unify Canadian engineering: the Engineering Institute of Canada. Once the challenges between the CCPE and the EIC are resolved, I will return to track the formation and growth of the CAB within CCPE.

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[261] CCPE Minutes, November 1969, 11–12.

4.2 "A common-law relationship": the Canadian Council of Professional Engineers and the Engineering Institute of Canada

Following the unanimous approval of the EIC-CCPE task force to "submit a definite statement of conclusions" at the November 1969 Board of Directors meeting, the working group surveyed CCPE Directors from the provincial associations about the relationship between EIC and CCPE.[262] Directors representing Ontario, Saskatchewan, and the Yukon favoured a CCPE-led technical board, "assuming that this would contribute to the ultimate objective of "The One Voice" for all Canadian engineers."[263] The Director from British Columbia felt that CCPE "should encourage Technical Societies to coordinate their activities, but [...] that the CCPE organization should [not] be used for this purpose."[264] While the Director for Alberta suggested that the first step toward unity should leverage CCPE's and its constituent associations' basic framework for an integrated administrative structure. The Director for New Brunswick strictly opposed CCPE's involvement in forming a technical board, and did not favour "the setting up of yet another Board."[265]

After meeting with EIC representatives in November 1969, CCPE representatives reported "considerable merit and logic" in establishing a National Technical Board to coordinate the activities of the engineering technical societies in Canada, taking a first step towards unification.[266] They felt that the EIC would be the appropriate organization to become such a board.

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[262] "Relations with EIC & Other Technical Societies," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1970, Appendix L, Engineers Canada Office, Ottawa: 1.
[263] "Relations with EIC," May 1970, 1.
[264] "Relations with EIC," May 1970, 1.
[265] "Relations with EIC," May 1970, 1.
[266] "Relations with EIC," May 1970, 2.

Things were not operating smoothly for EIC, however. J.H. Swerdfeger reported that although the formation of technical societies was proceeding well within Canada, with groups like the Canadian Society of Mechanical Engineering and the Canadian Society of Electrical & Electronics Engineering, there was growing opposition towards automatic or compulsory membership in EIC via these organizations. He remarked a tendency of these organizations to "drift away from the Institute."[267] An earlier report stated that "the other Canadian Technical Societies are generally satisfied with the status quo" and "were not prepared to or anxious [sic] to give serious consideration to the proposed establishment of an overall umbrella organization covering all engineering societies active in Canada."[268] Further,

> Canadian Engineers generally have a negative attitude towards their Societies and Associations and that they do not appear to be prepared to support financially and otherwise strong engineering organizations at any or all levels, although they would seem to want to have occasionally such strong organizations when the need arises.[269]

EIC representatives admitted that the structure and objectives of the EIC were "rapidly becoming obsolete"[270] despite "a need for interaction between individuals in the various engineering disciplines."[271] They recognized that the EIC might be "the ideal vehicle for the establishment of a Canadian federation of technical societies," and that CCPE would "be more inclined to offer its support and co-operation to such a federation."[272] Further, this arrangement would facilitate "co-operation between the professional and the technical bodies at the

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[267] "CCPE – EIC Task Force on Unity," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1970, Appendix L2 (Report of a Meeting, November 1969), Engineers Canada Office, Ottawa: 1.
[268] "CCPE – EIC Task Force," May 1970 (September 1969), 1.
[269] "CCPE – EIC Task Force," May 1970 (September 1969), 2.
[270] "CCPE – EIC Task Force," May 1970 (November 1969), 1.
[271] "CCPE – EIC Task Force," May 1970 (November 1969), 2.
[272] "CCPE – EIC Task Force," May 1970 (November 1969), 2.

regional provincial level."[273] Participants at the meeting identified avenues available to develop more successful operations including: creating a representative national voice and professional lobby, improving technical services, providing an educational forum, and creating a Canadian technical identity.[274] The task force concluded that EIC must undertake a more fulsome assessment of their situation, but that "closer liaison between E.I.C. and the Provincial Association and C.C.P.E. was still a very desirable immediate objective which should be pursued."[275]

Despite this goodwill, apparent cooperation between the CCPE and EIC quickly came to a halt. Later that year, at the November 1970 Board meeting, representatives shared that the joint EIC-CCPE task force had ceased making progress after the previous Board meeting in May. The EIC had failed to accept any of CCPE proposals for closer cooperation. Further, "the EIC had been taking a number of important steps towards restructuring the Institute without consultation with the Task Force or representatives of CCPE."[276] The CCPE Executive Committee recommended to the Board of Directors that discussions concerning merging with EIC be "discontinued forthwith."[277] This setback notwithstanding, the CCPE further identified that this communication breakdown was certainly not great but that the EIC's operation now even posed a threat to CCPE. EIC had recently created new bylaws with a provision for provincial associations to appoint representatives to the Council of the EIC, going as far as to extend invitations to CCPE's constituent associations.[278] The Directors viewed

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[273] "CCPE – EIC Task Force," May 1970 (November 1969), 2.
[274] "CCPE – EIC Task Force," May 1970 (November 1969), 2.
[275] "CCPE – EIC Task Force," May 1970 (November 1969), 3.
[276] CCPE Minutes of a Regular Meeting of the Board of Directors, November 1970, Engineers Canada Office, Ottawa: 9.
[277] CCPE Minutes, November 1970, 9.
[278] CCPE Minutes, November 1970, 9.

"serious danger" in this move by the EIC.[279] If all the provincial associations were represented on the EIC Council, "the EIC could, with some justification, claim to have the right to speak on behalf of the engineering profession in Canada."[280]

A motion was moved, and carried unanimously, discontinuing merge discussions with EIC, but reaffirmed CCPE's "willingness to strive for better cooperation and greater unity amongst the various Canadian engineering groups."[281] And then with the new year, discussions with EIC once again resumed with renewed cooperation.[282]

Meanwhile the Canadian Engineering Societies Committee (CESC) had appointed their own task force on Canadian engineering education. This task force was recommending that CESC and its constituent bodies jointly organize a national conference on engineering education "for the purpose of bringing together engineering societies and associations, engineering educators, employers of engineers and other interested parties to discuss the future of Engineering Education in this Country."[283]

Perhaps with CESC's involvement, the cooperation between CCPE and EIC improved. At the following year's CESC meeting, the EIC announced that they would be focusing their activities on their main function: "the dissemination of technical knowledge and information."[284] The EIC planned to "vacate entirely the field of welfare, including its existing insurance programs, employment service,

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[279] CCPE Minutes, November 1970, 9.
[280] CCPE Minutes, November 1970, 9.
[281] CCPE Minutes, November 1970, 10.
[282] CCPE Minutes of a Regular Meeting of the Board of Directors, June 1971, Engineers Canada Office, Ottawa: 21.
[283] CCPE Minutes of a Regular Meeting of the Board of Directors, November 1972, Engineers Canada Office, Ottawa: 7.
[284] CCPE Minutes, November 1972, 11.

etc."[285] CCPE and EIC finally agreed to a joint policy statement in March 1973 that contained a "clear division of responsibilities."[286] "Schedule A" designated the lion's share of responsibilities to CCPE and its constituent associations including: registration, licensing, discipline and enforcement; accreditation of Canadian and foreign engineering programs; provincial and federal legislation and policies; engineering manpower studies; non-technical services for engineers; and, international representation. EIC and its constituent societies would now be solely responsible for: diffusion and development of technical and scientific knowledge; encouragement and recognition of technical excellence; and, international representation in specialized technical or scientific fields. Together, EIC and CCPE would share joint responsibility of: engineering education and training; international representation concerning both technical and non-technical matters; standards and codes; and, other areas not specified.[287] President of the Engineering Institute of Canada, W. Harland, attended the May 1973 CCPE Board of Directors meeting and informed the Board that the EIC had discontinued their competing services with CCPE's constituent associations, including its guidance publication for high school students.[288] He explained that the Engineering Institute of Canada would focus on university-level guidance work, leaving high school outreach to CCPE's provincial associations.[289]

CCPE President Dan C. Lambert expressed his relief.

> The perennial problem of the relations between C.C.P.E and E.I.C., which had plagued our Executive Committees over the past years has, I believe, at last been solved. The

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[285] CCPE Minutes, November 1972, 11.
[286] "CCPE/EIC Joint Policy Statement," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1973, Appendix K, Engineers Canada Office, Ottawa: 1.
[287] "Schedule 'A,'" CCPE Minutes of a Regular Meeting of the Board of Directors, May 1973, Appendix K, Engineers Canada Office, Ottawa.
[288] CCPE Minutes of a Regular Meeting of the Board of Directors, May 1973, Engineers Canada Office, Ottawa: 12.
[289] CCPE Minutes, May 1973, 12.

> working relationship which now exists between the two organizations is excellent. It is based on the theory that, while legal marriage between E.I.C. and C.C.P.E. might be impossible, a common-law relationship may work quite well. In October, 1972, a meeting between the Executive Committees of E.I.C. and C.C.P.E. set the tone for a new era in cooperation.[290]

He went on to announce that Canada would be hosting the 13th UPADI (Pan American Federation of Engineering Societies/Unión Panamericana de Asociaciones de Ingenieria) Congress in 1974.

> I say Canada, rather than the E.I.C., because that is the way the member countries of UPADI regard the invitation. It is an invitation from Canada. More specifically, they regard it as an invitation from the engineering community in Canada.[291]

The program for the Pan-American Conference on Engineering Education announced papers titled: "Canada Tomorrow." "A Historical view of engineering education in Canada how it began and how it developed to the present with special reference to how it responded to local societal needs." "Is Today's Product from the Engineering Schools meeting the needs of the Country and of the Profession." "The Roles of an Engineering School." "Educating today's Engineering Student to work in the new Social Context of Public Participation in all major technological decisions." "The Technological Component of an Engineering Education."[292]

Now that CCPE and EIC had agreed to the terms of their "common-law" relationship, they could focus on their respective responsibilities toward the Canadian engineering profession. CCPE President N. Gilles Tanguay identified a common challenge shared by CCPE and EIC.

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[290] Dan C. Lambert, "President's Report," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1973, Appendix A, Engineers Canada Office, Ottawa: 2.
[291] Dan C. Lambert, "President's Report," 3.
[292] "XIII UPADI Congress – October 6–12, 1974," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1974, Appendix O, Engineers Canada Office, Ottawa: 1–3.

> There are many engineering organizations in Canada, too many. This proliferation of groups is similar to a cancerous growth that confuse the engineering body, is reducing the efficiency of the engineering family and tends to divide engineers at the benefit of others. It is time to look at ourselves and try to analyze how we should evolve and what kinds and types of organizations we should have and we should belong to.[293]

Tanguay recognized that engineers need representational bodies to cover professional, technical, and business activities. He explained that the legal requirements put the provincial associations and CCPE in charge of professional issues. He went on to detail how EIC, or some other entity, should unify the number of technical societies that exist, but that they are facing challenges with apparent conflicts between the Canadian Society for Electrical Engineering and the IEEE, and between the Canadian Society for Civil Engineering and La Société des ingénieurs civils de France. He went on to advocate for new attention on another engineering sector, stating that "a third national engineering branch should exist for the advancement of the business interests of engineers."[294]

4.3 *Autopoiesis*: Canadian engineering and Canadian engineering education

When we left the Canadian Accreditation Board, they had found a degree of stability but were still careful to side-step concerns the provincial associations might have about jurisdictional authority. They continued their accreditation activities of engineering programs, leveraging their constrained responsibilities to investigate other areas of national improvement. In 1970, the headquarters staff were instructed to publish the activities of the CAB and its responsibilities in the regular news release as to better inform membership of the Board.[295]

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[293] R. Hood, "President's Report," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1974, Appendix A, Engineers Canada Office, Ottawa: 3.
[294] N. Gilles Tanguay, "Report of the President," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1975, Appendix A, Engineers Canada Office, Ottawa: 4.
[295] CCPE Minutes, November 1970, 5.

By 1971, CAB was gaining traction as a more autonomous entity. Ontario officially transferred all accreditation responsibilities within the province to the CAB, although Ontario retained "full authority in the final determination of recognition for registration purposes."[296] The Association of Professional Engineers of Ontario further strengthened the roles of universities in producing engineers, being the first jurisdiction requiring a B.Eng. as a minimum entrance condition to the profession. This move necessitated phasing out the examination program for applicants with bachelor's degrees from outside of engineering programs.[297] This requirement for undergraduate education as eligibility to enter the profession was not universally embraced, however. Nova Scotia, Saskatchewan, Alberta, and Manitoba all rejected a proposal requiring examination candidates to possess a bachelor's degree in any discipline or similar academic experience.[298]

CCPE President J.B. Angel emphasized the organization's focus on education in his annual report, highlighting also the responsibilities of CCPE as service for the engineering community.

> In every province, through the constituent associations, we are interested in primary education; in secondary education; in basic engineering training at university; in continuing education, in accreditation of engineering programs; in the certification of engineers; in granting licenses to practice; in knowing the supply of and demand for engineers; in the financial welfare of engineers; in the admission standards to the profession; in pension and insurance schemes; in the technical and professional development of engineers and in their recognition by society. Yes, we are interested in every engineer and, figuratively speaking, from the cradle to the grave.[299]

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[296] "Semi-Annual Report of the Canadian Accreditation Board," CCPE Minutes of a Regular Meeting of the Board of Directors, June 1971, Appendix D, Engineers Canada Office, Ottawa: 3.
[297] CCPE Minutes, June 1971, 9.
[298] "Report – 1969 Committee on Admission Standards," CCPE Minutes of a Regular Meeting of the Board of Directors, June 1971, Appendix F, Engineers Canada Office, Ottawa: 2.
[299] J.B. Angel, "Report of the President," CCPE Minutes of a Regular Meeting of the Board of Directors, June 1971, Appendix A, Engineers Canada Office: 3.

So while the policy alignment of formal engineering education as the entry point for the engineering careers had not yet been secured, the vision of education as the foundation to engineering practice was in some minds. CCPE's relationship with EIC had not yet been eked out, but the above quotation appears to have been staking out desirable territory for CCPE that they would later assume responsibility for: education, accreditation, licensing, manpower studies, admission, and member services. While CCPE was still managing issues of unification on many fronts of the engineering profession, activities of the CAB continued with assurance. CAB Chairman I.W. Smith reported that "the Board had gained considerable acceptance amongst Canadian universities during the last year [...] although some obstacles still remained."[300] These obstacles are expounded upon in their May 1972 report.

Despite an upbeat introduction that surveyed how engineering faculties' reception of the CAB had improved, the report outlines a somewhat hostile environment to its operations. "Originally the climate for accreditation of Canadian universities varied from cool to frigid, but I am pleased to report that the climate today is generally favourable," it opened before detailing the setbacks.[301] The Commission on Post-Secondary Education in Ontario had drafted a report asserting that "[a]dmission to professional practice in Ontario, should be judged solely on the basis of written and oral examinations and experience. There should be no exception from examinations because of degrees of diploma held."[302] The CAB understood such a statement as striking "precisely against the purpose of C.A.B.

[300] CCPE Minutes of a Regular Meeting of the Board of Directors, May 1972, Engineers Canada Office, Ottawa: 13.
[301] "Semi-Annual Report of the Canadian Accreditation Board," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1972, Appendix D, Engineers Canada Office, Ottawa: 1.
[302] "Semi-Annual Report CAB," May 1972, 1.

accreditation."[303] They warned that "the interface between C.A.B., the Associations and the Institutions, will be at times, severely strained during the next two years" as the CAB undertook their "massive re-accreditation of programmes."[304] Optimistically, the CAB saw that through this process of re-accreditation that they would clarify the different expectations of engineering education by universities and provincial regulators, identifying the "relationship between what universities want to provide as engineering education and what the profession needs for registration."[305] Imagining a future with a stronger base to support the accreditation process of engineering programs, they reiterated the independent nature of universities and engineering faculties across the country. "Hopefully, too, the myth that C.A.B. seeks to make identical, all engineering programmes in Canada, will die a deserving death."[306] In their semi-annual report, the CAB language remained clear about their status or authority in managing Canadian engineering education. "Because it is advisory in nature, it interacts with the provincial Associations/Corporation and the Canadian education institutions through cooperation."[307]

Entering 1973 and the period of cooperation between CCPE and EIC, the CAB began to manage more organizational issues rather than existential ones. The Director from New Brunswick presented a submission on behalf of the Association of Professional Engineers of New Brunswick (APENB) concerning CAB policy and procedures. Their concerns included Board composition, visiting team composition, evaluation criteria, educational needs of the profession, and

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[303] "Semi-Annual Report CAB," May 1972, 1.
[304] "Semi-Annual Report CAB," May 1972, 1–2.
[305] "Semi-Annual Report CAB," May 1972, 2.
[306] "Semi-Annual Report CAB," May 1972, 2.
[307] "Semi-Annual Report CAB," May 1972, 1.

report confidentiality.[308] APENB straightforwardly recommended greater representation of practicing engineers on the Board, on the visiting teams, and in assessing the education needs of the profession.[309] Their other recommendations were a bit more complex. Their submission took aim at the purported flexibility of CAB's evaluation criteria. They cite CAB policy directly: "the criteria are general and a rigid schedule of regulation has been avoided."[310] They then reported that a recent CAB report to "a provincial university found it necessary to twice apologize for their 'letter of the law' interpretation of CAB criteria."[311] They subsequently recommended that CAB "avoid rigid interpretations of criteria," to recognize regional diversions in programs, and to allow engineering programs to innovate or experiment.[312]

APENB further outlined concerns regarding confidentiality of accreditation. They argued that the provincial associations have a vested interest in the accreditation of engineering programs at local universities. APENB stated the situation plainly, that provincial associations "must at all times be fully informed" of the accreditation status of degree programs in their province, including program deficiencies.[313] Only by openly sharing this accreditation information with the provincial associations can provincial associations help universities meet the goals outlined in the accreditation report.[314]

They recommended that all CAB reports to universities on accreditation status be forwarded to the relevant provincial association. The Directors from British

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[308] CCPE Minutes, May 1973, 5–6.
[309] "Submission of APENB to CCPE Concerning the CAB," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1973, Appendix E, Engineers Canada Office, Ottawa.
[310] "Submission APENB CCPE CAB," May 1973, 2.
[311] "Submission APENB CCPE CAB," May 1973, 2.
[312] "Submission APENB CCPE CAB," May 1973, 2.
[313] "Submission APENB CCPE CAB," May 1973, 3.
[314] "Submission APENB CCPE CAB," May 1973, 3.

Columbia, Saskatchewan and Manitoba supported the New Brunswick submission. The Directors from Ontario and Nova Scotia, however, expressed serious reservations concerning some of these recommendations.[315] The submission passed to the Executive Committee and the CAB for further study and to make recommendations.

Later that year, the CAB presented their findings on the New Brunswick submission. While the CAB agreed in principle with the recommendations of the submission, they edited the recommendations for the Board of Directors. They reported that it had proven difficult for the CAB to find non-academic engineers for their visiting teams.[316] Since the accreditation visiting teams already require an academic specialist for each department, including non-academic engineers would increase the costs of CAB operation by an estimated amount between $2,500 and $3,000 per year, an additional four cents per member.[317] Concerning the confidentiality of CAB reports, the CAB and the Executive Committee agreed that the CAB could not share reports directly with provincial associations.[318] However, they admitted that the CAB could urge universities to share their reports with provincial associations, suggesting that the local associations may be able to assist when program improvements were needed.

The CAB presented their five recommendations to the Board of Directors, with the Board of Directors choosing not to pursue the additional costs of non-academic engineers on the accreditation visiting teams. The other four motions

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[315] CCPE Minutes, May 1973, 6.
[316] CCPE Minutes of a Regular Meeting of the Board of Directors, November 1973, Engineers Canada Office, Ottawa: 4.
[317] "Canadian Accreditation Board New Brunswick Submission," CCPE Minutes of a Regular Meeting of the Board of Directors, November 1973, Appendix C, Engineers Canada Office, Ottawa: 2.
[318] "New Brunswick Submission," November 1973, 3.

carried included: changing the composition of the CAB to include non-academic engineers; revising evaluation criteria prior to the second round of accreditation; adding the interchange of educational needs of engineering to the CCPE agenda, and; urging universities to share their CAB reports with their governing associations.[319]

Aligning the functions of universities and provincial associations nationally when it came to engineering education had been nearly exhausted by the CAB at this point, but required further pushes. The Executive Committee and the Canadian Accreditation Board were in agreement that the CAB was not responsible for broad investigation of engineering education, conceding this role to the CCPE and the provincial associations themselves.[320]

Earlier that same year, CCPE President Dan C. Lambert addressed the ongoing struggle for unified action, calling out what he saw to be a somewhat empty, yet dangerous, threat by certain members. Acknowledging the political climate of post-confederation Canada, Lambert points out a trend that had "perturbed" him over the last few years: "it has become a fashionable thing in the government of our land for the provincial governments to demand more and more powers and the freedom to exercise them."[321] He explained that provinces increasingly viewed themselves as "sovereign territories" with little regard for what happens beyond their borders.[322] This approach to governance, he continued, undermines the federal government's ability to "retain any vestige of government in the national interest," as provinces must first act in their own interests.[323] In his mind, the

[319] CCPE Minutes, November 1973, 5.
[320] CCPE Minutes, November 1973, 6.
[321] Lambert, "President's Report," 4–5.
[322] Lambert, "President's Report," 5.
[323] Lambert, "President's Report," 5.

politics of confederation likewise elucidated the politics of Canadian engineering. "It is obvious that CCPE exists, just as Canada exists as a country, because the Provinces have united to form such an entity."[324] Such an arrangement, Lambert argued, also served provincial interests as CCPE provided the opportunity to address national engineering policy.

> It is my opinion that CCPE is needed by the engineering profession as a national forum where matters of national policy may be decided. This does not preclude unilateral action by any one association. On the contrary, unilateral action is frequently taken by a constituent member. However, the fact that there is a national forum, a common meeting of the minds, should give each association some cause for contemplation when unilateral action is being considered. Is the action good for the profession or only for the association initiating it? What inconveniences will there be to other members of the engineering profession in Canada? And yet, unilateral action in many instances may be the first step in a new direction which will benefit the profession in general. The feeling I have is that, as long as the Association/Corporation are on record as wanting a national body in the form of the CCPE, some restraint on unilateral action should be exercised to the extent that unilateral legislation which is restrictive to other members of CCPE should be avoided.
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> There is no thought in my mind that CCPE should attempt to be an independent national organization. Under the present rules this is neither possible nor desirable. CCPE is wholly dependent upon the engineering profession through the associations/corporation for the very lifeblood of its existence - its financing. Without this financing, little of the present work load of CCPE could be accomplished. The constituent members of CCPE have determined that CCPE is a desirable and viable organization. Otherwise it would not exist. To exist and function efficiently CCPE must be assured of financial support from the profession on a continuing basis.
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> On more than one occasion in recent years a Director has indicated that his Council may or may not appropriate the necessary funds to CCPE pending the approval of CCPE of certain proposals or subject to the disclosure of certain detailed budgetary information. I find this sort of pressure to be not only embarrassing but also not in the best interests of the engineering profession.
>
> I can well understand that the financial lever is, for some people, an almost irresistible tool to employ for ones own ends. But it would appear to me that it should be considered only if the consequences of withdrawing a major portion of the financial support CCPE are thoroughly understood.
>
> The financial budget of CCPE is carefully prepared and actively monitored throughout the year. All aspects of the disbursement of these funds are reviewed to ensure possible economies do take place. In my opinion any unilateral threat to withdraw financial

[324] Lambert, "President's Report," 5.

> support from CCPE is an expression of a desire for the destruction of CCPE. I do not believe the Associations/Corporation wish this to happen.[325]

R. Hood, the following year's CCPE President, provided a more optimistic tone in their annual address about cooperation between the provincial associations and CCPE, noting 1973–1974 as a potential turning point in CCPE's endeavour of becoming an "effective national body for the engineering profession."[326] Hood named the successes CCPE had achieved in responding to government policies affecting Canadian society and the profession: a science and engineering policy for Canada, amendments to the Competitions Act, changes to the Immigration Act, and an industrial strategy for Canada.[327] He conceded that the results of these efforts were not yet determined, but that, at the very least, CCPE had had "a substantial influence in the final implementation."[328] Further to these policy developments, CCPE had created a "more viable profile for the engineering profession" to inform "forward looking policies" at the federal level.[329] The purpose of this profile was not "based on a self interest benefit for the profession" but a commitment to "provide leadership" in improving the "standard of our society" that is "very dependent on engineering innovation."[330]

Hood was pleased to provide an update regarding the joint agreement with the Engineering Institute of Canada, and that the first year of cooperation had been a success at "removing the multiplicity of voices representing the engineering profession in Canada."[331] He hoped that similar agreements could be reached with other engineering organizations, like the CESC and ACEC.[332]

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[325] Lambert, "President's Report," 5–6.
[326] Hood, "President's Report," 1.
[327] Hood, "President's Report," 1.
[328] Hood, "President's Report," 1.
[329] Hood, "President's Report," 2.
[330] Hood, "President's Report," 2.
[331] Hood, "President's Report," 2.
[332] Hood, "President's Report," 2.

> The benefits to our society of having a coherent and strong profession and Canadian based technical community is obvious to the leaders outside the profession and it is imperative that we strive to make it just as obvious to the members of our profession.[333]

R. Hood eventually turned his attention to the CAB.

> The Canadian Accreditation Board will have completed its first round of accreditation this year and those who have been involved in this unifying program deserve the thanks of every professional engineer in Canada. However, it is important that we do not let the experience gained in this work be lost, and that the profession, the CAB and representatives of academic communities convene a meeting as early as possible to review the activities of the Board, assess the strengths and weaknesses of its operation, re-identify their objectives on the future needs of the engineering profession and, where necessary, modify the terms of reference of the Board.[334]

In 1974 the CAB report was published and made publicly available for the first time, despite protests from the CAB itself.[335] Clearly, the provincial associations still exerted a great deal of control over the functions of CCPE.

Despite a lack of consensus on many aspects of the CAB's function, however, questions of whether the CAB, or the CCPE for that matter, should even exist in the first place had subsided. Though debates over what engineering was and who was responsible for that determination continued. And again, engineering education played a crucial role.

New Brunswick Director Eric C. Garland announced that as of May 15, 1974, the Legislature of New Brunswick was the first province to approve a new Engineers' Act that incorporated the "model definition of engineering" developed by the Committee on Uniform Definition of Engineering.[336] Not all provinces approved the initiative though, with G.A. DePauw from the Manitoba association noting their preference for a "detailed listing of works reserved to professional

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[333] Hood, "President's Report," 2.
[334] Hood, "President's Report," 4.
[335] "Semi-Annual Report of the Canadian Accreditation Board," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1974, Appendix D, Engineers Canada Office, Ottawa: 3.
[336] CCPE Minutes, May 1974, 10.

engineers."[337] More resistance to the uniform definition concerned engineering education. Included in this uniform definition of engineering was the "teaching of engineering at an advanced level."[338] The Director from New Brunswick, Edward D. Stephenson, noted that staff from the University of New Brunswick raised "considerable opposition [...] on the basis that this constituted an infringement on academic freedom."[339]

However a September 1975 report to CAB from the "CAB Committee to Study the Teaching of Advanced Level Courses in Engineering" recommended precisely that: a requirement of those teaching advanced engineering courses to be registered as professional engineers.[340] Citing a number of points—the primary objective of undergraduate engineering education is to "prepare students for engineering practice," engineering subjects should be taught by "the most able and competent people," the CAB already had established criteria for accrediting engineering courses—the Committee recommended that courses in engineering science, design and synthesis be taught by professional engineers.[341] They further recommended that both those immediately responsible for engineering programs and all deans or associate deans of engineering programs be registered professional engineers.[342]

The recommendations accompanied the revised policy statement, terms of reference, and evaluation criteria submitted by the CAB to the CCPE Board of Directors in November 1975. The motion was carried with only one vote against,

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337 CCPE Minutes, May 1974, 10.
338 CCPE Minutes, November 1974, 19.
339 CCPE Minutes, November 1974, 19.
340 "Report of the CAB Committee to Study the Teaching of Advanced Level Courses in Engineering," Appendix "2," CCPE Minutes of a Regular Meeting of the Board of Directors, November 1975, Appendix I, Engineers Canada Office, Ottawa: 2.
341 "CAB Teaching Advanced Courses Engineering," November 1975, 3.
342 "CAB Teaching Advanced Courses Engineering," November 1975, 3.

from the Director for New Brunswick.[343] Representatives from New Brunswick were still dissatisfied with the terms of reference that did not adequately represent engineering industry on the Board and the visiting teams.[344]

The National Committee of Deans of Engineering and Applied Science similarly expressed opposition to the direction the Canadian Accreditation Board was heading. The Board of Directors had decided to charge universities a fee for accreditation: $300 per visitor, and up to $500 per program.[345] CCPE rescinded its cost-sharing proposal, assuming the full costs of accreditation for the 1976 budget.[346]

The recently accepted new terms of reference for the CAB attempted to explicitly address the concerns of universities and the provincial associations that had dogged their activities since their inception. Before listing the accreditation criteria for engineering curricula, the terms of reference clarified:

> The following criteria are intended to be used as guidelines only, and are open to reasonable interpretation by accredited teams.
>
> An accredited degree program, including its advanced standing policies, should normally include the following contents (based on a nominal four-year Bachelor's degree program. In some provinces, advanced standing policies are deemed to apply in the case of engineering programs that are nominally less than four years).[347]

The terms of reference then provided written descriptions of engineering curriculum using the year/half-year measurement system that would endure for 20 years until, in 1996, "years" were replaced by "accreditation units." These

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[343] CCPE Minutes of a Regular Meeting of the Board of Directors, November 1975, Engineers Canada Office, Ottawa: 12.
[344] CCPE Minutes, November 1975, 12.
[345] CCPE Minutes, November 1975, 13.
[346] CCPE Minutes, November 1975, 14.
[347] "Terms of Reference," Appendix "1," CCPE Minutes of a Regular Meeting of the Board of Directors, November 1975, "Semi-Annual Report of the Canadian Accreditation Board,"Appendix I, Engineers Canada Office, Ottawa: 7.

descriptions of year/half-year measurements were followed by the first appearance of Figure 3.1 I could find on record.

The disclaimer of generality returned in CAB's first published annual report from that year, assuring universities and provincial associations that the:

> criteria presented below are intended to serve only as an outline of requirements of degree programmes acceptable to the Provincial and Territorial Associations/Order for registration purposes. The intention is to provide general criteria, and not to present an inflexible detailed schedule of regulations.[348]

This wording remained relatively unchanged as of 2018:

> The criteria for accreditation are intended to provide a broad basis for identifying acceptable undergraduate engineering programs, to prevent over-specialization in curricula, to provide sufficient freedom to accommodate innovation in education, to allow adaptation to different regional factors, and to permit the expression of the institution's individual qualities, ideals, and educational objectives. They are intended to support the continuous improvement of the quality of engineering education.[349]

But, since the 1995 report, this disclaimer—this reassurance of leniency, flexibility and openness—has preceded rather detailed instructions on how to calculate precisely the accreditation units for each aspect of engineering curricula. And as of 2008, it has further preceded the desired twelve graduate attributes that engineering programs must demonstrate their students possess for accreditation status.

Self-reflection of the system, in its abstraction and specification, increases in correlation with increasing differentiation of its function from other systems.[350] From the middle of the 20th century through the first decades of the millennium, Canadian engineering education as a policy tool became increasingly differentiated and organized, concentrating attention and action on accreditation,

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348 "CAB 1st Annual Report," 11.
349 "CEAB 2018 Accreditation Criteria and Procedures," Engineers Canada (2018): 12.
350 Luhmann and Schorr, *System of Education*, 399.

curricula, and graduate attributes. These, occasionally successfully implemented, reforms sought to redress perceived problems with engineering education. The impetus for reflection is brought about by a difference, the difference between the current situation and "what takes place in the societal environment otherwise."[351]

But these reforms, imagining a future where engineering education is better, produce a present where engineering education is, by comparison, worse.[352] This selection is produced by the system itself. Better education does not exist outside the system, in the environment, shaking the current system awake. Instead, the system produces its own future targets of reform through reflection, simultaneously producing a better and a worse education. If the Canadian engineering profession did indeed leave behind worse versions of engineering education through the successes of the CEAB, has it substantively moved towards better education? I consider obstacles to changes in the engineering system in the next chapter.

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[351] Luhmann and Schorr, *System of Education*, 399.
[352] Baraldi and Corsi, *Niklas Luhmann*, 96–97.

CHAPTER FIVE

"WE MUST DEAL WITH THIS ISSUE OR IT WILL COME BACK TO HAUNT US."

SELECTIONS AND PERTURBATIONS

In this chapter, I investigate an unavoidable aspect of Canadian engineering culture: gender. Public perceptions of engineering's gender imbalance and the meagre improvements of said imbalance over decades of work to ameliorate the situation are fundamental to understanding the system of engineering in Canada. Positioning engineering education policy as engineering practice means that engineers do quite literal gender work as they engineer gender policies.

The politics of the Polytechnique terrorist attack extend from legislation concerning firearms and domestic violence to the imagined communities of Canada, and Canadian engineering. They further overlap with the politics of confederation and conceptions of Québecois nationhood during a time of intense antifeminism. These political dimensions are amplified considering Canadian engineering's organizational and financial ties with resource extraction industries and settler colonialism.

Traditional gender structures guide Canadian engineering. Concerns regarding women's representation in Canadian engineering were notably absent from Engineers Canada's historical records until 1989, the year of the Polytechnique massacre. Even following the mass murder of women in an engineering school, progress on improving women's representation and experiences within Canadian engineering has been markedly slow as Canadian engineering continues to be considered a profession dominated by men.

While efforts to address women's representation in engineering have improved since 1989 with scholarships and other diversity initiatives and targets, they largely do not address fundamental selection processes of Canadian engineering. In a Luhmannian sense, until women are selected for engineering in equal proportion to men, the gender hierarchy will persist.

Confronting the gender hierarchy in engineering through diversity or other initiatives to improve women's representation, while still marginal, exceeds simply sustaining a profession dominated by men. Targets like 30% by 2030 show a demonstrable effort to resist dominant power structures.

Despite the internal attention from women and men in engineering to improve women's professional representation, something appears to fight back. Is it the engineering system? Is it the gender hierarchy system? In pondering Luhmannian "perturbations" to the engineering system, identifying the selection of women out of engineering from their entrance to engineering culture via university program admissions elucidates how the system might impede educational reforms in spite of the best of intentions.

5.1 A national tragedy

> We could define entropy as a measurement of the disorder in a system. Any system that is subject to pressure from its external environment will undergo a conversion that results in imbalance and a transfer of energy. For example, water in a pot on the stove starts to move and change into steam. If we put a lid on the pot, the steam lifts the lid, which falls back down only to be lifted again and again until there is no more heat or no more water. At the microscopic level, this transfer of energy results in increasing molecular agitation, which we call entropy. […]
>
> Order cannot be restored until maximum entropy is achieved. […]
>
> On a more metaphysical level, the universal law of entropy also tells us that any isolated system, left on its own, is inevitably destined to irreversible degradation, to the point of self-destruction.[353]

[353] *Polytechnique*, directed by Denis Villeneuve (2009; Montréal: Alliance, 2009), DVD.

So lectures the person at the front of the classroom. Following a late arrival's walk to their seat in black and white, the camera pans across the audience of engineering students, revealing an older man half-seated on a desktop to one side of the room.

Figure 5.1. Jean-François joins Valérie and Stéphanie at the back of the class.[354]

The lecturer, a graduate student or teaching assistant perhaps, is then interrupted by the central horror of Denis Villeneuve's *Polytechnique*.

Not long before the gunman entered this classroom and preceded to separate the women from the men, instructing the men to leave, did our protagonist, Valérie, suffer a misogynistic slight during her interview for a mechanical engineering internship; the interviewer kindly expressed that civil engineering, rather than a career in aeronautics, would be easier for raising a family. "We're looking for candidates who won't quit…" he trailed off, letting the silence complete the unsayable. "And what did you say?" her friend inquires, walking to lecture afterwards. "Nothing. What could I say?"[355]

[354] *Polytechnique*.
[355] *Polytechnique*.

Figure 5.2. Valérie introduces herself.[356]

This violently misogynist world presents a stark contrast with the world the killer sees, the film opens with a reading of the terrorist's suicide letter decrying the advantages women experience in society. He is "enraged by feminists" who "cling to women's benefits, like cheap insurance, maternity leave, preventative leave, while seizing for themselves those of men."[357] While the killer is by no means sympathetic or a character whose observations about reality should be trusted, his ruminations ring increasingly hollow as the action proceeds and we see men easily escape mass death simply for not being his targets: women. Villeneuve thematically weaves engineering education, engineering practice, feminism, and misogyny into a coherent cinematic system that showcases both individual experiences and larger cultural forces at play. The murderer's actions, while being the most violent ones depicted on screen, are far from the only sexist elements of the story; the interview, the men-dominated institutional spaces, anti-feminism, and narratives of heroism are as much a part of this world as gun

[356] *Polytechnique*.
[357] *Polytechnique*.

violence and crises of masculinity. And although the characters in Villeneuve's telling are fictional, the suicide note and the massacre were very real.

"Campus Massacre." "Gunman kills 14 women before shooting himself." "'You are all feminsits!' he shouts as he fires." "13 wounded at Université de Montréal in hospital." "Killer smiled, then told men to leave."[358] These are the headlines that covered the front page of the Montreal Gazette the day after the attack, surrounding the infamous photograph by Alan McInnis. The province of Québec observed three days of mourning in the days following December 6, 1989. A funeral for nine of the women was attended by the Governor General and Prime Minister Brian Mulroney. The Polytechnique massacre was the second deadliest school shooting in North America at the time, and was the deadliest mass shooting in Canadian history until 2020.[359] The tragedy reverberated through other aspects of Canadian society: the aftermath saw political discussions concerning gun control, violence against women, popular media, and children's toys. The legacy of the massacre lives on as December 6th marks the National Day of Remembrance and Action on Violence Against Women.

If ever there were a singular event that could be described as cause for mass reflection, that of the national tragedy would surely qualify as possessing such a level of significance. The national tragedy is shared, among a *national* community. The national tragedy is dated, we live in the time *following* the tragedy. The national tragedy is storied, remembered and retold. The national tragedy unites, political and personal interests overlap. The national tragedy

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[358] *Montreal Gazette*, December 7, 1989.
[359] At the time of writing, three of the five deadliest school shootings in North America (United States and Canada) have occurred at engineering schools. Since 1966, two different engineering schools have been the deadliest site of a school shooting: University of Texas, 1966, and Virginia Tech, 2007.

undeniably changes things. That much is clear. But as to what reflection *on* the national tragedy produces, that connection is much noisier.

When beginning this line of inquiry, I fully expected to see some significant change in the archive following the events of December 6, 1989. What I did not expect was how exactly this difference would appear in the historical records, and what sort of story I might be able to piece together from the documents. The narrative cobbled below is disappointingly short. Certainly the limitations of the documents available to me hamper a more fulsome account of any grand changes that may have resulted from the terrorist attack. These records do not show what was said in offices or in communiqués, or presented at a meeting off the record. Nor can they alone explicate staff and membership motivations and connect organizational or policy decisions to tangible outcomes.

But, material shortcomings aside, the noticeable lack of record about women in Canadian engineering in the meeting minutes of CCPE prior to 1989 is stunning. I have found one single reference to examining women's representation in engineering, and it shows up, oddly enough, at the November 1989 meeting of the Board of Directors, fewer than two weeks before the Polytechnique massacre. Claudette MacKay-Lassonde, chairman of the Canadian Engineering Manpower Board (CEMB), presented her report "A Profile of the Engineering Community in Canada" to the CCPE Board of Directors.[360] MacKay-Lassonde provided an overview of the CEMB publications, which included the Canadian Engineering Manpower Inventory (CEMI) DataBook that in turn included "a special section

[360] CCPE Minutes of a Regular Meeting of the Board of Directors, November 1989, Engineers Canada Office, Ottawa: 14.

on women in engineering and salary data."[361] No further details were elaborated upon here in the appended presentation. After Mrs. MacKay-Lassonde's report had been formally received and approved by the Board, a discussion followed concerning statistics on women in engineering. G.E. Laliberte, Director of APEM, "commented that Statistics Canada has mixed other disciplines when dealing with engineering data on women."[362] Mrs. MacKay-Lassonde responded that the CEMI "has a much more detailed way of handling data on women in engineering and therefore will be more accurate."[363] But once again, no data or significance of any data, are discussed or presented on the record. Outside of this exchange, I found no other mention of women as a group within engineering through any of the meeting minutes or other documents and reports to which I had access.

Following the incident at École Polytechnique, some acknowledgements can be found within the available documents although if there were discussions about women in engineering, they are elided in the transcriptions. At the first Board of Directors meeting after the massacre, CCPE took action as Trustee of the 1989 Canadian Engineering Memorial Foundation—an organization to commemorate those women who were murdered and support women in engineering—encouraging CCPE membership to contribute to the fundraising campaign.[364] Only one other response registered in the recorded minutes here. And even when referenced directly, the discussion of the massacre was rather oblique. D.G. Laplante, CCPE executive director, who likewise attended the funeral in Montréal restrained his thoughts on the situation if he had any to share.

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361 "Progress Report of the Chairman of the Canadian Engineering Manpower Board," CCPE Minutes of a Regular Meeting of the Board of Directors, November 1989, Appendix A, Engineers Canada Office, Ottawa: 1.
362 CCPE Minutes, November 1989, 15.
363 CCPE Minutes, November 1989, 15.
364 CCPE Minutes of a Regular Meeting of the Board of Directors, June 1990, Engineers Canada Office, Ottawa: 22.

> Mr. Laplante outlined the major point of his report by mentioning the importance of the work of the CCPE Committee on Professional Issues, CCPE's Activity Plan which outlines the many activities of the three Boards, CCPE's increasing visibility as an authority regarding the supply and demand of engineers, involvement in the Outlook on Engineering Study, revision of the Labour Market Survey, national insurance programs with 47 million dollars in premium from participants. He then outlined briefly meetings with federal ministers, visits with representatives of NCEES, NSPE, ABET, WFEO and UPADI. It is CCPE's objective to have a Canadian representative on each of the WFEO and UPADI committee. He then reported on his attendance at the funeral of the fourteen students of the Ecole Polytechnique. For the future, Mr. Laplante expressed hope that Canadian engineers will strive to keep the high standards in their profession and thanked the constituent associations for their support.[365]

Despite this rather tepid acknowledgement internally to CCPE, the École Polytechnique massacre is referred to elsewhere as a major source of departure within the engineering community. The Canadian Committee on Women in Engineering (CCWE) was formed in 1990 and acknowledged "one catalytic event" as an impetus for their inaugural investigation of women in engineering: the mass murder of women at École Polytechnique.[366] And while gender issues had thus far been missing from CCPE documentation, beginning with the formation of the CCWE, one can begin to trace a history of Canadian engineering's reflection on women's representation through CCPE. And while the successes of this work remain limited, the CCWE's formation that resulted from the Montréal Massacre, at the very least, literally put women's issues on CCPE's agenda. Given the clear significance of this event for the Canadian engineering system, how might one understand this event in Luhmannian terms? Is it a disruption or perturbation of the system? Is it a response of the system itself?

In this chapter, I study Luhmann's concepts of selection and perturbation through developments in Canadian engineering concerning women's representation and

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[365] CCPE Minutes, June 1990, 5.

[366] "More Than Just Numbers: Report of the Canadian Committee on Women in Engineering," Canadian Committee on Women in Engineering, April 1992, "Introduction," https://www3.carleton.ca/cwse-on/webmtjnen/repomtjn.html.

organization. First, I chronicle CCWE and their recommendations to CCPE regarding women in engineering, and the policy work of CCPE in the decades that followed concerning women, ending with the 30 by 30 goal. Second, I take the Polytechnique massacre and the policy work described earlier together and relate them in Luhmannian terms. How might his concepts of perturbation and selection redirect efforts to better reflect on structural changes to the engineering profession to include women? How well does Luhmann's analysis of education apply to understanding events in the education system?

5.2 "Why does Canada need more women engineers?"

On February 23, 1990, Parliamentary Secretary to Minister of State of Science and Technology, Suzanne Fortin-Duplessis, addressed parliament:

> Madam Speaker, yesterday I accompanied the Minister of Science and Technology and the Member for Outremont to the polytechnic school to present engineering students with Canada Scholarships. I took this opportunity to let the public know about the private sector project supported by the Minister of Science and Technology and the Minister of Employment and Immigration, whose purpose is to increase the number of women in engineering.
>
> This project will focus on: the supply of and demand for engineers and the importance of women for supply; the prejudices and challenges faced by women at every level of training and in the workplace; attitudes and practices of peers and institutions affecting women engineers; obstacles, in particular at the school level, blocking women's access to that profession.
>
> This program will be headed by four organizations: the Canadian Council of Professional Engineers, the Association of Universities and Colleges of Canada, the Canadian Manufacturers' Association and the Association of Consulting Engineers of Canada. Representatives of women engineers associations, engineering students, university professors, engineering faculty deans and colleges will sit on the 15 member adjustment steering committee that will manage the 18 month project. In addition, the private sector will be represented by the SNC Group, Noranda and General Electric.
>
> An important conference will be held in the spring of 1991 to consider the preliminary findings. The final report and action plans will be made public before the end of 1991.[367]

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[367] Canada, Parliament, House of Commons, Debates, 34th Parliament, 2nd Session, February 23, 1990, https://www.lipad.ca/full/1990/02/23/1/#3815185.

The project to which Fortin-Duplessis announced was the formation of the Canadian Committee on Women in Engineering and their subsequent investigation, public fora, conference, and published report. CCWE was funded largely by Employment Immigration Canada's Industrial Adjustment Services and Industry, Science and Technology Canada.[368]

Years earlier, Dalcor Innoventures Ltd. had been hired by CCPE to produce a labour market study on engineering called "Engineering The Future: A Report on the Availability of Engineers in Canada." A 1988 CEMB presentation mentioned Dalcor's potential involvement with an engineering demand forecasting model.[369] In another presentation by CEMB in May of 1989, they listed CEMB's products including "studies related to engineering manpower/demand phenomena" and "employment equity information," although nothing about women or women's representation was mentioned.[370] So preceding the events of December 1989, it appears that there was some interest on the part of CCPE to investigate the supply and demand of engineers, and that this may have been connected with "equity" in some capacity. While it is difficult to determine the extent to which women's representation in Canadian engineering may have been a burgeoning concern for the CCPE prior to the mass shooting, it most certainly became one after the fact. The announcement by Suzanne Fortin-Duplessis above indicated that the "supply" of women engineers as an important component of CCWE's work.

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[368] CCPE Minutes of a Regular Meeting of the Board of Directors, November 1990, Engineers Canada Office, Ottawa: 24.

[369] "Report of the Incoming Chairman of the Canadian Engineering Manpower Board," CCPE Minutes of a Regular Meeting of the Board of Directors, November 1988, Appendix "A," Engineers Canada Office, Ottawa: 5.

[370] "CEMB Annual Report," CCPE Minutes of a Regular Meeting of the Board of Directors, May 1989, Appendix A, Engineers Canada Office, Ottawa: 5.

Having been formed earlier in 1990, CCWE updated the CCPE Board of Directors at the November meeting on the status of their report as their work progressed.

> Consultants are in the process of being hired to prepare using the case [study] technique, an evaluation of policies which are successful in attracting women to engineering and to suggest appropriate procedures to redress the historic under-representation in Canada of women in engineering. The Committee's final report is due next Fall.[371]

The CCWE went on to organize six regional public fora from Autumn 1990 through Spring 1991 (Ottawa, West Coast, Montreal, Prairie, Ontario, and Atlantic) and a national conference in May 1991. Over 240 people attended the conference in Fredericton, two-thirds of whom were women.[372] The final report of CCWE was further presented to the Minister of Employment and Immigration Canada at the time, Bernard Valcourt.[373]

In their final report, the CCWE stated their mandate simply: less than four percent of registered professional engineers in Canada in 1991 were women, and they were tasked to both uncover barriers and "design bridges" to women's full participation in the profession.[374] Positing that "there is no physical or intellectual barrier to women entering the engineering profession," they acknowledged the Polytechnique massacre catalyzing their work.[375] They further referred to an earlier 1990 consultant report by Dalcor predicting a shortage of Canadian engineers by the year 2000 due to: relatively decreasing engineering enrolments

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[371] CCPE Minutes, November 1990, 24.
[372] "The Canadian Committee on Women in Engineering," CCWE, "More Than Just Numbers: Report of the Canadian Committee on Women in Engineering," April 1992, Appendix A, https://www3.carleton.ca/cwse-on/webmtjnen/appa.html.
[373] CCPE Minutes of a Regular Meeting of the Board of Directors, May 1991, Engineers Canada Office, Ottawa: 29.
[374] "More Than Just Numbers," "Introduction."
[375] "More Than Just Numbers," "Introduction."

in university programs, decreasing immigration of engineers, and economic growth.[376]

Despite the CCPE's interest in the future labour needs of the engineering profession, it is not clear that they demonstrated any initiative in advancing women's representation internally. Some have identified the formation of CCWE as emerging strictly outside of the CCPE, as a government-led endeavour to address representation of women in the profession.[377] The Canadian Committee on Women in Engineering was created by Industrial Adjustment Services under the Minister of Employment and Immigration. Further, the agreement included a number of parties beyond the CCPE representing both government and engineering organizations: representing government were both Ministers of Immigration and Employment, and State for Science and Technology, and other engineering parties were the Canadian Manufacturers' Association, the Association of Consulting Engineers of Canada, the Association of Universities and Colleges of Canada, in addition to the CCPE.[378] Again, the meeting minutes do not explicitly demonstrate a connection one way or the other between the CCPE labour demand studies, employment equity data, and women's representation in engineering. It is entirely possible that the CCPE was on the brink of giving attention to gender troubles in engineering before the attack. Regardless of any intent that may be elided in the historical documentation, the CCPE was now involved.

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[376] "More Than Just Numbers," "Introduction."
[377] Jeanne E. Inch, "Educators, Employers and Engineers Design New Bridges for Women in Engineering," (presentation, Women in Engineering ProActive Network (WEPAN) National Conference, Washington, D.C., May 31–June 2, 1992): 84.
[378] CCPE Minutes, June 1990, 32.

Donald G. Laplante, executive director of CCPE, presented some of the terms of the new agreement to the Board of Directors at their June 1990 meeting.

> Under this program, the Industrial Adjustment Service of CEIC is authorized to enter into agreements with provinces, employers and workers in respect of labour mobility, and adjustment incentives. With this agreement, the participating Associations through the facilities of the Industrial Adjustment Services (within the context of available information on the supply of and the demand for engineers) will be able to examine and identify ways to improve the environment in the engineering profession in Canada in order that women will receive equitable treatment as professionals within the engineering community in Canada and women will be attracted to and remaining in the engineering community.[379]

Explaining the program, Laplante again linked the future needs of the engineering profession and labour forecasts for Canadian engineers to women's "equitable treatment" so that they may be attracted and retained in increasing numbers. And while it appears somewhat callous that women's representation and experiences in engineering were not treated as important in their own rights, one wonders if this rhetorical connection with labour shortages was merely a foot in the door to begin studying the issue in detail.

"Why does Canada need more women engineers?" asked the 1992 Report that was eventually released by the CCWE. "More Than Just Numbers" divided Canadian engineering into four areas of intervention: pre-university engineering recruitment and education, university engineering education, engineering workplaces, and engineering associations. The Committee produced 29 recommendations that were accepted by the CCPE Board of Directors in June of 1992.[380] Along with recommendations from two other reports, "The Future of Engineering Education in Canada" and "The CEHRB/EIC Engineering Outlook Conference," CCPE members Don Laplante, Micheline Bouchard, and Bob

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379 CCPE Minutes, June 1990, 32.
380 CCPE Minutes of a Regular Meeting of the Board of Directors, June 1992, Engineers Canada Office, Ottawa: 20.

Burridge consolidated 104 recommendations for the Board of Directors. They in turn separated these recommendations into five target areas for engineering: gender equity, continuing education, awareness, teachers, and careers.[381] Representatives from the provincial associations then took responsibility to develop action plans including costs and schedules for their respective foci, with the Association of Professional Engineers of Ontario taking responsibility for gender equity.

Out of the 29 recommendations for CCWE's report, 18 concerned education directly. So while only half of the four target areas focus on educational environments per se (pre-university engineering recruitment and education, and university engineering education), the authors overwhelmingly isolated education as a mechanism to enact their desired changes regarding women in engineering. Even those recommendations that concern workplaces, engineering associations, or careers propose change via "awareness," "advisory programs," or "improving the information base."[382] Taking euphemisms for informal education into account left only four of the recommendations as seemingly unrelated to education. These recommendations included: corporate strategies to hire, promote, and provide career development opportunities for women; employer policies for women's career development and promotion strategies; workplace policies to balance family, personal, and professional responsibilities; and, employer workplace harassment policies.[383]

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[381] CCPE Minutes, June 1992, 20.

[382] "List of Recommendations," CCWE, "More Than Just Numbers: Report of the Canadian Committee on Women in Engineering," April 1992, Appendix D, https://www3.carleton.ca/cwse-on/webmtjnen/appd.html.

[383] "List of Recommendations."

After the release of "More Than Just Numbers" and PEO's assumed responsibility of the gender equity file, women in engineering as an organizational topic languished for the following six years in CCPE. Stage One of their National Action Plan on Gender Equity was completed in November 1992, and Stage Two was approved in principle in May 1993. OIQ joined PEO to work on Phase Two but they stalled in attempting to determine which actions CCPE could take.

This delay ran counter to the desires of the CCPE Executive Committee that had compiled five relevant recommendations for the Action Plan that same year. The majority focused on workplace and sexual harassment issues:

> 1. Develop policies regarding sexual harassment and implement complaints procedures which are appropriate to their organization.
>
> 2. Encourage employers of engineers to develop policies regarding sexual harassment for their workplace and should offer support and education in policy development and fair complaints procedures.
>
> 3. Define a Code of Professional Conduct which makes gender fairness an important attribute of professional conduct and which censures harassment and discrimination against clients and colleagues on the basis of gender.
>
> 4. Develop networks of professionals in the areas of alternative dispute resolution and employment equity who can act as referrals for members or employers who require support.
>
> 5. Strive to achieve gender equity through gender-balance in the membership of executives, councils and committees, and the use of gender inclusive language in all documents and awards. Specific initiatives in this area were presented in Part I of the National Action Plan for Gender Equity.[384]

G. Tanguay explained that OIQ could not approve the motion, stating that the recommendations did not do enough to address gender equity, maternity, and promotion. Further, "G. Tanguay commented that OIQ would like to see stage two modified to emphasize problems such as gender equity, women in

[384] CCPE Minutes of a Regular Meeting of the Board of Directors, November 1993, Engineers Canada Office, Ottawa: 9–10.

engineering, promotion and maternity leave, not just sexual harassment."[385] The Board of Directors consequently deferred Stage Two of the National Action Plan on Gender equity to allow "further enhancements" by PEO and OIQ.

The following year, the human and financial resources necessary to investigate equity of women in the profession beyond a focus on sexual harassment had not yet been identified.[386] Desiring to show progress on implementing the National Action Plan on Gender Equity developed by PEO and OIQ, H. Stéphenne reported that OIQ recommended that CCPE appoint a permanent staff member to implement the recommendations.[387] Specifically, this person would contact PEO and OIQ to submit one action that CCPE could implement in the near future.

In March 1996, the Board of Directors decided that they had insufficient funds to carry out the tasks and the plan was not implemented.[388] Instead, a sub-committee was formed to produce an action plan that resulted from a conference in 1995. The Board did approve the completion of this action plan with associated costs, but a final plea from Monica Frize in May 1998 suggested that it would take more effort to keep issues of gender equity in the discussions at CCPE's Board of Directors.

> M. Frize reported that there is a need to address some of the issues. She noted that she understands the transition period has been difficult for CCPE. She suggested that the committee and CCPE work together to get this committee back on its feet. She advised that this issue must be discussed continuously. She noted that female engineers need the committee to give them moral support, and welcome them to the profession. The public must be informed and made to understand the basic needs to achieve a female friendly profession. She went on to say that the profession must show leadership, and provide more visibility to the public. She referred to the much needed budget and the need for the

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[385] CCPE Minutes, November 1993, 9.
[386] CCPE Minutes of a Regular Meeting of the Board of Directors, May 1994, Engineers Canada Office, Ottawa: 6–7.
[387] CCPE Minutes of a Regular Meeting of the Board of Directors, November 1994, Engineers Canada Office, Ottawa: 18.
[388] CCPE Board of Directors Meeting, September 1997, Engineers Canada Office, Ottawa: 17.

> committee to function in 1998 and 1999, including web site space. She referred to the action plan which had been prepared by a sub-committee which is a guideline for associations to adapt to their needs. She requested that the action plan be approved in principle as soon as possible. She indicated that the committee would like to change its name to "National Advisory Committee on Women in Engineering". She concluded by saying that the committee would like to be more visible on the agendas of the meeting of the Board of Directors, to help identify some of the concerns.[389]

After this report by Monica Frize, further mention of women or gender equity in engineering became conspicuously absent from CCPE's meetings for a number of years, only surfacing stochastically over the next ten years when connected to other CCPE initiatives.

February 2000 saw the creation of a medal of distinction for women role models in engineering.[390] But otherwise, CCPE left the work of gender and engineering to the National Advisory Committee on Women in Engineering. This group would subsequently expand its focus from women in engineering to diversity in engineering more broadly, referencing concerns about other underrepresented groups in the profession, namely minorities and disabled individuals. Not all the members of CCPE encouraged this change however, expressing unease "with the extent of the diversity policy and potential dilution of effort and loss of focus on women when implemented."[391] CCPE's efforts were further reduced in this regard with the standing down of CERB in September 2002, rolling its responsibilities under a committee of the CCPE Board.[392] While the Board of Directors had

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389 CCPE Board of Directors' Meeting Minutes, May 1998, Engineers Canada Office, Ottawa: 37–38.

390 Minutes of a Meeting of the CCPE Board of Directors, February 2000, Engineers Canada Office, Ottawa: 8.

391 Minutes CCPE Board of Directors' Meeting, September 2000, Engineers Canada Office, Ottawa: 9.

392 Minutes CCPE Board of Directors' Meeting, September 2002, Engineers Canada Office, Ottawa: 6.

approved the Women in Engineering Policy Implementation Plan in 2001, they had only approved the 2002–2003 in principle, due to budgetary concerns.[393]

CCPE's interest in these initiatives continued to stagnate. The 2002 National Survey of the Engineer Profession asked members zero questions and presented zero information about gender.[394] Reference was made to the "good job in the promotion of women in engineering" by CCPE and the provincial associations, and that "similar effort should be given to Canadian indigenous [sic] groups."[395]

Again, years passed without documented discussion about women in engineering on the part of CCPE. Curiously, in 2004, an agenda item on inclusion concerned the "inclusivity and the inclusion of technicians and technologists" but not of women or other underrepresented groups in the profession.[396]

In 2008, the Women in Engineering Task Force was created by Engineers Canada.[397] This Task Force in particular was a turning point, compared to CCWE in the 1990's, as the motivation and mandate to tackle gender issues in the profession emerged internally from Engineers Canada in the formation and support of this Task Force. The Task Force explained their plan to conduct interviews and investigate how professions like medicine and law were able to achieve parity in gender representation.[398] The next year, the Task Force's recommendations were approved, and their mandate extended first to May 2010

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[393] Minutes CCPE Board of Directors' Meeting, May 2001, Engineers Canada Office, Ottawa: 6.
[394] Minutes CCPE Board of Directors' Meeting, November 2002, Engineers Canada Office, Ottawa: 5–6.
[395] Minutes CCPE, November 2002, 13.
[396] Minutes CCPE Board of Directors' Meeting, May 2004, Engineers Canada Office, Ottawa: 11.
[397] Minutes Engineers Canada Board of Directors' Meeting, October 2010, Engineers Canada Office, Ottawa: 15.
[398] Minutes Engineers Canada, October 2010, 15–16.

and then again to May 2011.[399] The Task Force targeted employers and were in the process of "developing [a] list of attributes that defines employers shown as advancing (attracting and retaining) and supporting women in the profession."[400]

Alongside the Task Force's work, the Engineers Canada Board of Directors demonstrated a renewed vigour in discussing gender equity issues in the profession. For the first time since 1998, actual discussion of the problem of women's representation in engineering was documented in the meeting minutes. One member drew attention to the lack of importance and funding that Engineers Canada had directed towards these issues:

> [G]iven that we have only 10 percent women in engineering, and given that enrolment has decreased, there is concern that we may not be taking this issue seriously enough and have not invested enough money in finding the answers and changing attitudes.[401]

Another echoed the lack of resources devoted to the advisory group, suggesting that gender equity in engineering will have to be dealt with inevitably: "as much as we say we are dealing with this issue, the reality is the problem is huge and the advisory group is under-resourced. We must deal with this issue or it will come back to haunt us."[402] Engineers Canada was seemingly already managing the repercussions of neglect on this file as women's representation had been on the decline since the early 2000s:

> [T]here has been a lot of good work done with respect to this tremendously important issue but since 2001, the percentage of women going into the field of engineering has been steadily declining. Barriers still exist and extensive research has been conducted but it is still a massive problem.[403]

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[399] Minutes Engineers Canada Board of Directors' Meeting, May 2009, Engineers Canada Office, Ottawa: 17. Minutes Engineers Canada Board of Directors' Meeting, May 2010, Engineers Canada Office, Ottawa: 17.
[400] Minutes Engineers Canada, May 2010, 17.
[401] Minutes Engineers Canada, May 2010, 18.
[402] Minutes Engineers Canada, May 2010, 18.
[403] Minutes Engineers Canada, May 2010, 18.

Despite these rather frank and self-aware assessments of the situation, Engineers Canada members did not necessarily see their body as solely responsible to amend gender disparity in the profession: "this is an issue that cannot be tackled solely by Engineers Canada; [...] a coalition of several groups of peoples is required to make an impact."[404]

In May 2011, Engineers Canada had the Women in Engineering Task Force stand down, replacing it with an official standing committee of Engineers Canada and committing to the 30 by 30 initiative.[405] Later that year, the terms of reference for the Women in Engineering committee were approved.[406] The 30 by 30 initiative set the goal of raising the percentage of newly licensed engineers who are women across Canada to 30% by the year 2030. Since collecting data three years previous, Engineers Canada found that approximately 17 per cent of newly registered engineers were women. This somewhat modest goal of 30%, as opposed to, say, parity, may appear determinedly insufficient yet may prove to be an impressive accomplishment when contextualized against three decades of studies and policies to improve women's representation in the profession.

5.3 Selections and perturbations

There is a system and an environment. If indication differentiates a system from its environment, and a functionally differentiated society is comprised of a number of coupled, overlapping, or intersecting subsystems, then the environment attributed to any one subsystem may form part of the system of another. Thus, in a functionally differentiated society, there are environments both internal and

[404] Minutes Engineers Canada, May 2010, 18.
[405] Minutes Engineers Canada Board Meeting, May 2011, Engineers Canada Office, Ottawa: 18–19.
[406] Minutes Engineers Canada Board Meeting, October 2011, Engineers Canada Office, Ottawa: 21.

external to society; selecting elements of society as part of one subsystem, selects other elements of society as part of the environment of that same subsystem. Differentiation always considers the unity of "system and environment."[407] Luhmann's systems theory asks one to consider interaction between the system and its environment. "[W]hat happens when a system that can observe and describe itself is confronted with an external description?"[408]

Luhmann and Schorr probe the relationships between the education subsystem and the state subsystem, "a marriage which was in no way difficult or unhappy at the start."[409] Analyzing the development of university entrance requirements, they identify state, legal and administrative intervention as a "crystallization point for the formation of pedagogical opinion."[410] What was once a parental determination to pursue university education had now been supplanted by this nexus of state and education in the form of a child's test performance.

"Pedagogical selection," according to Luhmann and Schorr, ought to be the subject of pedagogical theory but has been sidelined in favour of testing and "self-occupation of the pupil."[411] By focusing, rather, on the ways pupils manage themselves, pedagogues have obscured selection in education.[412] Testing serves both as a site of state regulation and a method of selection in the education system. Students are selected out of further education due to their (lack of) innate abilities, or how they manage themselves (to study, learn, and perform well on tests). The centrality of the pupil in pedagogical theory therefore enables state intervention in education, and defers responsibility for selection in education onto

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[407] Luhmann and Schorr, *System of Education*, 30–31.
[408] Luhmann and Schorr, *System of Education*, 400.
[409] Luhmann and Schorr, *System of Education*, 267.
[410] Luhmann and Schorr, *System of Education*, 267.
[411] Luhmann and Schorr, *System of Education*, 268.
[412] Luhmann and Schorr, *System of Education*, 268.

pupils themselves. "[C]riteria for better and worse performance are assumed as given, because otherwise one could not recognize deviation; but the criteria are not applied in order to realize the corresponding evaluation, but rather in order to avoid it."[413] This negation of social selection in education—education in democratic societies is for everyone—in fact gives selection predominance over education, abandoning issues of individual justice or forming personal talents.[414]

Equality, then, is introduced. Selection means both utilizing and amplifying existing social inequalities.[415] If social selection is unjust and undesirable for democratic education, then pedagogical reform considers instead implementation programs to achieve equality, as both the negation of inequality and as "protection against having responsibility for selection."[416] By attempting to avoid selection, however, ideologies produce problems of selection (since selection is indeed happening) that are "more intense and more widespread than they ever would have been in the traditional system."[417]

Organizational differentiation of the system enables mobility of individuals within the system. But if this mobility falters, the system responds in kind to restore movement.[418] Of course, by virtue of the, sometimes hidden, selection process, mobility will always falter eventually. The self-observing system that functionally differentiates itself *selects itself*. The system further differentiates itself organizationally to increase its operations. These selections produce problems as the social system and personal systems continue to react to the "contingency of all

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[413] Luhmann and Schorr, *System of Education*, 288.
[414] Luhmann and Schorr, *System of Education*, 288.
[415] Luhmann and Schorr, *System of Education*, 285.
[416] Luhmann and Schorr, *System of Education*, 285.
[417] Luhmann and Schorr, *System of Education*, 297.
[418] Luhmann and Schorr, *System of Education*, 281–82.

situations and to the awareness of selection such that is thus imposed."[419] Immune responses indicate the awareness of selection. The situation intensifies, as both movement and non-movement within the system are selected and observed, and then they affect the system itself.

Symptoms, perturbations, or irritations, depending on the Luhmann text, threaten the system. Since the system cannot interact with the environment directly, these symptoms are felt internally by the system: "a system that is subject to internal pressure to select also reacts more strongly to itself."[420] The "immune response" of the system is carried out through operative processes. Either the perturbation will be subsumed by the system, maintaining the system's identity, or the system will be undone by the perturbation. In the context of education, the major perturbation for Luhmann and Schorr is the unrealized symbolism of equality: "the society in which we live reproduces inequality, and the system of education is merely at the whim of powers that it cannot control."[421] The ongoing observation of inequality in society and in education reproduces educational reforms to achieve equality. When the goal is something other than equality, connectivity to future careers, for example, then the reforms will likewise differ.[422] Regardless, the goals are convincing without even determining whether they are achievable or not. But because they orient action, they are accepted and reflection stops. Education does not reflect on its identity in such an application.[423]

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[419] Luhmann and Schorr, *System of Education*, 282.
[420] Luhmann and Schorr, *System of Education*, 283.
[421] Luhmann and Schorr, *System of Education*, 289.
[422] Luhmann and Schorr, *System of Education*, 297.
[423] Luhmann and Schorr, *System of Education*, 297.

Luhmann and Schorr do offer the possibility that the system can sacrifice control of selection, leaving selection up to chance and the environment, but this would be "nothing less than the sacrifice of autonomy."[424]

Drucilla Cornell applies Luhmann's systems theory to feminist legal reform to argue that gender hierarchy can be understood as a system.[425] Cornell highlights that an important hypothesis of Luhmann's theory is that the transition from traditional societies to modern society marks a transition from primarily stratified to primarily functional differentiation.[426] This postulate on the part of Luhmann could explain why other feminists have been reluctant to apply Luhmann's systems theory to gender analyses; if modern society is characterized by a transition away from stratification, what might one make of the persistence of gendered hierarchy? Cornell responds to this question, stating "the category of functional differentiation may itself disguise the way in which this differentiation can only seemingly be functional, as opposed to stratified, if one implicitly takes for granted the already-in-place gender hierarchy."[427] The example Cornell provides is that of "mommy track" in the legal profession whereby women's "access to the labor market is curtailed by operations of the gender hierarchy."[428] If gender is a Luhmannian system, in Cornell's account, it clearly intersects with other functionally differentiated systems, like the legal system.

Cornell diverges from Luhmann in her own analysis of "irritants," preferring instead the word "symptom" to categorize how a system may accommodate outside systems: "the repressed feminine 'is' only a symptom and, indeed, from

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[424] Luhmann and Schorr, *System of Education*, 299.
[425] Drucilla L. Cornell, "The Philosophy of the Limit, Systems Theory and Feminist Legal Reform," *New England Law Review* 26, no. 3 (1992): 784.
[426] Cornell, "Philosophy of the Limit," 793.
[427] Cornell, "Philosophy of the Limit," 795.
[428] Cornell, "Philosophy of the Limit," 796.

within the meaning given to it in that hierarchy."[429] Borrowing from Derrida, Cornell sees symptoms as the more apt descriptor for the structural couplings between different systems, structural couplings that in part determine system contours.

> Once we understand that no system can guarantee itself against the constant shift of its boundaries because of structural coupling and, I would add, iterability, then we can only understand self-referentiality as a future-oriented aspiration that can never be […] completed. Although this is clearly not Luhmann's own conception of self-referentiality, I believe it is the necessary outcome of understanding just how structural coupling itself is what continually opens every system to its deconstruction.[430]

In many ways, women have not been positively selected for in Canadian engineering. And while the École Polytechnique massacre has been identified by some as a catalyzing event, as a watershed moment, and as a disruption (even I have narrated it as such), a systems theory approach provides an alternative understanding. Considering strongly the social goal of equality in opportunity through education, the lack of women engineers in Canada seems like a strong candidate as a "perturbation" to the system, rather than what might be considered the more shocking system event in the massacre. Certainly the mass shooting had ramifications, it affected social and personal systems alike. But is it better framed as an externality to the system? I see two possibilities: 1. The terrorist attack was a perturbation to the Canadian engineering system, and the system responded to address the problem of the exclusion of women in engineering; or, 2. The selection of men by the system of engineering (the selection of women out of engineering) is obscured by individualizing participation in the system ("entrance requirements," "qualifications," or "cultural fit"), producing a predominance of selection that is hostile towards women.

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[429] Cornell, "Philosophy of the Limit," 798.
[430] Cornell, "Philosophy of the Limit," 801.

Misogynistic actions may be understood as singular transgressions, anomalies that have no part in civil society: "oppressive behaviour will not be tolerated." But these same sorts of acts may likewise be understood as indicators of deep-seated bigotry, indefensible but comprehensible results of entrenched power abuse: "it is not a bug, but a feature."

I wish to tread carefully here, because I think there is merit in both positions and I do not want either to detract from the tragedy of Polytechnique massacre and ongoing violence against women. From a Luhmannian perspective, however, I think the latter route, considering the attack as emerging from a system of engineering, opens the possibility for greater analysis. Simply viewing the mass murder as an aberration, committed by a single operator that consequently spurred serious reflection and reconsideration about women engineering, does not provide much insight into how one might try to improve things. Perversely, saying as much attributes influence for the development of widespread awareness about women in engineering to the tragedy, which feels trite and inappropriate. This position does not preclude the possibility of considering how elements from the environment of engineering—anti-feminism, or even feminism, for example—might shock the engineering system, so I do not see anything lost by moving to another perspective. Taking the pedagogical goal of equality of opportunity seriously and considering the absolutely poor representation of women in Canadian engineering, the selection of women out of engineering seems, to me, to be a more generative place to explain the reactions that followed the Polytechnique shooting.

From this perspective, the exclusion of women from engineering (selecting women for the environment of engineering) was always an elided selection, one that would grow in breadth and intensity.

Further, while the fallout from the Montréal massacre certainly brought a degree of visibility and scrutiny to women's representation in engineering, it does not appear to have significantly altered the system of engineering. Conversely, the state system seemed more altered by reactions to the mass violence: new restrictions on firearms, and laws on violence against women. The funding for the Canadian Committee on Women in Engineering that initiated their important work originated from state agencies external to engineering. And while CCPE partnered with the structuring of the organization and was involved in accepting their recommendations, the apparent fizzling out of the CCWE's mandate within CCPE by the end of 1990s makes one wonder if this would constitute a true perturbation to the system in Luhmannian terms.

On the other hand, considering the process of selection in engineering education and operational differentiation of education within engineering, the circumstances that made the Polytechnique massacre thinkable and actionable to the killer better represent a "blind spot" of engineering caused by the selection problem. Selecting women out of engineering while denying this selection spreads and intensifies the selection operationally. The consequent selection of some women for engineering (through scholarships, mentorship programs, admission targets) then appears as undemocratic, as social selection independent of selection processes that were already in place.

From a systems theory point of view, the mass murderer is not a perturbation to the engineering system, nor is he an immune response to protect the traditional system of engineering. The perturbation was always the selection of women out of engineering in the first place, an action the murderer replicated.

Using this framework highlights contemporary issues within engineering. The deliberate selection of women for engineering while continuing to not to select them by avoiding strict parity targets or quotas suggests a continual failure to resolve the selection problem. The representation of women in Canadian engineering continues to stagnate despite decades of work to make the profession more attractive and hospitable towards women. According to Luhmann's theory, it will not be possible to progress on this file until the selection problem is resolved directly, when the system no longer encounters external descriptions.

Thus far, a Luhmannian perspective has provided a decent scaffold on which we can build an understanding of Canadian engineering education. However, there are still questions remaining about the applicability of Luhmann to this case. "Equality of opportunity can only be realized—at least in democratic states—by increasing opportunities, not by decreasing them."[431] For Luhmann and Schorr, any selection is not in line with the democratic ideal of equality of opportunity "because positive selection is always negative selection for others and vice-versa."[432] Thus selection can neither be an end nor a means to an end in education. Luhmann and Schorr explain directly that a generous admittance policy, for example, under the aegis of equality or to exhaust talent reserves "increases the proportion of failure, drop-outs, and along with that, the frequency of negative experiences with far-reaching consequences among those people who were originally supposed to have been helped."[433] Does this mean that the selection problem cannot be resolved until selection in the social system is resolved?

> Inclusion cannot extend to performance roles—only to their complementary roles: not everyone can become a doctor, but everyone can become a patient; not everyone can become a teacher, but everyone can become a pupil. For precisely this reason, it is not the differentiation within the larger population according to stipulations of function-specific complementary roles that is the key occurrence which breaks apart the class order and makes it impossible for anyone to be classified in one and only one subsystem of the

[431] Luhmann and Schorr, *System of Education*, 297.
[432] Luhmann and Schorr, *System of Education*, 354.
[433] Luhmann and Schorr, *System of Education*, 356.

> society. Thus, inclusion does not mean membership in the society; instead it means that, as the mode of full membership, anyone has the ability to enter any function system.[434]

Maybe, then, CCWE had it right all along to target engineering education when trying to improve women's representation in the profession. Not everyone may be able to become an engineer, but anyone should be served by their work enabled through engineering education.

5.4 Gendered states

By March 31, 1991, the 1989 Canadian Engineering Memorial Foundation's account totalled $463,059.71, a combination of donations and interest. APENB, APEPEI, and NAPEGG had donated to the foundation, and APEM and APEO had solicited their memberships for donations.[435] The largest donor mentioned, however, came from Energy, Mines and Resources Canada at $40,000.00. CCPE used this account to fund three annual scholarships: two $5000 scholarships for one woman entering first-year engineering and one woman entering fourth-year engineering, and one $10,000 scholarship for a team project that attracts students ("particularly women") to engineering to be shared between team members (including men) and their school's engineering student society.[436]

I do not see much value framing these initiatives as negative selection of men, and I am not sure that Luhmann's systems theory would intend such an analysis either. The important problem that Luhmann's theory draws attention to is that selection is central to understanding education and that it happens regardless of intention. Deliberately crafting policies and organizations to select for women in engineering does not correspond to a negative selection of men in a system dominated by men, where men are still overwhelmingly positively selected. The

[434] Luhmann and Schorr, *System of Education*, 37.
[435] CCPE Minutes, May 1991, 33–34.
[436] CCPE Minutes, May 1991, 33–34.

only real concern that bears out of these situations are that, for some, these actions are indeed understood as negatively selecting men, and the varied response to this perception can be used to justify even further discrimination.

Equity, diversity and inclusion initiatives are increasingly popular among engineering faculties. But rather than considering their, admittedly rather small, selection of those poorly represented in engineering for engineering as a negative selection of the traditional system, what else might be negatively selected in concentrating these activities organizationally?

The funding program to support women in engineering education described above brings to light an interesting tension. Profits from resource extraction of Indigenous lands were used to address women's underrepresentation in engineering. Not to place undue scrutiny on these particulars just because they support women—as much of engineering in Canada is closely tied to resource extraction and overwhelmingly supports men—but this scenario demonstrates what might be negatively selected more clearly: an engineering system that functions independently from the traditional system of the state. The identity of the system of engineering remains unchanged even though the identities of those within it do. Integral to the engineering system are the relationships engineering education shares with state administration and traditional social selection via gender hierarchies. A new engineering is possible insofar as a new world is possible.

Valérie, our protagonist from *Polytechnique*, survives the ordeal and her education, pursuing her dream career in aeronautics and eventually having a family. And while the tone is hopeful, it remains a sombre reflection on those who did not survive. Two students committed suicide who attributed their decisions directly to the attack, and Villeneuve shows us one, fictionalized, in the film. The traditional social selection that plays out in engineering, one firmly anti-women, likewise selects others out of engineering.

Scott MacKenzie connects some of the gender tropes presented in *Polytechnique* to conceptions of the nation, arguing that the "specific trope of the Québécois male (and, by extension, the Québécois nation) as emasculated is a longstanding one."[437] MacKenzie points out that *Polytechnique* rather perversely centres two men in its telling, both of whom suffer crises of masculinity, taking their own lives rather than suffer continued emasculation:[438] the killer blames women and feminism for failing to be a successful man, and Jean-François blames himself for failing to save the women during the attack. Both of these narratives in the film were borne out of reality as the killer's suicide note reveals his personal motivations, and many blamed the men bystanders for doing nothing during the attack.[439] Contextualized within Québec's political climate during the late 1980s, the Montréal Massacre takes on more political significance. The Massacre came on the heels of some of the largest feminist protests in Québec's history—along with anti-feminist counter-protests—regarding the Québec Superior Court decision in *Tremblay v. Daigle*.[440] Thus the narrative of *Polytechnique* that universalizes the tragedy among individuals ("we all suffer together") rather than focusing on the collective rights of women mirrors a central political debate in Québec: "the on-going struggle between federalism, which promotes individual rights, and nationalism, which favours collective ones."[441]

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[437] Scott MacKenzie, "It's not Always that Black and White: Universalism, Feminism, and the Monochromatic Worldview of *Polytechnique*," *Canadian Journal of Film Studies* 22, no. 1 (2013): 78.
[438] MacKenzie, "Black and White," 74–75.
[439] MacKenzie, "Black and White," 71.
[440] MacKenzie, "Black and White," 79.
[441] MacKenzie, "Black and White," 80.

What I find the most surprising is how easily the tragedy at École Polytechnique may be reframed to conform to both narratives of nationality for both Canada and Québec. The specifics of 1980s Québécois feminism, anti-feminism, and nationalism signify a different relationship to the event than the Canadian engineering context provides. Yet both may claim the event as theirs. Further, the gender hierarchy or system is contoured differently in the varied locales: society misogyny, Canadian misogyny, Québécois misogyny, and engineering misogyny all intersect when analyzing the Montréal Massacre. Perhaps the clearest lesson one can take from this study, following Cornell's prompt, is that systems are not wholly determined by themselves. Systems collide with other systems. Systems are confronted with external descriptions, as Luhmann says, that cause the system to react. For the system to maintain its identity, the strongest response from the system to the perturbation, be it the system of the state, engineering, or gender hierarchy, is to enrol the perturbation into system operations.

Engineering faculties across Canada willingly display the names of Geneviève Bergeron, Hélène Colgan, Nathalie Croteau, Barbara Daigneault, Anne-Marie Edward, Maud Haviernick, Barbara Klucznik-Widajewicz, Maryse Laganière, Maryse Leclair, Anne-Marie Lemay, Sonia Pelletier, Michèle Richard, Annie St-Arneault, and Annie Turcotte. The perturbation is managed internally to the system. But how willing might these universities be to correct the process of selecting women out of engineering in the first place?

CHAPTER SIX

"ENABLING DR. FRANKENSTEINS"

PROVOCATIONS—AND DISRUPTIONS—AND INNOVATIONS

In this chapter, I return to my analysis of the Engineering Change Lab through a series of vignettes and interviews concerning engineering education culture. I expand the ethnographic data to include other relevant documents while keeping a keen eye on the ECL's somewhat novel approach to provocation and contemporary culture surrounding "innovative disruption." Engineering education here includes policies as before, and further expands them to workshops, conferences, and university campuses. As the ECL attempts to leverage a self-evident relationship between education and practice to correct a perceived weak link between engineering education's relevance and professional engineering practice, they uncover a diversity of interests through the engineering community that sustain some trends while resisting others.

By educating engineers about Indigenous cultures and Canadian settler colonialism and providing support to Indigenous engineers, possibilities are opened up to challenge how engineering might relate with the Canadian state. Further, more open conceptions of engineering as a discipline, ones that do not reaffirm the power structures of Engineers Canada, provincial regulators, and state administration, enables engineers to distance themselves from these power structures.

Traditional gender structures guide Canadian engineering and animate discussions about what the future of engineering should or could look like. Confronting gender hierarchies in engineering through diversity or other initiatives to improve women's representation, while still marginal, exceeds simply sustaining a profession dominated by men. Groups like EngiQueers show a demonstrable effort to resist dominant power structures from within engineering communities.

Technological change and innovation give meaning to Canadian engineering culture. Historically, technological change and the suitability of engineers to appropriately manage technological change through their education and professionalization have been omnipresent frameworks to make engineering education reforms relevant interventions for the engineering profession. Technological change can pose a threat to society, but educated and well-trained engineers can act as a corrective.

Fears over contemporary technological concerns, the engineers who have produced them, and engineering education's inability to train pupils to behave otherwise have led engineers to embrace disruptive innovation, not just within the technological realm, but within education itself. The Engineering Change Lab—as a social lab that seeks to "provoke" the Canadian engineering system—educates engineers in hopes of stimulating emergent behaviours within engineering communities towards "technological stewardship." Other engineering educators openly advocate for disrupting the conventional structures of Canadian engineering education and the national curriculum.

But which aspects of Canadian engineering culture are susceptible to change, disruption, and provocation? And which aspects endure despite coordinated effort to transform the system? From a systems perspective, these obdurate characteristics of engineering may be better understood as system redundancies that repeat over time and place. So too may “disruptions” that are devised to preserve the system identity of engineering be better understood as forces of system stability, future-proofing the profession in anticipation of threats from external descriptions. Innovations, after all, are devised to persist.

6.1 Guest provocateur

My quads ache and my legs spin in a low gear. Pushing over the final climb, I coast the remaining hundred or so metres of the 19 kilometre bike ride. Meandering through campus on sidewalks and paths standing on my pedals, I still feel the morning sun warm on my back. Campus is all but deserted on the walkways and I glide easily around the building entrance, gently breaking to scan for a bike rack along the walkway.

It hits me: I don't have pants. The campus drops away. I stop breathing. My mind empties. I need pants. I brake completely, post my left leg, and dismount. I had spent the better part of the ride rehearsing my presentation, clarifying my thoughts, and now, 55 minutes and 48 seconds later, my Strava tells me, I am finally remembering my clothes. Zipping open my pannier and clawing through the contents, my stomach sinks and I picture a pair of chinos and a collared shirt neatly folded and rolled in a white plastic bag sitting on the kitchen table. I text my partner if they can confirm what I already know. What time is it? I look at my phone. I'm early for the workshop but I definitely cannot bike back home in time. The bus also takes an hour so that is not an option. I could get an Uber, I think, but that would still take an hour there and back. I unzip the other pannier and am relieved that the black splash pants, stored in case of inclement weather, are indeed there under a U-lock, next to a bike pump and some extra tubes. Better than nothing. My phone rings, I answer. My clothes are at home and not strewn about a trail somewhere. We assess my options. The splash pants are probably fine, we conclude. I enter the Bergeron Centre for Engineering Excellence and follow the signs on the second floor to the washrooms.

At the sink, I rinse dried mud splatters off the waist, seat, and legs of the black nylon, wiping them dry with bunched-up brown paper towel. It is by no means a formal engagement, but I did want to be taken seriously. I scrub. And breathe. At least I'm not stuck in spandex. At least the pants are black. At least the shirt is grey. I check the fit in the mirror. I wish I had a jacket or sweater to cover the athletic t-shirt. I stare at the relaxed cut of the nylon pants and sigh. It is probably fine. The pants are waterproof. And warm. Luckily they have large black zippers up the sides for ventilation. I look in the mirror one more time and leave.

"Travis! What do you need?" It's Charles. We run into each other in the hallway. I honestly explain that I am in the midst of coming to terms with a wardrobe malfunction, modeling the splash pants for him. He smiles understandingly and replies, "Well you'll just have to go ahead with what you can." I feel reassured, despite my mostly bare arms.

I am finally attending my first Engineering Change Lab workshop. Charles invited me as a guest provocateur. I am not feeling the confidence I had wished, but I stride into the conference room anyways to make small talk.

By the time I begin my presentation later that morning before the group of roughly 40 people, I have settled into my provocateur role. Assessing the conversations and activities in the workshop so far, I get the sense that I have a message and knowledge that the Lab participants might be willing to receive and engage with. I am also not the first provocateur to speak, and it is almost always a relief to see another's performance first.

When it is my turn, I present what I considered to be a failure in engineering. Framed positively, my provocation for the Lab is: How can engineers support Indigenous communities? In under ten minutes, I present two concerns, as I see them about engineering and Indigenous communities, the first one being engineering works themselves and their impacts on Indigenous communities. I expound on resource extraction in mining and petroleum industries, on hydroelectric projects, and on treaty relationships and Indigenous sovereignty.

Certain engineering projects have negatively affected some communities' abilities to continue their traditional lifeways. Even more conventionally benign engineering works like housing, water infrastructure, roads, and environmental assessments disproportionately negatively affect Indigenous communities. The structure of federal government funding for infrastructure on-reserve is inadequate to manage these challenges, and plays into settler colonial trappings of political management.

The second concern I explicate is the inclusion of Indigenous folks in engineering. Three days earlier, at the Canadian Engineering Education Association (CEEA) National Conference, there had been a session titled "Sharing Circle on Indigenous Engineering Education in Canada." Here, representatives from different engineering faculties shared their policy successes for supporting Indigenous engineering students. I shared these strategies with the Lab. I addressed the lack of knowledge about Indigenous peoples in Canada as a general barrier, and that engineering graduates are generally unprepared to work successfully within the political and governance environment of Indigenous communities. I closed recognizing that although the Truth and Reconciliation Commission's *Calls to Action* do not identify engineering as a specific discipline for action (unlike medicine, nursing, law, and education, which are named directly), calls to action numbers 7–11, 16, 57, 62, and 92–94 arguably apply to engineering.[442] I end my presentation, saying that I am eager to get into the details in the breakout session I will be facilitating on my provocation. One more provocateur presents, another STS graduate student who challenges the group to consider the "banality of evil" that might lurk within engineering culture. The

[442] Engineers and Geoscientists British Columbia has advanced five Calls to Action including 7, 13, 57, 75, and 92. https://www.egbc.ca/About/Programs-Initiatives/Equity-Diversity-and-Inclusion/Truth-Reconciliation

group disperses for the newly opened breakout rooms, with seven people joining me in a small meeting room with a table and chairs and glass wall.

The Bergeron Centre for Engineering Excellence opened in 2016. Its rounded exterior—a tessellation of triangles in blue, grey, and glass—drifts atop a setback base of windows and concrete, evoking natural inspiration from Ontario's environment: clouds over stone, sky above earth. The building's "ambitious goal [is] to voice the Lassonde School of Engineering mandate to educate future Renaissance Engineers: entrepreneurial engineers with a social conscience and a sense of global citizenship."[443] "An engineering school like no other," the Centre is a challenge to the "tradition of engineering buildings to define and confine students by discipline."[444] A mix of spaces and their intended uses animate the design throughout the structure: "flexible collaboration spaces are allied in a network."[445] "The Rock," an innovation plaza, sits outside, an intersection of entrances and exits, a place for impromptu occurrences.

It is in one of these multipurpose flexible spaces off of the large conference room that my enthusiasm wanes. Most of the group is quiet. Across the board, they feel reluctant to say much at first, but would like to learn more. One person, however, has strong convictions that leave me perplexed. They have a "data obsession." They think data transparency is paramount. They think that we need more access to more data. All problems, according to them, can be resolved with the correct data. Some of the data that is missing, they explain, concerns engineering work outside of work, pro bono engineering or volunteering in the community. "We never hear about the community work of engineers," they explain, suggesting we

[443] "A Home for Renaissance Engineers," The Bergeron Centre for Engineering Excellence, accessed January 22, 2022, http://thebergeroncentre.ca/design-vision/.
[444] "Renaissance Engineers."
[445] "Renaissance Engineers."

should collect data on precisely that. My confusion subsides momentarily, I am intrigued. Maybe one way of improving engineers' contributions to society could have less to do with improving engineering work itself, and more to do with improving engineers' contributions to society outside of work. It is an interesting thought. But I quickly compartmentalize this generous interpretation as they reiterate that data transparency is needed and we simply need the data, segueing into a soliloquy about Cambridge Analytica and the international uniformity of engineering. We are officially off topic.

And once again, I am feeling self-conscious. Had I done a poor job of provoking? Or facilitating this discussion? Why are we so far off topic so quickly? Is this person in the wrong room? I try to gently steer the discussion back to the topic by engaging other participants, sensing my responsibility as facilitator. One person suggests a problem of urbanity in engineering, that rural infrastructure lacks some cultural caché among engineers, and thus a diminished focus of attention and respect. Which groundbreaking innovations are revolutionizing rural life? They further suggest that engineering serves the stereotype of the prosperous. Another participant explains how they found engineering to have a cult-like vibe that extended into workplaces, a vibe that could explain why engineers may not be adequately serving Indigenous communities.

Eventually, though, the data concerns return. This time I bite. Struggling to understand how this person thinks what they are saying applies to engineering in Indigenous communities, I ask, "Are you saying that Canadians should have access to data on Indigenous communities?"

"Yes. Then we would know what's going on," they reply.

I wonder if they are suggesting something about corruption, or resource mismanagement, as the connection between their "data obsession" and our conversation, but I do not ask to clarify. I seize the low-hanging fruit instead to introduce how that expectation of access to information about Indigenous communities might infringe on Indigenous sovereignty. They acquiesce slightly in their data demands, and I feel like I was able to reach some sort of take-home message for the other participants. Maybe they were sincere in their belief about data and Indigenous communities from the start after all.

Ten minutes later, the Lab rejoins into a large circle to debrief the breakout discussions. I author a “headline” to summarize ours, apprehensive about what I wish we had covered rather than the actual dialogue. I read it before the circle: “The typical experiences and knowledge systems of Canadians and Canadian engineers are not currently commensurable with supporting Indigenous communities.” It is weak, but happily accepted by the group. I hope none who attended the session feels betrayed by the low fidelity with our experience. Participants share their personal outcomes of the session. One says that they thoroughly enjoyed it and that they have “a lot to learn.”

Throughout the day, I mentally return to the conversation. Was this intentional? Were they provoking *me*, the provocateur? Am I being tested? I thought I had been invited in a certain capacity but was not in a position to contribute as I had expected.

Later, in the hallway, Charles and Colleen ask how the session went. “We spent most of the time talking about data transparency,” I say. They return sceptical glances.

“What does that have to do with…?” Charles begins.

“I have no idea,” I answer.

It was a day of disruptions. Three provocateurs were invited to the ECL to shake up their thoughts about engineering, to challenge their approach. I left, however, feeling as though other events had caused greater disruption to me than I had caused in the Lab. I certainly felt *provoked*. Further, as a participant in the Lab that day, I did not leave with any novel insights about engineering's higher potential. As I biked home at the end of the day, what about me was changed by the experience? What made my invited provocation desirable, but other disruptions were unplanned and necessary for correction?

This chapter is about disruptions, intentional and otherwise. I will continue to employ Luhmann's concept of perturbation to think through the provocations of the ECL. Conceived as a disruption to the system of engineering, how do ECL members situate the work of the Lab within or without the system? According to Luhmann, perturbations from the environment can irrevocably alter the system, changing its core identity, or they can be subsumed by the system, integrated into system operations. Can blind spots in system observation be harnessed to steer system operation? How successfully might one situate a disruption to maximize effectiveness? In short, is it possible for deliberate human action to change the system? What makes disruption, provocation, perturbation, or irritant useful for thinking the system?

I explore these questions using a few more vignettes from ECL workshops and interview data from lab members, along with analysis about recent developments in Canadian engineering education. I expand this thinking to further trouble "disruption culture" of contemporary tech start-ups and social innovation initiatives.

6.2 Smoothing things out

Cloud cover, heavy and grey, glides slowly over green-tipped treetops, alternating spells of overcast, mist, fat raindrops, and, occasionally, a break of hot spring sun. Canopy tents provide shelter from the wet, or the intermittent rays, for maybe a dozen of us on the gravel driveway that leads from the highway, our white school bus parked just past the shoulder. The remaining forty or so tough out the rain in Gore-tex and Nylon, hiking boots and cross trainers, mingling in small groups around a large propane stove. Maple syrup boils in a deep stock pot and sweetly scents the humid deciduous forest air. We are making maple sugar.

It has been cool the past few weeks and the earth is sighing to life, despite the drizzle. Wooden paddles scrape the reduced syrup from the walls of a dry wooden bowl, drawing more water from the mixture to form first, maple butter and then, later, maple sugar. The viscous fluid gradually thickens as volunteers work it around the surface of the bowl, it becomes smooth and paste-like. Another batch of syrup is poured into the pot and put on to boil, while the first continues to be processed in the bowl. Twosomes and threesomes hand off the equipment. Everyone gets a turn. Lab members chat with each other while they wait, and introduce themselves to the workshop facilitators and other presenters. Conversation bubbles like the syrup. In Michi Saagiig Anishinaabeg territory, known by many as Toronto’s cottage country, our cohort has been grappling with questions about the commensurability of Western knowledge systems with Indigenous worldviews. It is a provocation.

Workshops in the Engineering Change Lab are generally closely facilitated, leading to a fairly tight control of certain learning and doing outcomes and timing has been quick. But space is opened at times to encourage networking and improvisation, to enable more than what has been planned. The potential for innovation structures the world of social innovation. And this particular workshop stretches the conventional settings of university campuses and corporate boardrooms for the group.

Once the maple sugar, now similar to brown sugar in appearance and texture, is packed into individual containers and we enjoy a catered lunch, the facilitator invites us to go for a dialogue walk with someone we do not yet know from the group “out” on the land. The driveway continues past the Elder’s house whose property we are on, eventually becoming a path that winds its way down a slope and through the ash, birch, and elm. They encourage us to commune with nature and share what is on our minds.

Less than one day into the workshop and we have been facilitated into making it a personal experience in multiple ways. The night before consisted of a sharing circle that lasted until ten in the evening. The mostly white, mostly settler, and—surprisingly for an engineering community—mostly women group divulged their personal histories with Indigenous peoples and the engineering profession. Laying bare their ignorances, many confessed desires to do more for Indigenous communities professionally or to find new purpose in their professional work. This morning began with a sacred fire and a sunrise ceremony. In jackets and denim jeans, we greeted each other outside of a teepee, hugging everyone in the circle good morning, twice, as directed. The personal connections both with the subject matter and with other attendees continue as pairs break away to stroll through the underbrush.

With day two of the workshop wrapping up, I make my way up the driveway to the bus. Peter and I talk for the first time on the grey vinyl upholstered seats of the white school bus that would soon be jostling down the highway from Curve Lake First Nation. Still parked in the driveway across from Smoke Cignals, we discuss our respective research projects on engineering education. We do not get into much detail, but we do arrange to speak again. Others have joined us near the back of the bus and the conversation has moved on.

It is a warm summer afternoon one month later. I am in my office hundreds of metres from the Atlantic Ocean, beginning my interview with Peter. With my earbuds plugged into my speakers and my mouse hovering over a QuickTime display recording our separate audio channels, I look at the Skype window. He is in Hamilton. I am in St. John's. I ask Peter to tell me how he first became involved with the Lab. He explains being interested in a job posting from the ECL, and attending the 2017 Canadian Engineering Education Conference in Toronto to see Charles' keynote.

> I think this is kind of pivotal to at least what the perception of the Engineering Change Lab was in my mind. And Charles' keynote kind of riffed off of the engineer of 2020 stuff from a while ago, but now we're talking about the engineer of 2050. And so his keynote was an hour and half long and sort of talked about skills that engineers are gonna need to have, kind of, going forward in the future, and pretty, like, broad and high level. And talking about, you know, how society is changing and technology is changing, and they're kind of both going along, and engineers sort of play that length. I think it's one of my favourite slides that encapsulates the Engineering Change Lab, there's a slide of a double decker bus in London and a guy running after it. And the slide is like: "technology is the bus and the engineering profession is this guy running after it." And so that kind of resonated with me having gone through several engineering degrees, and not really seeing that broader societal impact really taken into account.[446]

[446] "Peter" in discussion with the author, July 2019.

Figure 6.1. Image from the Engineering Change Lab slide deck.[447]

Peter was hired to coordinate a national program on Canadian engineering education funded by the Engineering Change Lab. He is not shy to reference his own experiences in engineering when discussing his study of Canadian engineering education and the gaps he sees in how engineers are currently educated.

> I finished a whole PhD before really learning many fundamental research, higher, more broad level research principles, talking about epistemologies and theoretical and conceptual frameworks. So much of that is implicit in engineering, you know, the way everything is a very positivist approach. You know, like, there's very little room for that kind of, well, what background are you coming from? What lenses are you bringing? Is this the only way to think about this? Is this valid in this context but is it valid in other contexts? I think that's a tremendous gap. I'm almost embarrassed to think that I got my doctorate without knowing what epistemology is. Like how did that not come up? How did that not come up in over 15 years of education? I think that is a tremendous gap. And I think especially because, that, we're churning out engineers that only think of things in

[447] "Technological Stewardship for Organizational Cohorts," Engineering Change Lab, October 2018.

> one, sort of, set framing with these implicit built in assumptions around, kind of, the ways of thinking. This is broader than, like, do we have the right material properties for steel? This is, like, are we thinking about this using the right type of thinking? So I think that was a humongous, humongous gap.[448]

Peter mentions his interest in new research trends in the burgeoning field of engineering education. I ask him to explain the novel directions he sees engineering education research going. The first aspect he identifies is that "high-level trends tend to be driven by external motivators."[449] For example, "big overhauls in accreditation cause ripples throughout this entire system."[450] He explains that these changes are fairly obvious when you look at the papers presented at a conference like CEEA where there are phases of focus on issues like accreditation and graduate attributes.[451]

But now that accreditation procedures concerning graduate attributes have reached "homeostasis," Peter sees a new trend emerging in engineering education research interested in social responsibility.[452]

> The first thing I did in my role, one of the first things was to go and perform, you know, a pseudo-scan of the system. So I went to all ten funding institutions, if that's relevant I can name them off to you if you want to know them.
>
> TH: Sure
>
> SM: Okay so going from west to east we've got: UBC; Calgary; Manitoba; then five Ontario ones, Western, Waterloo, McMaster, UofT, Queens; McGill; Memorial. Those are the ten. But I visited and had discussions with people from 14 different institutions. So the extra institutions that I talked to on top of that were: Guelph, Prince Edward Island, Conestoga College, and Saskatchewan. And so from this, I kind of distilled, like, three main needs in the engineering education system. So the first one is- And these are kind of needs that, like, lots of people were expressing, either that they're working on, or there's energy kind of around, or there are barriers, or they don't know how to do this.

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[448] Peter.
[449] Peter.
[450] Peter.
[451] Peter.
[452] Peter.

So the first one, kind of, non-technical skills, and particularly the meaningful integration of non-technical skills. Having, like, a technical communication course, like, in second year, like, isolated in second year doesn't cut it anymore. And we're learning that because our students are lacking in these skills. And so how do we integrate these skills, you know? Communication, team work, leadership, lifelong learning. Like, I think, it's seven of the twelve graduate attributes are related to these non-technical skills. So bringing them in in a meaningful way so that they have value, ethics, social, like, impact on society and social responsibility, like, all of these things, and, kind of, how they're systemically devalued. And it was actually Paige, was the one that was talking about it. She teaches a course in ethics and it gets scheduled for Tuesday night at seven pm. Like, what does that tell the students before they've even shown up, the value of that? Like, no, their critical design course is Monday, Wednesday, Friday at one pm, you know, prime slot. But this other one is, you know, some random night slot. Another aspect there being that these, the instructors themselves are not trained in these skills. You know, all of, pretty much all engineering profs, not all of them, but most of them. Most of the people that are responsible for educating our engineers of the future are ones that went through your traditional technical academic pathway. So how does someone who is, like, the foremost expert on material bending in micro-scales suppose to teach students how to work properly in teams? You know, like, there's a discon- it's assumed that they will know how to do this, but they don't. And that affects the students because they're not getting meaningful feedback. They're not getting coached on how or why they're not reaching competencies. You know, instructors say, "Oh that's not good enough. Your presentation is not good enough." But aren't able to articulate why or how they could improve. [...] So that's non-technical skills.

The other one that's kind of related to that, and whether or not you'd clump it together, is that, I already mentioned, social responsibility. And these are things like: equity, diversity and inclusion; Indigenous perspectives within engineering; impact on society; lots of the things related to the Engineering Change Lab. And I see there, it's almost a more realizing that this is important but really not knowing how to address it, you know, the Indigenous perspectives one is a huge one. There's a ton of energy across the country right now of people realizing how critical this is and how we need to bring this into the curriculum, but there's no, nobody's modeling how to do it. You know, we don't know how to do it. Like, that's why I thought that last Change Lab workshop was awesome. Because it's taking a step in that direction of, how do we figure out how to do this? So there's a, there's a major gap there, but there's lots of interest. You know, I remember someone telling me, like, "How do we crack the nut on getting women in engineering? Like, how have we not figured that out yet?" And they're, because I think, they're complex issues. And it kind of, it goes back to this being beyond engineering. Engineering intersects beyond itself, with non-engineers and, perhaps, those are the peoples' skill sets and expertise that we need to address some of these problems. Which is where, like, the Change Lab approach comes in.

Then the third other need, that is not, not as much content related but more system related, is kind of the pathways and the barriers with respect to scholarship of teaching and learning. And so, kind of, the values, how do we get our teachers to, kind of, value this? And to put energy and put interest into this? And there are lots of people that do, and they just might know how, they don't know how to get it, you know. "Oh, I'm interested in engineering education and/or education research. But I don't know where to start." You know? "Nobody at my institution is doing it, so I don't know who to ask."

> You know, those type, those types of things. Or you, you know, you see it all over the place. Where you've got teaching track faculty positions who are judged in tenure and promotion based on the same criteria that the technical research professors are judged on. But it's different. You know, you've got different tracks, and different positions, different roles, and then you're judging one the same as the other. It doesn't quite make sense. And so I think, and that sort of goes to where I see energy. There's energy growing in all three of these realms.[453]

Peter places these three needs he identified alongside the emergence of engineering education as a field of study. These two foci, reflect back on each other. First, that the needs of engineering are changing, or are unmet, or haven't been studied. Second, that engineering education is produced by these needs, but also must identify and satisfy these needs. Studies of engineering education reveal the deficiencies of how observers would like engineering to be. Massive upheavals, paradigm shifts in technology and society, further justify analysis of and control over the particularities of education.

> Think back to, like, World War II and, sort of, the need to make bombs and weapons. It was like, resources are put into making engineers technical specialists. You know, a massive societal change and need, the war, influenced, kind of, how that profession changed. And it, kind of, stayed like that for a while. But when you look at how, like, kind of, how the world has changed since then, and, kind of, the importance and the prevalence of interdisciplinarity, and how everything is connected now. I think that's kind of what's fueling this. There aren't job positions anymore for technical expert engineers. You know, we don't, we've got computers with machine learning and artificial intelligence that can do that. We don't need engineers in rooms with calculators crunching numbers. We need engineers to be working with other people that are doing different things and applying skill sets in unique and different ways. And like, like a microcosm of that, if you look at, like, grad student research. So much of it now is interdisciplinary. Like, look at your research. You're an engineer basically operating as a social scientist because of this sort of interdisciplinarity that's needed there.[454]

But the needs of industry and society are not necessarily clear factors that influence engineering education. These needs are presumed as future engineers will be the ones that seamlessly transition from university to industry, or will be the ones to demonstrate appropriate ethics in developing new technologies. Peter

[453] Peter.
[454] Peter.

explains that there is also demand on the part of students to engage with these issues.

> The Lab aspect that I'm working on still is developing technological stewardship modules, like, for students. So Billie and I have been traveling around. We've, I don't even know how many times, we've run it, and how many institutions we've run them at. But it's interesting because there's a thirst for it. Engineers are thirsty for this type of thing. Like, to think in different ways. To experience a discussion, you know, for us to have discussions in classrooms. Like, I'm so used to discussions, I have them all the time now, and based on my context. But I forget that engineering students are used to following along PowerPoint slides, and copying equations, and then, you know, date night with the textbook versus actually having these discussions. And it's, it's amazing. Like, the students are coming towards it. There's, it feels like there's movement coming from the student population that realizes that this stuff is important. They're growing up with technology, you know, they're, they know these issues more than we do. You know, so it's in, it's bringing these to the Change Lab context. You know, we bring in senior leaders from these corporations and tell them these things. And they're like, "Oh, wow that's important!" It's like these students know that because they've grown up with it, you know. So it's, it's actually embedded in the fabric of their own lives. But it's not being addressed because the people that are teaching them aren't thinking about those types of things. So there, there's an appetite for it. That's kind of what I'm getting at here, there's an appetite for, kind of, these concepts: the technological stewardship concepts, and the approaches of how we deal with them. You know having these discussions and valuing other peoples' opinions and asking questions about whether or not we should be doing these things and who's not here and who's not being represented, like, the students are really, mind you it might be a self-selecting population, the ones that we're, kind of, dealing with, but there's, there's energy there. And a lot of insight comes from them once you, kind of, tap into it because of, kind of, where they're coming from.[455]

6.2.1 The Pivot

McMaster University launched "The Pivot" in 2019, a $15-million initiative, to reform their engineering curriculum. Stephen Elop, distinguished "engineering executive in residence," and Ishwar Puri, dean of engineering, from McMaster titled their 2019 Globe & Mail op-ed simply "University education is ripe for disruption."[456] Surveying the landscape of disruption—the Internet, cellphones,

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[455] Peter.
[456] Stephen Elop and Ishwar Puri, "University education is ripe for disruption," *The Globe and Mail*, May 12, 2019, https://www.theglobeandmail.com/business/commentary/article-university-education-is-ripe-for-disruption/.

email, social media, Uber, Lyft, Skip the Dishes, Airbnb, Netflix, Microsoft, the cloud—they liken disruption to viral infections that must survive immune responses from established businesses and institutions. But, of course, disruption is positive, in this case.

> Overcoming resistance to change, especially when there is no apparent immediate crisis, remains an essential element of successful self-disruption within an organization. Resistance to change weakens as evidence mounts in favour of the self-disruption strategy.
>
> Candidates for self-disruption now include universities - traditional institutions that face limited competition. For too long, the prevailing view has been that public universities should be insulated from disruptive change.[457]

The future is now and post-secondary education has not kept pace. The demands on students are changing faster, and universities are not equipping them for success. "We must teach students how to engage with disruptions by disrupting our own model of education."[458] They conclude:

> Students rely on us to guide them toward careers with meaningful, useful and competitive credentials, so we must make change not recklessly but responsibly - remembering, of course, that failing to disrupt the prevalent model of university education would be irresponsible.[459]

In this light, both reckless disruption and changing nothing might both be irresponsible. Post-secondary education has progressed unchallenged for too long and has produced two challenges: universities are not "equipping [students] for success" currently, and students must learn to "engage with disruption" by being disrupted themselves. Students will be living in a world of disruption, but a disrupting intervention may reconcile their impending disruption. Disruption, in this case, is inevitable.

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[457] Elop and Puri, "Education ripe disruption."
[458] Elop and Puri, "Education ripe disruption."
[459] Elop and Puri, "Education ripe disruption."

McMaster rolled out their reimagined, nay, *disrupted*, first-year engineering curriculum in 2020. Their "disrupting" approach to education combines what were previously four separate engineering courses into one single year-long course, shown in Figure 6.2.

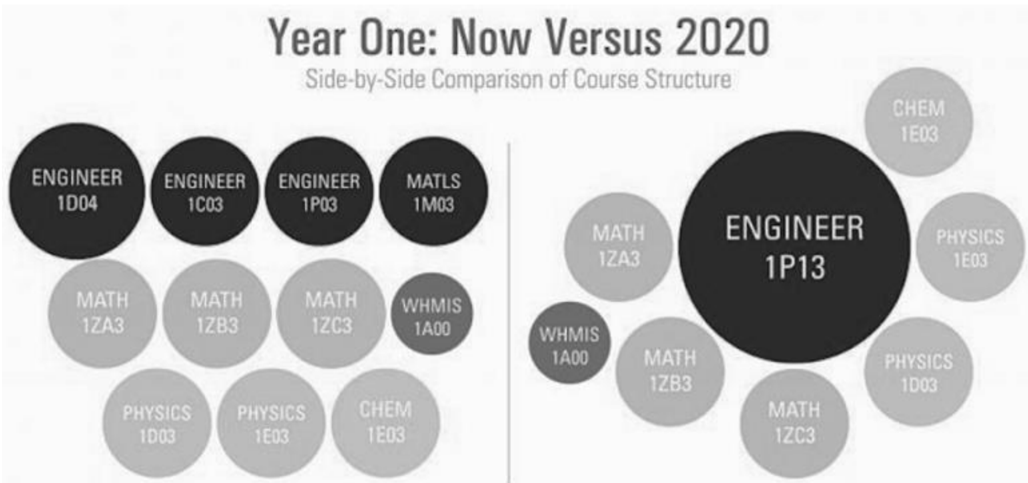

Figure 6.2. Year One engineering curriculum McMaster University.[460]

This unified course covers the same previous topics as the preceding structure—engineering design and graphics, engineering computation, engineering profession and practice, and structure and properties of materials—but does so through four design projects. By exploring the subject matter through project experience, the goals of the revised curriculum are to emphasize innovation, flexibility, design thinking (failure and iteration), teamwork, and industrial relevance. The projects, while open ended with no obvious resolutions, are crafted to engage with relevant technical and social issues: an autonomous vehicle, renewable wind technology, healthcare sterilization systems, recycling and sorting

[460] "New First Year," Faculty of Engineering, McMaster University, The Pivot, accessed January 22, 2022, https://www.eng.mcmaster.ca/about/pivot#New-First-Year.

systems, and a device to assist a "working mother with autoimmune conditions."[461]

According to Luhmann, to attempt to reform education is to forget all previous attempts at reform. Reform is only possible if one forgets. Which is not to say that educational reforms accomplish nothing. They simply fail to accomplish what they are intended to. So instead of creating an education system that produces socially, technically, and corporately knowledgeable and capable professionals, what might reforms to Canadian engineering education accomplish? One wonders what current reframings of engineering education, as a site of innovation or disruption concerning novel socio-technical problems, might produce as changes for the future of the engineering education system.

6.2.2 Opportunities to lead

Charles elaborates on the opportunity for engineering to grow its responsibility.

> Once we had this recognition of, well, the bigger frame is this relationship: tech and society. Well who's thinking about that? What's going on there? Right? And it's been fascinating, even in the last couple years, like, when we started talking about this it was before Cambridge Analytica and CRISPR babies. Like, you can hear, you can *feel* the temperature globally turning up on these issues just in the last couple years in a really interesting and powerful way. So I actually think there's a huge opportunity right now, if engineering can get out of its kind of inward looking thing and see these bigger trends that are happening. There's a huge opportunity for us to play a leadership role if we can understand our potential more and play a bigger role.[462]

This logic for the ECL is similar to the redesign of McMaster's engineering program: disruption is happening, and there is an opportunity to jump on the trends early. One of the trends is that there are no clear lines of responsibility for contemporary technological development. For Charles, a large part of this absence

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[461] "New First Year."
[462] Charles.

of responsibility for many contemporary technological problems stems from problems in engineering education.

> Some people make the argument now that "Oh engineering is the liberal arts degree of the 21st century and everyone should have an undergrad doing engineering" which I would disagree quite wholeheartedly with the existing engineering undergraduate. Because the existing engineering undergraduate is teaching you *how* to create technology but it's not even giving you by default even a reasonable sort of level of understanding of what it is you're creating in a way like, say, a social scientist would talk about technology. And it's not giving you, I would argue, the ability to kind of steward those technologies responsibly. So on one side of campus we're training engineers and how to create technology, and on the other side of campus we're training social scientists to understand the creations i.e. "technology" in a much more reasonable way. So in a way I'd say the modern engineering profession is churning out and enabling Dr. Frankensteins.[463]

The opportunity of the situation Charles describes parallels the opportunity the ECL itself seized upon. Organizational determinants of the increasingly differentiated system of engineering in selecting the system of engineering have abandoned significant elements for the environment of engineering, elements that now perturb the system. But are these the same sort of perturbations as the ECL's own system provocations? Some disruptions are positively determined from the outset, even before their results are known. Others, ones that seem to occur as a result of unintentional action, produce undesirable disruptions to system performance or serve as indicators of "blind spots." While Luhmann's theory places no moral value on perturbations, this agnosticism does not seem to be at play in contemporary disruption culture where disruptions that provide future opportunities for advancement (capital, resources, acumen) are esteemed, and disruptions that limit ones current position are reviled (regulations, accidents). Government responding to disruption culture by taxing AirBnB operations, ruling Uber drivers as employees, or otherwise regulating new industries is hardly taken as positive by disruptors themselves, although these measures may likewise be

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[463] Charles.

constituted as disruptions to these sectors that materially benefit more people. Thus the value ascribed to any disruption signals the likelihood that one stands to benefit from the disruption regardless of the outcome. What Luhmann contributes to this understanding is that a perturbation stems from fundamental selections of the system. Not all disruptions share that ontology, nor that threat of systemic transformation.

6.3 Personal identity

It’s day two of the Vancouver workshop and I’m running late. I crashed on a friend’s couch and borrowed their bicycle, detouring to a Yaletown bakery for some single origin coffee. I briskly walk my coffee and my friend’s bicycle through downtown crowds spilling out of a yoga studio, a spin studio, a bus. Coffee splashes on my hand as I take a gulp, my other fingers gripped around the bike stem, lifting the front wheel off a curb, across the street, and up another curb. After a few hurried blocks, I secure the bike to a bike rack between a parking meter and a tree. I feel that I am starting to perspire as I rush to the entrance. I pass through the glass doors of the two-storey mezzanine, approach the elevator touch screen, take my phone out of my pocket, open my Gmail, type “ECL” into the search, flick through the returned emails, open the email with the workshop information and the conference room number, and enter the room number on the elevator touch screen. I untuck my right pant leg from my sock, clip the bike helmet to my bag, tie up my hair in a man-bun, and continue to wait for my lift while surveying the lobby doors for the stairs. There has to be another way up, I think. I make an effort to take note of the door when I come back down the stairs later so that I can avoid this rigmarole next time.

Exiting the elevator on the second floor, I can see through the glass walls at the end of the hallway that workshop participants are still eating and circulating about the room. I slow my pace, take a deep breath, and relax. I haven’t missed anything. The conference room door is held open from the inside, but the doorway is crowded. Arrivals queue up waiting for others to exit the conference room for the washrooms. Another person paces the hallway, one ear plugged and their phone pressed against the other, taking a call. Standing, I take my place, slowly crossing the threshold.

“I like your sticker!” says a voice next to me. I turn, confused, not sure who is speaking to whom, or to what they are referring. “On your helmet” she smiles gesturing toward my bag as we make eye contact, maybe noticing my hesitancy.

“Oh that’s not mine,” I say. She looks surprised. I clarify, “This is my friend’s helmet. They lent me their bike.” I flip the helmet over to inspect the sticker in question, not knowing which it might be. I see it. A white bicycle is silhouetted against a horizontal triband of pink, lavender, and blue, the bisexual pride flag. The rear wheel is a transformed symbol for Venus, and the front, Mars. White lettering below the bike reads “Bi-Cyclists.” “But I’m sympathetic to the cause!” I add quickly with some laughter, reinterpreting my previous clarification. I recognize that I am speaking with Tabitha, a representative of EngiQueers Canada. We formally introduce ourselves and move on from the mistaken identity while filling our styrofoam plates with slices of strawberry, cantaloupe, and pineapple. I mention that I had been meaning to speak with her, given her involvement with the Engineering Change Lab and EngiQueers. Our discussion is easy and energetic and too quickly interrupted. I promise to reach out.

The chairs are arranged in a circle on one side of the conference room. Charles welcomes everyone to take a seat so we can begin. He explains that while the focus of the technological stewardship workshop thus far has been “head and heart. Today is hands.” Today we start our strategic doing. Charles asks the group if there are any other deltas—any other changes to the workshop requested by the group—pointing out the schedule of the day’s activities that participants had asked for yesterday is now posted at the front of the room. No further deltas are expressed. Charles hands over facilitation to Pamela to do a check-in for the day.

Tabitha explains what happens next.

> So essentially what happened was Pamela was leading an Indigenous, kind of, welcoming morning ceremony. So we're talking, like, I'd woken up really early, rolled out of bed, walked across the street to get breakfast, and we're like now *in this space*. So I'm super, super, like, raw [laughs] from the morning. And because the whole purpose, if memory serves, the purpose of it was to, like, it was, like, to thank... It just had this, kind of, like, not religious context necessarily but, like, spiritual context. And I personally as, like, a human have, like, a lot of, like, for lack of a better term, pent up shit related to, like, [laughter] religion and spirituality and all of that. And it's just something that I've never really navigated, and I so, so strongly associate with, like, hate and death and bigotry related to the queer community.[464]

Tabitha continues

> So that morning, specifically, as I said, I was really raw. We started going around and, I just, my brain just starts going there. I'm sitting there, like, we're trying to thank, like, the day or talk about whatever it was, something, like, relatively harmless. But I just couldn't get it out of my head that, like: "This feels religious. I'm not religious. Oh my God, I'm uncomfortable. Oh my God, people are dying because of this." So when it came to me [laughter] I basically, like, said a lot of that kind of thought and, like, broke down crying in front of everyone and was just, like, trying to, I think I maybe said one or two things that I tried to get out about what I was thankful for or whatever the actual activity was.[465]

Tabitha excuses herself from the room, and the sharing circle continues as the wampum shells are passed clockwise to the next speaker. More recollections are offered on yesterday's workshop. Another participant recognizes that in one of yesterday's activities, only women stood in the "respect diversity" group as a priority for the Engineering Change Lab. The men need to take diversity in engineering more seriously. She feels "destructive to liberate women" and wants to "destroy the box." Still another communicates some personal confusion that came out of learning about technological stewardship, "Who am I? Where am I? Who do I want to be?" they wonder aloud. Eventually Tabitha returns quietly to

[464] Tabitha in discussion with the author, August 2019.
[465] Tabitha.

her seat while the shells complete their journey back to Pamela at the front of the room. Pamela explains how wampum shells are a technology. She acknowledges Tabitha and gifts her a shell as a thank you for sharing with the group and to use as medicine for herself. Pamela hands the facilitation over to Billie to introduce strategic doing.

Reflecting on this experience over our Google Hangouts call, Tabitha provides additional context.

> Within the scope of the Change Lab, like, I think it's worth noting, like, my relationship with the Change Lab is... I feel like when I enter that space I am in a room of people who are actively acknowledging the profession needs to change, needs to improve. I'm in a space of people that are leaders, and are caring about the future of our profession. And I know we strive to always have, like, we don't want it to be an echo chamber. So we strive to have, like, dissenting opinions and all that of course. But, like, even with that in mind, like, that is still the fundamental objective of what it is, so I always feel, like, at home or myself or very at ease in that space, because that's very aligned with, like, how I think and feel. And having entered that space a few different times as, like, one to present or to provocate, like, felt typically more in control or in, kind of, like, almost a position of power, if you will. And then to have it, kind of, go so the opposite way of, like, now I have, like, no control, totally powerless [laughter] totally. Like, this is, like, this deep dark thing inside of me was definitely I think what triggered a lot of the emotion in that way.[466]

Erika, another Lab member, shares a similar outlook regarding her participation in the engineering community and the Engineering Change Lab:

> I have not seen forward thinking, *advanced thinking*, by people who sit around the committee tables and who sit around the governing tables en masse. Like, maybe here and there, but I don't see it en masse. And what excited me about the Lab, is the Lab is a segment of people en masse who are deep thinking and questioning and struggling through the difficult stuff. So that, you know, says to me that if I just sort of leave it to the way it is right now, I don't really think I'm gonna see any movement on the PEO side. I think the Lab might go and do great stuff but I don't, I don't know if it's gonna interject into their.. And I was a committee advisor for one of the committees at PEO so I saw that, you know, good natured people trying to do stuff and after five years of a committee never a result. Like there was never a product of their work. Nothing ever happened. Just, they considered things, but never actually came up with a policy, never changed anything whatever else.[467]

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[466] Tabitha.
[467] "Erika" in discussion with the author, May 2019.

Tabitha compares her moment in the Engineering Change Lab to her work with corporate training through EngiQueers Canada and her own work experience as an engineer.

> In terms of engineering being innately heteronormative or homophobic, there's loads of instances and cases of and reports of these things all over the place. But I, also from my experience, have noticed that, you know, by nature of the demographic of the current situation, most boards and such are older white men. Or most people in charge are older white men. But I find that when I come in from the lens of [EngiQueers] as, like, a young queer woman of colour, I find that I get a lot of really positive responses and a lot of, like, interest in changing, on average, when I come in in that capacity of the EngiQueers Canada founder. But I also do have my own experiences as just an intern in engineering on, like, a shop floor in a manufacturing facility experiencing, like, the operator saying inappropriate things. Or my manager not understanding that sexism is alive and well in this male dominated workspace.[468]

A paradoxical relationship between system and disruption is at play with the change lab approach. Systems are changed through changes in individual cognition which themselves can result from novel or challenging experiences. In somewhat contradictory fashion, change labs purport to induce these sorts of psychic interventions by selecting for perturbations within their operations. Organic or natural disruptions to cognitive systems are manufactured by privileging perturbations over the banal.

Adam Kahane, one of the founders of change labs, writes about his own "personal journey" in developing the change lab approach.[469] His work with Indigenous communities in Canada and Australia, along with his discovery of systems and leadership thinkers like Bill O'Brien, Joseph Jaworski, Peter Senge, Arie de Geus, and Humberto Maturana, influenced his conceptualization of social change.[470] The colonial encounter features pre-eminently in Kahane's writing. His work on

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[468] Tabitha.
[469] Adam Kahane, *Power and Love: A Theory and Practice of Social Change* (San Francisco: Berret-Koehler Publishers, Inc., 2010): 23–25.
[470] Kahane, *Power and Love*, 30–32.

social issues has taken him to India, South Africa, Canada, Australia, and Israel, locations of settler colonialism.

Ranulph Glanville characterizes systems theory and second-order cybernetics as thought systems similar to Buddhism, "a religion of acceptance and response rather than of proselytization and domination."[471] These ways of thinking are responsive. They respond *to something*. Encounters with the colonial Other generate response. But, of course, not all encounters are worthy of response.

Kahane's experiences were worthy because he was able to make use of them, even if the projects themselves, by his own admission, were not successful. He counts them as disruptions, encounters that altered his cognitive system. Yet the scope of these projects, and many other change lab projects, that focus on complex social issues are likewise attempting to manage a social disruption. Are these disruptions, ones that unsettle centralized state power, equally considered valuable disruptions? Shaking ones core beliefs through cultural exchange until one can emerge with a renewed and expansive conception of the world is now a clichéd, albeit worthwhile, endeavour. The change lab approach strives for these outcomes. These altered mindsets are fundamental for system change. Yet, what if disruptions are removed from this isolated or utilitarian perspective? What value is ascribed to the provocations that pre-determined those discretely esteemed in change labs?

I am not suggesting that disrupting the engineering system by enlightening engineers of gender, race, and sexuality issues within the profession misses the mark. Instead, I wish to square this perception that disruption is beneficial from a

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[471] Ranulph Glanville, "Cybernetics: Thinking Through the Technology," in *Traditions of Systems Theory: Major Figures and Contemporary Developments*, ed. Darrel P. Arnold (New York: Routledge, 2014): 61.

change lab perspective with the Luhmannian view that perturbations are produced through the selection process itself. Yes, highlighting gender discrimination within the engineering profession is incredibly important work. Disrupting engineers' conceptions of engineering and gender can produce eureka moments that in turn change one's engineering and gender work, and, thus, the system. But the selection of men into engineering remains untouched. The original perturbation, produced by the selection, in turn generates the conditions of the disruption. With sufficient disruption to the correct psyches, the system could change substantially for more people. Such a move, however, would require more deliberate selection of the Lab regarding its attendees, a selection that could risk reifying existing power structures by focusing participation on university administration and provincial regulators, and undermining the ambition of reimagining the system. Luhmann's systems theory does not face this same double bind.

Charles explains one of the "eureka moments" that happened in the Engineering Change Lab as they first explored what they would focus on.

> And so what emerged from that exploration phase, like, so the themes just keep coming up and we get deeper and deeper. And so in that very first workshop there was a mic drop moment when, you know, we were talking about this higher potential of engineering and one of the deans of the major schools in, kind of, a frustrated moment said, "Wait a minute! What *is* engineering?!" And it was, like, silence in the room. And it was like this mic drop moment because if there was ever a room that should be able to answer that question with confidence, you know, this was probably it. You know, leaders, you know, as much as possible, representing engineering. But the fact that that question is not clear, I think has been a big part of the thing. Like, engineering has become clear to me over time, it's a community, it's a profession that doesn't actually engage in a lot of self-reflection.[472]

These sorts of revelations are desirable for social labs. Someone's paradigm shifts, they see the world differently, and the change is felt through the lab.

[472] Charles.

Highlighting more of the exploration process, Charles sees value in the ECL's delayed success in securing financial resources.

> And, I think, one of the things that we did well, which was actually, I think, partially as an unforeseen unintended benefit of not attracting massive resources early allowed us to stay a little bit more nimble and in the space of big picture exploration.[473]

Clearly an undercurrent of start-up innovation still flows through the ECL. Susi Geiger casts Silicon Valley's rhetoric of disruption as an eschatological narrative: uncertainty of the future promises both opportunity and doom. At the same time, the future is narrowed to a choice between the status quo and a single viable alternative.[474] Stuart Hogarth likewise argues that disruptive innovation mediates the relationship between moral worth and economic value in Silicon Valley entrepreneurial culture.[475] What values do social labs generate in provocation?

Conventional wisdom of Silicon Valley tech startup disruption culture guides entrepreneurs to become essential features of a system they seek to disrupt, securing a market share of an existing economy quickly. Leveraging venture capital to become ubiquitous and then indispensable to daily lives ideally produces a future monopoly that completely controls a desired market, evading regulation by growing too quickly to contain.

Disruption for social labs seeks also to become indispensable by engendering participants' abilities to understand themselves as essential in a system. The disruption is not the technological insertion or mediation of pre-existing relationships that so commonly characterize tech start-up endeavours. Rather this

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[473] Charles.
[474] Susi Geiger, "Silicon Valley, disruption, and the end of uncertainty," *Journal of Cultural Economy* 13, no. 2 (2020): 169.
[475] Stuart Hogarth, "Valley of the unicorns: Consumer genomics, venture capital and digital disruption," *New Genetics and Society* 36, no. 3 (2017): 250.

disruption is a psychic one: that individuals reimagine their current career roles, aligning them to the social lab's system, a lesson in interpellation.

This approach though, rather than reimagining how the profession of engineering operates, simply reiterates its foundational structure: self-regulation. A future where qualified individuals take professional responsibility for artifact design and use because of perceived benefits with holding such a professional position (pay, benefits, cultural caché, social importance) does not stray wildly from older or current conceptions of engineering. In this way, the ECL does replicate the mediator role that so many industrial disruptors assume. But instead of taking a cut for providing a platform for others to interact or provide services, this social lab mediates how engineering might efficiently reconnect engineers with their profession, to empower them to be engineers.

Again, what might superficially look like a provocation can be reconstituted as a reaction, an immune response to restore system operations. So if the ECL, like perhaps EWB before it, as an organization that meets some socially responsible need for the Canadian engineering education community can be understood as internally generated by the system, to what are they responding? The original selection, the one that generates a wide-reaching foundational problem for the engineering profession, is selecting for itself a unique education with a unique curriculum and a unique student body: the infrastructural core of engineering education.[476]

6.4 Professional identity

In running shoes and a rain jacket, I bring my vegetarian wrap under the white canopy tent. The structure is the size of a small garage but it feels cozy out of the

[476] Downey, "Critical Participation", 237.

humid cold. You can not see your breath—so it is not *that* cold—but the thin shelter feels like an improvement nonetheless. Some participants are still stirring pots of maple syrup and bowls of maple sugar under the sky, others hold umbrellas over their crouched bodies. I sit atop a ride-in mower, place my lunch on the seat next to me, and open my notebook to jot some notes. A group of half a dozen women are sitting in chairs nearby, talking. After a few moments, one of them calls to me and asks me what my deal is. What exactly am I doing here? I explain my research, that I'm interested in the work of the Engineering Change Lab and Canadian engineering culture. I detail some of my career background in engineering briefly saying that I was an engineer but no longer am.

"I can't call myself an engineer…" I explain.

"Why not?" she challenges.

"I'm not registered."

"So? I'm not registered and I'm an engineer. I have an engineering degree. I have that training. I wouldn't call myself a *professional* engineer. People who have an engineering degree but aren't professionals still call themselves engineers." She thinks I am being unnecessarily pedantic, I think.

I concede the point, and the conversation moves on. I feel like she already understands the point I was gesturing towards, that the word "engineer" is an official mark of Engineers Canada that only those registered are permitted to use in identification. And I feel like I already understand her position, that respecting the authority of Engineers Canada by only using these words according to their strict letter of the law approach prematurely restricts a reimagining of engineering itself. I do not feel like pushing this disagreement, as interesting as I find it, especially with an audience. But it is not really a point I wish to concede. I have returned to this interaction many times in my mind. I admire the confidence in reconsidering engineering identity, especially flying in the face of somewhat dogmatic control of the terms "engineering" and "engineer" by Engineers Canada as official marks. But is it not important to acknowledge the power Engineers Canada has in this regard, constituting engineering as a legal *brand*?

Erika agrees somewhat. In our interview she admits that she sees a trajectory where engineering becomes less relevant.[477] The onus of self-regulation on the part of membership has created a situation where provincial regulators hope that graduates feel compelled to register as engineers, regardless of their varied careers. Erika explains that engineering continues to grow but that's largely dependent on new Canadians getting licenced as engineers.[478] "The percentage of graduates that get licences is dropping off," she says.[479] Erika thinks this important, not simply because engineering should hold its numbers.

> The way I see it, if there's no profession, like, if there's no licenced engineering profession there's no *engineering*. If people don't get licenced and the profession starts to dwindle then why would we educate engineering and get accredited universities? And I just see its disappearance. And why does it matter if the engineering profession disappears? Because it's more than technical knowledge, it's technical knowledge with an ethical lens. Which is the same thing as a doctor. So I just think that that needs to be sustained in society, some sort of accountability to technology outside of the legal system.[480]

These concerns regarding engineering graduates choosing not to register as professional engineers has been a concern since at least the early 1990s. At the November 1991 CCPE Board of Directors meeting, President Kerr announced a study "to determine why nearly 30% of all engineering graduates fail to enter the engineering labour force."[481] The previous chapter likewise dealt with this

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[477] Erika.
[478] Erika.
[479] Erika.
[480] Erika.
[481] CCPE Minutes Board of Directors' Meeting, November 1991, Engineers Canada Office, Ottawa: 20.

perceived shortage and its pressure on the engineering profession to improve women's representation.

Erika goes on to explain some of the other perception challenges that accompany the legal frameworks around engineering regulation, even within the Lab.

> You'll have heard from some organizations in the Lab where they say that, you know, "PEO is a member-based association and it's just serving its members' needs, it's missed the point about trying to serve the public's needs first." Right? So I hear to this day active conversations where people say, "Well you're not serving engineering *members* you're serving the public." And, you know, it's, it's sticky because in the legislation a licensed engineer is called a 'member of the Association.' Like, that's the legal word for me. I hold a licence and I'm a member of the Association. We're called the Association of Professional Engineers of Ontario, so the language of 'association' and 'member' are right in the Act. But people will turn that around and say, "Well if you're a member, then you're doing stuff for the members." Like, you elected me as President, so I must be serving the members. The members elected me on the Board, so I must be serving the members, right? And, "You're an association, which means you're self-interested." But that's just the language of our Act. But I think people take it that way, and some people believe it, and so there's- it takes some work to kind of say, "Well, no, we're a regulatory body and the public's interest comes first." So I think that's part of the tension that we create ourselves.[482]

Erika explains how she was first invited to be involved with the Engineering Change Lab.

> I think I was asked because I worked at PEO and I, so I was kind of getting to know regulation of the profession by working at PEO versus working and practicing the profession I wasn't as informed. And I guess I had this sort of sense that something was missing or that you know there were gaps in how engineering was operating. So, anyway so I was asked to do a phone interview [...] so I asked to have..[483]

An incoming phone call interrupts the recording on my iPhone, and our interview. We are in Erika's office in downtown Toronto. The building is new: quiet and open, a university campus on a Monday evening in late May. The office is new: empty except for two chairs, a desk, some shelves, and us. The shelves are bare of even a scrap of paper, let alone the books, file folders, and binders one would

[482] Erika.
[483] Erika.

expect to adorn an engineering professor's office. It is the two of us sitting on either side of Erika's desk, glass windows and walls, concrete columns, and steel beams.

The lobby of the Myhal Centre for Engineering Innovation and Entrepreneurship, opened in 2018, breathes modernity in concrete and glass, black steel and baltic birch. The building's facade more closely resembles the built environment of the surrounding campus: masonry, concrete, glass, and dark bronze. Designed to enable "cultural change," the Myhal Centre stimulates multidisciplinary collaboration and social interaction.[484] Auditoriums, maker spaces, garages, labs, vehicle ramps, offices, and an impressive four-storey skylit atrium with concrete staircase connect to each other, balancing programmed and unprogrammed space: "a recognition that learning happens everywhere, anytime."[485] Architect Peter Clegg says "I think there is a place for modesty, longevity, gravitas and seriousness in architecture. [...] That's what this building is about—it is a backdrop to serious engineering."[486] It feels serious in Erika's office: the shadowy skyline out her window diffuses indirect light on the shadowed, grey concrete walls as I apologize profusely for the disruption. I begin a new recording to continue our interview on my smartphone, first setting it to "do not disturb."

Erika explains her first phone interview with the ECL and how she shared their perspective with some of the concerns they had with the engineering profession. At the beginning of the ECL, K to 12 education was one of the biggest teams and

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[484] Stephanie Calvet, "Campus Classic: Myhal Centre for Engineering Innovation & Entrepreneurship, University of Toronto," *Canadian Architect*, September 5, 2019. https://www.canadianarchitect.com/campus-classic-myhal-centre-for-engineering-innovation-entrepreneurship-university-of-toronto/.
[485] Calvet, "Campus Classic."
[486] Calvet, "Campus Classic."

the Lab was concerned about educating young students about engineering. Erika details some of the resistance that this type of work faced.

> So the Lab kinda started out saying, you know, "What are we missing in terms of why kids from kindergarten to grade 12 don't know what engineering is?" It's not on their radar. They low-level want to apply to it, like, you know. What's the disconnect between it and science? It's not interesting, it's not emotional and so forth. So, and then, I think the Lab has had a harder time basically saying, like, if engineering exists today, what is it that's going on that is being missed because engineering isn't there? And therefore what is it that, what is it really that we're here to do? Because there's always this sort of complaint that you're self-perpetuating yourselves to what purpose, right? To what end? So I think there's been back and forth by people who challenge and say, "Well you're just trying to self-perpetuate" in the Lab. People that say, "No I think there's some really important that has to happen here." There's a tension around that.[487]

Engineering associations aspire to provide membership services enticing enough for engineers to enrol themselves into the association. They are invested in educating people about engineering and educating people into engineering, lest their membership base evaporate. In this context, overt gestures of public education can be easily seen as naked self-promotion. Engineers serve society, thus the profession was justifiably closed and self-regulated to protect the public. Society must be educated about the benefits of engineering to attract future engineers to willingly join the club. And while control of the profession is no longer at stake—there appear to be no external risks of engineers losing self-regulation—then the battleground around the benefits of engineering will continue to focus on the benefits to membership, rather than the benefits to society. Society need not be convinced that engineering ought to be a self-regulating profession, that fight has been determined; instead society must be convinced that people should become engineers.

[487] Erika.

Taking the Engineering Change Lab itself as a disruption to Canadian engineering makes their reach all the more tenuous. A deliberate stance to change the system accompanying a simultaneous positioning within said system requires balance.

I asked Tabitha about these challenges.

> I mean, so much has happened politically lately in the engineering community. Where like Engineers Canada, I was at the Engineers Canada meeting where they pulled out of the Change Lab formally. And I was, like, jaw on the floor. "What is happening?" I've in contrast seen OSPE, the Ontario Society of Professional Engineers which is an advocacy body, I've seen them run with technological stewardship to like the 20 trillionth degree. And so, it's, like, okay you've gotten certain groups like bought in to it and then you have other groups that, like, do *not* see the value at all. The other challenge, it's not, like, up to Charles as an individual to, like, fix these things and like change them and run initiatives and whatever. Like, It's up to the community of the Lab and the culture of the Lab, and for that change to kind of, like, come organically in a way. And obviously these things take time.[488]

The ambiguity of what exactly a provocation might mean for a system cannot be settled. Provocations and disruptions in the change lab setting do not map neatly on Luhmann's system perturbations or irritations. What makes the ECL a disruption to the engineering system, rather than immune response? If professional membership is indeed under threat, could the work of the Change Lab not be considered a mechanism to ensure that the engineering system survives?

Adam Kahane quotes Michael Chender when discussing the challenges of change-making work:

> When you get very close to the heart of the system, that is when the devils will appear. By devils I mean the system's strongest and trickiest defenders: its autoimmune system. If you aren't prepared for this, then you will be overwhelmed, and your efforts to change the system will fail.[489]

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[488] Tabitha.
[489] Kahane, *Power and Love*, 68.

But how might one determine when they are beleaguered by a devil, rather than simply being irritated? Again, Luhmann's systems theory points toward an examination of fundamental selections for answers.

6.5 "Who knows what could happen?"

I open the Engineering Change Lab's March newsletter in my Gmail and am immediately floored. My mind reels at the headline. It announces in bold type across the top of the page "BREAKING NEWS: Facebook corporation dissolved, operations turned over to non-profit trust."

I have just sat down at my computer to begin my workday, and had not yet seen this news. I read on, enthralled. What is going on with Facebook? I had not heard anything newsworthy about them this week. This must have happened last night, I think. Or earlier this morning, maybe. The release quotes Mark Zuckerberg saying

> I heard about a workshop that is coming to Silicon Valley in July, run by something called the Engineering Change Lab. So I looked into it, and found myself spending hours on my computer reading about the relationship between technology and society. It changed my entire worldview.

I am incredulous and astounded. I continue reading. Another quote from the "former" CEO of Facebook explains the company's actions: "We need to ensure this technology, which has become so widespread, is beneficial to all."

I cannot believe it. I had not been planning to attend the ECL workshop in July, as I was happy to focus on their Canadian activities, but this seems like a tremendous opportunity. Is Mark Zuckerberg going to be there? Should I try to attend? Imagine getting an interview with him. An American version of the ECL had been recently formed and this was going to be a jointly hosted event, maybe I could get myself an invitation. I also was not particularly interested in doing research on Facebook, or social media, but here was Mark Zuckerberg explaining a fundamental change in his understanding of technology and society because of the ECL. This could be huge.

As I try to process this news and if I should scramble to find my way into this event in California, the shoe drops: “The new Facebook is currently seeking a Chief Technological Steward to lead the organization’s transition. Meanwhile, the Engineering Change Lab wishes everyone a happy *April Fool’s Day*.”

They got me.

I smile and sit back in my chair. I was not expecting a prank here and am thoroughly amused. My mind stops racing and my heart rate settles, I do not need to plan a trip to San Francisco. I do not need to apply for more travel funding. I am not missing anything. Everything is fine.

Upon further reflection on this joke, though, I wonder if the ECL undermined their own process. “Who knows what could happen?” They ask after the confession, a lure that recipients should still consider attending, that there is still transformative potential in the workshop even though the bait was a lure. Leveraging the social lab method as a jest highlights the absurdity of the situation they presented: a contemporary technological leader with outsized influence changing their worldview and behaviour because of what they learned about a workshop. And it is absurd, to think that such transformations could be so simple (and that someone would describe it in the way quoted). And yet, is this situation not precisely the ethos of the change lab approach? An education achieved through having one’s worldview disrupted will produce more responsible action that is “beneficial to all.”

In my interview with Charles, I asked him about this newsletter.

> TH: Would you welcome Mark Zuckerberg to an ECL workshop?

> C: Yeah! I mean, the Lab methodology, you know, as we were driving up here you heard a little bit of our second radioshow podcast pilot with the Energy Futures Lab right? The idea, the ethos of the lab is really about welcoming in as diverse perspectives as you can and unlocking the potential of having people who don't normally either have opportunities to connect and share perspectives and think about the future or even if they are in the same room don't hear each other because you know the stage isn't set, the space isn't set. So the ethos of the lab is that anyone who wants to participate in good faith on the bigger question, you welcome in, right?[490]

And while "innovative disruption" does not seem to equate as a concept to Luhmann's perturbation, examining it through a systems theory lens helps to clarify why that might be the case. These popular disruptions share little with system operations and fundamental selections that risk altering system identity on a substantial level. The change lab approach, however, is seemingly more easily agrees with systems theory: expanding fundamental selections of engineering education—who, what, where, how—to see what might happen. These educational practices, while limited, further clarify the fundamental selections of engineering education more conventionally, in terms of both the content and practices of engineering education. The ECL's reimagings of engineering education and practices does indicate some of what has been selected for the environment of engineering education.

[490] Charles.

CHAPTER SEVEN

"IF IT AIN'T BROKE!"

CONCLUSIONS AND RECOMMENDATIONS

Change is in the air. And so is the humidity. I am seated in the fourth-floor faculty lounge of an engineering building on the east coast of Canada on a hot summer day. A facilitator asks our group of 15 workshop participants the following: "If technological stewardship was a graduate attribute, how would education shift?" Meaning: if demonstrating student competencies in the "responsible development of technology for the benefit of all" (i.e. technological stewardship) was a requirement for the accreditation of engineering programs, how might engineering education change?

Some 40 years after their undergraduate engineering program had been accredited and this building was first opened to new engineering students, our group of academics and engineering educators contemplates the transformative potential of engineering education policy on what takes place within this building's classrooms and wherever its graduate choose to go afterwards. The engineering faculty invited the Engineering Change Lab to host this workshop titled "Engineering a better world: building capacity to maximize the positive impacts of technology (physical, digital, and biological)," and the group is eager to follow the prompt.

The question, though generative, presumes comprehensible through-lines from engineering policies to engineering education to professional practices. It has been assumed that a policy concerning engineering curriculum enables certain educational outcomes that in turn enable certain practical outcomes. And while the group is perhaps optimistic about how such a dictate could drive curricular change—and any resultant engineering knowledges and practices—they have already identified current shortcomings of similar practices in engineering education during the workshop.

One of the twelve current graduate attributes for Canadian engineering programs is that students be able to “analyze social and environmental aspects of engineering activities.” Further, engineering graduates should understand the “interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society” and “the uncertainties in the prediction of such interactions.” Detailing how graduate attributes are incorporated into the classroom presently, one participant explained, “There is the mandatory section on societal impact for accreditation and then, ‘Go back to work.’” The group agrees that current policies do not guarantee their intended pedagogical and educational goals but merely the bureaucratic checklist to maintain accreditation.

A facilitator asks the group to consider how a paradigm shift toward technological stewardship could be included in engineering. The group does not accept that political awareness about technological issues could be seamlessly incorporated into the classroom; there are other barriers in place. A participant ruminates that “something is lost in the process of education.” Another elaborates, “We don’t give our engineers enough time to think about their broader political environment.” And yet another adds, “They become very isolated.” Before the group can stray too far into the minutiae of what is wrong with education, a facilitator reorients them toward the workshop goal: “The practice of zooming in and zooming out... We are focused on technological stewardship, but it connects to political systems. The challenge is what action we can take.” And thus, we are segued into the activity—our projects—for the day’s workshop.

And while the groups convene to begin work on their projects, a contradiction looms. Engineering education is not working and must be improved. Important considerations about how engineering interacts with society are simply given lipservice in the classroom to meet accreditation requirements rather than substantive or protracted engagement. Students, according to educators, do not seem to be aligned with the policy intentions that influence their curriculum. Yet, in the workshop described above, imagining how engineering education might work differently, if not better, posits an alternative where technological stewardship supersedes, in policy and practice, the current graduate attributes in the regulatory regime. Engineering education is insufficient in its current form, but it might be rendered relevant and transformative for the profession if the content were framed differently.

And herein lies the contradiction: engineering educators presume a weak link between engineering education and practice (engineering education is not relevant to contemporary professional issues) that can be addressed through the presumed strong link between engineering education and practice (education determines professional practice). Simultaneously, engineering education is cast as the problem and the solution for the engineering profession. It is central to making important changes to the profession, yet irrelevant in the actual professional workings of Canadian engineers in its current form.

Participants in the workshop acknowledge how difficult it can be to change cultural systems, but there does seem to be some promise nonetheless. After working in smaller teams for the remainder of the session to devise our projects on technological stewardship, the group returns to a large circle of chairs to do a "check-out" before concluding the workshop. Sharing their thoughts on the workshop, the speaking proceeds counter-clockwise around the circle. After each speaker finishes, the group preemptively focuses their attention on the speaker's neighbour to their right, anticipating the next contribution. Someone jokes about how hard it is to "break the paradigm" of speaking in such a sequential order. Another retorts through the din, "If it ain't broke!" The group laughs harder, leaving the “don’t fix it” unsaid. Wrapping up and encouraging us to follow through with our projects, a facilitator remarks that “having humanities and social sciences invited to the engineering building already feels like a win.” As the group is being prepared for dismissal, a facilitator reiterates the point of the workshop and the Engineering Change Lab, “We are a group seeking to look into the future and take responsibility.”

7.1 Systems

The above vignette outlines some of the important features of engineering culture I have analyzed through this study. There are systems that guide and give meaning to engineering culture, like the structure of Canadian nationalism as determined by the professional organization, regulation, and accreditation of engineering education. Coordinating the engineering profession on a national scale bolsters conceptions of the Canadian state as the profession is coupled to state administration, a form a banal nationalism that creates an imagined community of Canadian engineers. Outside of the technological impacts this community may exert over or through the state, this community exists on paper in policies and agreements. In Luhmannian terms, these nationalizing endeavours

I have likewise demonstrated the centrality of gender/sex and the system of gender hierarchies in guiding Canadian engineering. The men-dominated spaces of Canadian engineering reify the omnipresent sexism of contemporary Canadian culture and further exacerbate knowledge about and action against the discrimination of women within engineering. A systems theory analysis in this vein elucidates how women’s representation in Canadian engineering simultaneously occupies a place of tremendous concern and attention while also being maligned and ignored. The selection of women out of the system of engineering (or the selection of women for the environment of engineering), in Luhmann’s approach, creates a system where gender/sex concerns are hidden from view, a blind spot. Only through certain perturbations to the system do gender troubles become actionable concerns, and thus far the initial system selections have gone sufficiently unaddressed.

Another system—that of the concept of "technological change"—further animates engineering education cultures. Technological change and its associated complexities make the system of engineering education meaningful. Technological change, as an omnipresent moving target, is sustained through the promotion of technoscientific progress and innovation in engineering cultures. Innovation is good and can be achieved through many avenues. But there are also pitfalls. Technology is always changing, and the rate of change, if some engineers are to be believed, has been unprecedented since the 1960s. The point is not whether or not technology has changed and how significant the ramifications of certain changes may be. Rather, the issue is that technological change appears more of a rhetorical strategy to make engineering education reforms meaningful—"we have to keep up with technology"—than it does as an insightful or enlightening perspective of engineering or education. It becomes impossible to imagine a world where technology does not change, where it does not change often, in unexpected directions, or without unintended consequences. But if such a world existed, would there not still be opportunities for educational reforms? The rhetoric of technological change, and also technological stewardship, do more to ascribe power or authority to engineers in addressing technological problems than they necessarily do in providing a better way of understanding the problems to begin with.

There is, however, promise. These systems may exceed these trends of nationalism, gender/sex, and technological innovation as some engineers resist dominant sociocultural forces, or attempt to re-engineer engineering altogether. The recent and growing interest in Indigenous issues in Canada and within

Canadian engineering are beginning to make clear the tight couplings of engineering to the Canadian state and its relationships with Indigenous territories and resource extraction. As engineers are made more knowledgeable about Indigenous history in Canada, and as Indigenous representation within Canadian engineering continues to grow, it is difficult to guess which directions these national tensions may push the profession. So too are the longstanding gender/sex issues within Canadian engineering difficult to forecast when the track record is poor yet one may find themselves in an engineering workshop that is not focused on gender where the overwhelming majority of attendees are women. Plus, greater attention to various gender/sex identities within engineering will likely improve how women's roles within engineering may be understood. Although the rhetoric of "technological change" is unlikely to dissipate, concepts like disruptive innovation may prove fruitful if they gain real traction professionally and within the engineering education system. So while deliberate interventions within engineering education and engineering culture are clearly constrained by various systems, there remains anticipation that it could still be made otherwise.

7.2 Engineering education reforms

In my dissertation I have sought to describe Canadian engineering cultures by looking at engineering education, education that emerges from some unconventional sites of engineering practice. Following engineering education through board rooms, workshops, policies, and reports on the profession reveals significant aspects of engineering cultures outside of classrooms, laboratories, shop floors, and construction sites. These educational practices are omnipresent, as engineers continually reevaluate what they know and what they could know better, justifying educational reforms to anticipate future needs of, and future threats to, the profession.

Regardless of the enacted changes, these attempts to disrupt or reform engineering education can be read as stabilizing forces from a systems theory perspective. Attempting to make prognoses about what the future of the system will be and evaluating the competing interests of the various individuals and organizations involved ties the present to the future. Graduates are currently unprepared for the working world. Reforms are needed now. But these reforms cannot succeed in their goals without addressing the fundamental selection problems of the system. The tightening of engineering curricula at universities nationally may indeed produce certain educational outputs: engineers are educated in math, physics, chemistry, engineering science, design, and professional practice; professors incorporate graduate attributes into their courses. But supplementing a rigid national curriculum with in-house humanistic lessons does not guarantee a humanistic education when such an education remains selected for the environment of engineering education in the first place. So too will reforms to attract and retain women in engineering fall short. How can professional gender parity be achieved without first securing gender parity in engineering admissions at universities? How can recent interest in Indigenous engineering be genuinely supported when the engineering system is so closely tied to the system of the Canadian state and its settlement of Indigenous lands?

Curiously, a contradiction in the relationships between engineering education and engineering practice emerged through this research. Engineering educators and policymakers presume a strong link between education and practice: if education changes, the behaviour of professionals will correspondingly change. Such interventions, however, rely on a perceived weak link between education and practice: engineering graduates are unprepared for the working world because of the lack of relevance in their education. Education can fix systemic problems because it can be made to be relevant.

Luhmann's systems theory proves enlightening when examining these contradictory relationships between engineering education and engineering practice—where engineering education weakly corresponds with professional practice but also strongly determines it. The weak relationship between education and practice stems from the structure of the system of education: reforms are justified by supplanting current "worse" education with future "better" education, moving towards perfection of individuals and society. If outcomes are currently imperfect, then they must be improved.

The strong relationship between education and practice is likewise generated by the structure of the system of education: society accesses subsystems through state administration of education. This access to the system of engineering education by society means that social issues concentrate within education. Education is the mechanism by which social changes can be ushered in, a postulate that engineering education constructs engineering practices.

This research project has thus characterized engineering as a reactive discipline, partly due to this future-looking approach. By forecasting what the future might look like, potentialities supersede actualities, and the present is exceeded. In spite of certain contemporary values surrounding disruption, conservatism remains firmly entrenched. Provoking changes in engineering education has less to do with radically altering system performance than it does with securing system stabilities, redundancies, and repetitions in an uncertain future.

Revisiting the early work of the Canadian Accreditation Board from 1976, one wonders how much has been accomplished to manage the shortcomings of engineering education over the past 50 years.

> Students must be made aware of the vital role of the professional engineer in society and the interaction of engineering work with the economic, social and human goals of the nation. An understanding must be acquired of: a) the quality of the natural and human

> environment and the impact of technology; b) the function and activities of our society, business and government in shaping our society and its values; c) the legal responsibilities and ethical guidelines and constraints applied to the profession. Every opportunity should be seized to weave into the fabric of engineering education an awareness of such matters through course material and through liaison with practicing engineers and other groups outside of the educational establishments.[491]

Would the Engineering Change Lab exist had more success found these goals of the Canadian Council of Professional Engineers/Engineers Canada?

I wonder if instead of treating engineering education as a tool for the production of professional engineers it were considered as engineering practice in its own right, then concerns about engineering education's relevance or perceived shortfalls could be more usefully reframed. Engineers willingly accept that learning happens throughout one's professional career; it is in fact a requirement of professional practice. I have contended that engineering education is engineering practice, and historically others have debated this point. But if engineering undergraduate education is as much engineering practice as professional practice is education, how might Canadian engineering be improved for the better?

For starters, expectations that universities train readymade engineers-for-hire may wane. And the casual dismissal in professional practice of the value or relevance of formal post-secondary education in scientific disciplines may too soften. More importantly, though, engineering students may more seriously be considered not as the future of the profession in need of preemptive intervention but its very real present. What engineers learn, where they learn, how they learn, and who they are *as students* might clarify how reforms could be implemented successfully for the profession rather than fearing what they may become in the future.

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[491] "CAB Annual Report June 1976," CCPE (1976): 10.

Mechanistic understandings of systems abound through this dissertation. Engineers engineering engineering education consistently concern themselves with the future to justify their education policies and practices in the present. Returning to the thermostat, cybernetics and system thinking provide a locus with which to tie the present to the future, to hold them in a measurable relationship. But has systems thinking led to system change in engineering education? Regardless of the successes or failures of any of the educational reforms presented in this dissertation, these forward-looking concerns for engineering education, even when admirable, continue to elide present-day fundamental selections of engineering education. The technical core of engineering education curriculum, the confederation of Canada, engineering education program accreditation, and men-dominated spaces in engineering select other elements for the environment of engineering. These selections require reckonings if one hopes to see real systemic change.

7.3 Recommendations

Through this research project I did seek to make my own contributions to engineering education, acknowledging all of the challenges in doing so that I have presented thus far. In this spirit, I turn to the two organizations I studied. For Engineers Canada, I return to fundamental selections of its undergraduate curriculum and the creation of the graduate attributes (the preferred educational language used in contemporary Canadian engineering undergraduate programs). Attributes offer ways of standardizing and controlling specified attainments but lend themselves to instrumentalized pedagogies focusing on efficiently delivering these learning outcomes. Such approaches contrast to collaborative learning practices attending to specifics and practicalities of selected engineering cultures and contexts. Perhaps enabling students to expand their educational experiences outside of such a regimented focus on engineering courses could achieve some of the goals that the graduate attributes and other educational reforms have sought to address, albeit in a far less instrumental manner.

I see the Engineering Change Lab as a step in this direction. With a more open conception about what engineering currently is and what it could be, including which sorts of lessons and experiences are relevant to engineers, the ECL does not so strictly produce the same attempts at standardizing education. In contrast, my challenge for the Engineering Change Lab is much less severe, but a challenge nonetheless. It is to consider seriously which systems they might unwittingly be sustaining through their attempts at “disruption.” In particular, my focus here has been on nationalisms, gender hierarchies, and technoscientific progress, which in light of my analysis still warrant sustained critical attention. I would further recommend a reckoning with the complex relationships that engineering has with Canadian nationalisms, as I documented in this research project. Moves of inclusion towards Indigenous peoples, reconciliation, and decolonization within engineering and engineering education may appear straightforward. I have shown, however, that inclusion of Indigenous peoples or issues does not necessarily address the ties engineering shares with Canadian nationalisms which may be at odds with Indigenous sovereignties. That said, I look forward to the ECL’s continued work.

I make further recommendations to those who are perhaps most interested in this stream of research: engineering educators. Following my assertion to frame engineering education—in all its various contexts—as engineering practices, I recommend educators consider teaching practices as engineering practices. A series of questions now emerge including closer attention to the types of engineering practices occurring in lecture halls, laboratories, and tutorials and through assignments and tests. Particular practices promulgate specific cultural values, hierarchies, ethics, and politics. As STS has long established, technoscientific practices are open to critical analysis and deliberation. Many engineering faculties have incorporated design work earlier into their programs as ways to expose students to the messy realities of engineering practices they will eventually encounter; failure, iteration, and social context soften the applications of fundamental principles and governing equations. Further, science and technology studies scholars provide wide-ranging research that can make excellent complements to existing engineering coursework. More specifically, bringing focus to maintenance or upkeep and an ethics of care as relevant, timely, and important engineering issues can balance other dimensions of engineering practice that uncritically promote technoscientific progress as a cultural good. These knowledge sources, in addition to somewhat more conventional applications, like case studies, can serve as supplementary means of changing one's engineering classroom practices that emphasize social contexts of engineering practices over simple technoscientific applications.

For researchers of engineering education, I recommend ethnographic methods as offering particular openings to explore engineering cultural practices and methodologies as enlightening means of data collection, communication, and analysis. As I write, ethnographic studies are not particularly popular in engineering education research, and as a consequence this research tends to downplay certain features of engineering practices. Practitioners of engineering education in a variety of contexts—teachers, students, administrators, professionals—experience education in multifaceted, diverse, and complex ways. Without exploring these myriad contexts of engineering practices in ethnographic detail with associated understandings, engineering education research and reforms stemming from this research risk perpetuating a rather deficient view of professional educational practices. In this light, while I, as a white settler man in engineering, would hesitate to position my view of engineering as emerging from the margins, so to speak, my use of ethnographic narrative still enriches more conventional views from the centre. Similar approaches may prove useful, especially when examining gender hierarchies in engineering contexts, focusing on how women navigate gender hierarchies through engineering educational practices.

This research recommends further studies of engineering framing engineering education as engineering practice. Such a framing would provide useful insights in the disciplines of engineering studies and science and technology studies. More importantly, engineering organizations could begin to see engineering education as not merely foundational to engineering practice but as actual sites of active engineering practices themselves.

This research project uncovered ambiguity around the term "engineering education" that could be further unpacked and complicated. While "engineering education" conventionally referred to undergraduate engineering education through this research, the term is also used as a catchall to include design education, engineering education prerequisites, graduate engineering education, professional development, on-the-job training, certification and credential education, outreach activities, teacher training, and familial education. Investigating the myriad uses of "engineering education" could help specify and coordinate attempts to reform engineering education as a whole.

Further research on Indigenous engineering in Canada is also recommended. In particular, I am interested in how engineers and researchers might square the close ties engineering shares with the Canadian state and with Indigenous knowledges and governance systems. Other sociocultural megatrends—racism, ableism, classism—would further provide fruitful analysis of engineering culture.

Last, this research recommends applying Niklas Luhmann's systems theory to other areas of engineering education and science and technology studies. I am curious if others find it as useful as I have here, or if science and technology studies may provide some fruitful critiques and refinements of Luhmann's work.

The system of Canadian engineering has relied and continues to rely on technological change as an urgent justification for their professionalization, regulation, and education reforms. However, this impetus of intervention is belied by a noted lack of progress on many fronts to improve engineering education, despite incremental gains in others. Coordinated national action on engineering has produced a system that is uniquely Canadian, but one that is so insecure in its future that it fails to see its present. I can only hope that engineers may begin to see it now.

APPENDIX A

THE SONS OF MARTHA

The Sons of Mary seldom bother, for they have inherited that good part;
But the Songs of Martha favour their Mother of the careful soul and the troubled heart.
And because she lost her temper once, and because she was rude to the Lord her Guest,
Her Sons must wait upon Mary's Sons, world without end, reprieve, or rest.

It is their care in all the ages to take the buffet and cushion the shock.
It is their care that the gear engages; it is their care that the switches lock.
It is their care that the wheels run truly; it is their care to embark and entrain.
Tally, transport, and deliver duly the Sons of Mary by land and main.

They say to mountain "Be ye removèd." They say to the lesser floods "Be dry."
Under their rods are the rocks reprovèd—they are not afraid of that which is high.
Then do the hill-tops shake to the summit—then is the bed of the deep laid bare,
That the Sons of Mary may overcome it, pleasantly sleeping unaware.

They finger Death at their gloves' end where they piece and repiece the living wires.
He rears against the gates they tend: they feed him hungry behind their fires.
Early at dawn, ere men see clear, they stumble into his terrible stall,
And hale him forth like haltered steer, and goad and turn him till evenfall.

To these from birth is Belief forbidden; from these till death is Relief afar.
They are concerned with matters hidden—under the earthline their altars are—
The secret fountains to follow up, water withdrawn to restore to the mouth,
And gather the floods as in a cup, and pour them again at a city's drouth.

They do not preach that their God will rouse them a little before the nuts work loose.
They do not preach that His Pity allows them to drop their job when they damn-well choose.
As in the thronged and the lighted ways, so in the dark and the desert they stand,Wary and watchful all their days that their brethren's ways may be long in the land.

Raise ye stone or cleave the wood to make a path more fair or flat;
Lo, it is black already with the blood some Son of Martha spilled for that!
Not as a ladder from earth to Heaven, not as a witness to any creed,
But simple service simply given to his own kind in their common need.

And the Sons of Mary smile and are blessèd—they know the Angels are on their side.
They know in them is the Grace confessèd, and for them are the Mercies multiplied.
They sit at the feet—they hear the Word—they see how truly the Promise runs.
They have cast their burden upon the Lord, and—the Lord He lays it on Martha's Sons!

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