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Transformational Engineering: Developing the Next Generation of Engineering Innovators, Experts and Leaders for a Changed World

CONCEPT PAPER

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Abstract

How can we learn from the current global crisis and apply those lessons to pressing global challenges?

Since 2017, the GEDC Industry Forum has brought together engineering and technology leaders and stakeholders from academia, industry, civil society, and government to develop the next generation of engineering innovators, experts and leaders. This initiative, organized in partnership between Petrus and the Global Engineering Deans Council (GEDC), will convene online in 2020, reflecting the times we live in today. The Faculty of Engineering of McMaster University in Canada, with a global reputation for research and education with impact, will host this year's digital event.

Much has changed in three short years. The pressing issues the first GEDC Industry Forum sought to address included the growing skills gaps in the workforce, cross-border and open innovation and socially conscious engineering. While these topics remain critically important, Covid-19 has fundamentally altered our world in 2020. Higher education institutions closed campuses and moved learning entirely online, while companies had to adapt business models to the new global reality to survive. A lifeline during the pandemic, digitalization continues to transform the world at an accelerated pace, yet the 'digital divide' persists. The pandemic has also created a renewed sense of urgency surrounding ongoing issues such as climate change and sustainability and systemic social inequalities and injustices.

Through rapid change and uncertainty, 2020 has provided the GEDC Industry Forum an opportunity to completely rethink the topics it has been addressing in the past few years — including skills gaps, to innovation, to socially conscious engineering — as well as more fundamental ones, such as the role of universities and industry in society and how they should collaborate. The 2020 GEDC Industry Forum Concept Paper provides further context on these topics ahead of our event and dialogue.

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Introduction

In 2017, the GEDC Industry Forum held its first global event in Fontainebleau, France. Engineering deans, industry partners, and other key stakeholders from around the world gathered to address what all understood as an urgent issue – **growing skills gaps in the workforce**, especially in engineering and digital fields. At that time, and still today, many young people are unemployed, while employers struggle to find the talent they need. The driving idea behind the Industry Forum was that through improved collaboration between universities and industry, these skills gaps could be minimized through progressing engineering education for the benefit of all – universities, students, employers, and society as a whole.

Undeniably, tackling such a complex topic takes time, and following editions of the Industry Forum have continued to design creative solutions to persistent skills gaps, while evolving and expanding discussions and targeted solutions to include other critical topics such as **cross-border and open innovation and socially conscious engineering**. [1]

This year is different. The 2020 Industry Forum will of course continue to address enduring skills gaps, how to collaborate to innovate, and how to educate the socially, environmentally, and ethically responsible engineers and leaders of tomorrow. However, in 2020 the world has experienced unprecedented, sometimes systemic, disruption due to the global Covid-19 pandemic, and in this context many other preexisting issues have been thrown into sharp relief, such as climate change and economic and social inequalities. While challenging, the current situation presents a window of opportunity to completely rethink engineering education and university-industry collaboration, and to make some fundamental, long-lasting changes.

Setting the Scene

Since 2017 and the first edition of the GEDC Industry Forum, there have been multiple important developments that warrant further discussion and incorporation into the Industry Forum agenda. The most conspicuous issue today is the Covid-19 global pandemic, a truly novel challenge, while others are preexisting, ongoing challenges that have evolved over the past few years. Highlighting the interconnectedness of the world today, there is considerable amount of overlap among the following developments, and many preexisting issues have been exacerbated by the Covid-19 pandemic.

Covid-19

This year Covid-19 shocked the world. In a matter of days and weeks, the way we learn, work, travel, and live together drastically changed. In an effort to respond to the disruptions caused by Covid-19, economies, governments, health systems, and indeed entire societies around the world have been strained.

This year, UNESCO estimated that over 1 billion students globally – a full two-thirds of enrolled learners –stopped attending school regularly as 144 countries closed their school systems entirely due to Covid-19.[2] **Higher education institutions** have been no exception, and as university campuses closed, university educators have had to adapt their lesson plans to online courses and find innovative alternatives to traditional experiential learning conducted through labs and other hands-on, physical programs. For students, full online courses have required adaptation to learning software, adjusting to group dynamics in remote teams, and managing their time in homes where personal life inevitably overlaps.

In the **private sector**, entire industries have been negatively impacted, such as tourism and hospitality, and sports – both of which require large gatherings, close human interaction, and business and/or leisure travel.[3] Towards the beginning of the pandemic, start-ups – both high-profile ones such as Airbnb and Bird as well as smaller ones – that existed before 2020 were forced to lay off large numbers of employees and cut costs as revenues plummeted and investments dried up.[4] However, the pandemic has also positively impacted other industries, especially those delivering online products and services (e.g. Apple Inc., Amazon.com, Facebook Inc., and Alphabet Inc.) and many

[1] See the 2019 GEDC Industry Forum reports from Bucharest and Fontainebleau for more information on these topics and how the Industry Forum has developed since 2017
[2] (UNESCO, 2020)
[3] (De Mey & De Ridder, 2020)
[4] (Griffith, 2020)

companies have managed to quickly adapt their business models to the new global reality, oftentimes not only for the purpose of saving the company, but to also help provide socially beneficial, critical goods and services. [5]

With so many university courses moving online, and a significant number of employees working online from home, it is difficult to imagine a return to the old ways of business and education. Prior to the pandemic, only seven percent of Americans worked remotely.[6] In Australia and the European Union, about six percent of citizens telecommuted on a somewhat regular basis—a figure that has remained relatively stagnant over the past decade.[7] However, a recent multi-country survey reported 70 percent of respondents found remote work has had a positive impact on their "finances, mental health, physical wellness, and social lives," with nearly 53 percent wanting to telecommute permanently. [8]

While it is unlikely that education providers will continue to provide all courses 100 percent online, and not all employees are able to work remotely, some experts are asking whether working online is becoming the 'future of work'. [9] Indeed, a survey by Gartner of 317 CFOs found that 74 percent of respondents said that they will move at least 5 percent of their workforce to permanently remote positions (with nearly a quarter stating that they will move at least 20 percent of their workforce to permanent remote positions) – a move that offers cost-saving opportunities for companies, and will have a long-lasting impact on how companies do business and the daily lives of individuals around the world.

Digitalisation and its Far-reaching Impact

Already in 2017, when participants convened for the first GEDC Industry Forum, the world had been changing at a rapid – and accelerating – pace. This is due to digitalization and several other related concurrent megatrends:[10]

- **Digitalisation** – digital technologies are 'revolutionizing the way we think, communicate, design, work, move, play and do business.'[11]
- **Globalization** – while 2020 has presented some challenges to globalization, it continues, because today it is 'no longer about trading goods across borders, but about trading ideas, know-how and services.'[12]
- **Horizontalization** of the socio-economic world – with information and knowledge spread ever more rapidly and openly today, traditional hierarchies have been flattened.
- **Blending of technical, economic, and societal structures** – innovation and business are increasingly driven by clients and consumers rather than technology, leading to a situation where 'the focus is no longer on making the cheapest, but the smartest and most personal products'.[13] Growing access to information, know-how, and inexpensive and user-friendly software, tools, and materials, means that it is now easier for nearly anyone to design, develop, manufacture, finance, and sell products.

These trends continue today, and while the increasing ubiquity of digital technologies presents many opportunities, it also exacerbates existing inequalities in society. One example of this is 'digital inequality' or the 'digital divide' which separates people into two groups: those who have the 'material, cultural, and cognitive resources required to make good use of information and communication technology (ICT)', and those who do not.[14] This divide exists within countries, but it is perhaps most apparent when comparing developed and least developed countries. In 2019, 87 percent of people in the former used the internet, while only 19 percent of people in the latter did.[15] While the Covid-19 pandemic has not necessarily had an impact on these numbers, it has made access to the internet and digital technologies 'a matter of life or death' according to United Nations (UN) Secretary-General António Guterres, due to the fact that digital technology 'is central to almost every aspect of the response to the pandemic'.[16]

[5] (King, 2020). See (Reuters, 2020) and (Flynn, 2020) for some examples of companies working to produce socially beneficial products
[6] (Desilver, 2020)
[7] (Sander, 2020)
[8] (Coworking Insights, 2020)
[9] (UN News, 2020)
[10] This group of megatrends was outlined in Aldert Kamp's (2016) publication *Engineering Education in the Rapidly Changing World*, with each trend updated thanks to Kamp's 2020 publication *Navigating the Landscape of Higher Engineering Education*.
[11] *Ibid*. p. 19
[12] (Kamp, Navigating the Landscape of Higher Engineering Education: Coping with decades of accelerating change ahead, 2020), p. 19
[13] *Ibid*. p. 20
[14] (OECD, 2015)
[15] (United Nations, 2020)
[16] *Ibid*.

Threats to Society - and Survival

In the past few years, focus has increased on issues that threaten the very survival of humans, namely climate change and sustainability, as well as those that threaten the effective functioning of societies worldwide, such as inequalities between groups of people.

The **Sustainable Development Goals (SDGs)**, which were set at the end of 2015 by the United Nations General Assembly with their global indicator framework being adopted in 2017[17], have been influential in shining a spotlight on sustainability. From the adoption of the SDGs, studies have shown that citizens support the goals. For example, an IPSOS survey found that they 'strongly support' SDGs, with between 80 and 95 percent of respondents supporting each individual goal.[18] Individuals also strongly consider it important for businesses to pay attention to SDGs. For example, 90 percent of respondents in a PwC survey 'believe that it is important that business signs up to SDGs', and 78 percent stated they were 'more likely to buy the goods and services of companies that had signed up to the SDGs'.[19] Businesses have been responding, although there is still progress to be made. In the 2020 United Nations Global Compact survey of 10,000 business participants, 84 percent of respondents reported 'taking specific action' to advance SDGs and 61 percent are developing products and/or services that contribute to SDGs.[20] However, only 46 percent of respondents are embedding SDGs into their core business and only 37 percent are designing business models that contribute to the SDGs.[21]

Unsurprisingly, environmental challenges feature heavily in the SDGs, and goal 13 is dedicated completely to climate action. **Climate change**, considered by experts to be a multi-faceted challenge intricately connected to every facet of human lives[22], has been recognized as a global issue for decades now. However, due in part to the efforts and popularity of young activists like Greta Thunberg (who only held her first protest in 2018)[23] and in part to consistently worsening climate conditions, focus on climate change has intensified in the past few years.

In 2020 particularly, the impact of humans on the environment was highlighted in a dramatic way as lockdowns due to Covid-19 resulted in the significant reduction of CO_2 emissions and the vast improvement of air quality in some major cities, especially in China.[24] One study found that in the 123 countries covered (who are responsible for 99 percent of CO2 emissions), global CO_2 emissions dropped by more than 25 percent in April 2020, and nitrogen oxides (NO_x) by 30 percent.[25] The past few months have only served to further heighten awareness of climate change, as for example, 33 rivers in China flooded to the highest levels in recorded history in July 2020[26] and several regions in the western United States of America have seen record forest fires engulf forests and towns in August and September.[27]

The global pandemic has also highlighted many of the **underlying and systemic inequalities and injustices in societies** around the world, for example as certain populations are disproportionately impacted by Covid-19 itself, as well as the ensuing economic crises.[28] This has led to a renewed sense of urgency to address social issues, building on an already notable year for global collective action in 2019.[29] While the topics that activists are addressing have been the focus of civil society for decades (e.g. equality and justice, worker rights, technology governance), the way in which people are mobilizing has changed significantly this year due to social distancing requirements, and most activism is now online.[30] This digital activism has been especially popular with young people, and there are many examples of online youth activism occurring in 2020.[31] Even before this year, however, social activism has been found to be important to young people, with one survey for example finding that 75 percent of Generation Z respondents consider political or social engagement to be 'very important to their identity'.[32]

[17] (United Nations, 2017)
[18] (OECD, 2017)
[19] (PwC, 2015)
[20] (United Nations Global Compact & DNV GL, 2020)
[21] *Ibid*.
[22] (Intergovernmental Panel on Climate Change, 2018)
[23] See for example (Woodward, 2020)
[24] (He, Pan, & Takana, 2020)
[25] (Forster, Forster, Evans, & al., 2020)
[26] (Al Jazeera, 2020)
[27] (Yan, Mossburg, Moshtaghian, & Vercammen, 2020)
[28] (UNDP, 2020)
[29] (Wright, 2019)
[30] (Çilem, 2020)
[31] (Pelter, 2020)
[32] (MacColl, 2019)

Going Forward

Considering the ongoing global issues originally addressed in the 2017 Industry Forum, as well as the post-2017 developments outlined above, **what does this mean in the context of the GEDC Industry Forum?**

Implications for Skill Development

The 2017 Industry Forum Concept Paper built a list of desired skills and competencies for an engineer, using Boeing's 'Desired Attributes of an Engineer'[33] list developed in the early 1990s as its foundation, and then adding to this from a number of sources[34]:

Transversal Engineering Skills/Competencies

- Engineering Science (mathematics, physical and life sciences, information technology)
- Proficiency in design and manufacturing processes
- Multi-disciplinary, systems perspective
- Profound understanding of the context within which engineering is practiced (business, economics, environment, customer and societal needs)
- Problem identification, analysis, and solving

Soft and Professional Skills/Competencies

- Effective communication (written, verbal, graphic, electronic) with both technical and non-technical audiences
- High ethical standards and behavior
- Critical and creative thinking, independently and cooperatively
- Resilience – the ability and self-confidence to adapt to rapid or major change
- Desire and willingness to learn (lifelong learning)
- Teamwork
- Commercial awareness
- Entrepreneurship
- Global and cultural awareness and sensitivity
- Awareness of and sensitivity to development issues

Current High Demand Skills/Competencies

- Design thinking
- Data science/digital skills
- Cybersecurity
- Artificial Intelligence
- Sustainability

This list is meant to cover all the skills needed to prepare a modern global engineer for the professional world, no matter how the world changes. However, this year the world has experienced profound, unprecedented disruptions, which have highlighted the extreme rapidity with which the way people live, work, and learn can change. In this environment, it is worth revisiting this list of skills, and asking: **are there any additional fundamental skills that engineers need to successfully navigate the working world today? Are there any skills that engineering students need to thrive during their studies**

[33] See (McMasters & Komerath, 2005) for an explanation of the original Boeing list
[34] See (Collins, 2017) for these additional sources.

Implications for Innovation

Because 'innovation and creativity love crises and constraints', 2020 has seen some remarkable examples of ingenuity.[35] Especially in the technology, consumer goods, and pharmaceutical industries, individuals and organizations have produced swift solutions to the problems created by the global Covid-19 pandemic.[36] Many innovations came from groups of companies working openly together, demonstrating the tremendous value of open innovation.[37]

However, by showing that this kind of rapid, collaborative innovation is possible (or that 'some elephants can dance when they must'), the global pandemic has exposed pre-crisis innovation systems as 'cumbersome and cautious' burdened by 'risk-averse' decision-making.[38] For example, while the 'massive potential' of open innovation has been discussed for over a decade, for most companies, it 'remains an ambition that hasn't yet come true'.[39] And even now, as the window of opportunity for dramatic change is open, only 21 percent of executives surveyed by McKinsey & Company said they have the expertise, resources, and commitment to pursue new growth successfully, despite 90 percent of them believing that the Covid-19 crisis will 'fundamentally change the way they do business' over the next five years. In fact, the survey showed that only 23 percent of executives listed innovation as their top priority today, compared with 55 percent pre-crisis.[40]

Open, cross-border innovation is already a focus of the Industry Forum following its initial event. The question for the 2020 Industry Forum, then, is **how can universities, industry, and other stakeholders collaborate to leverage the opportunities to build better innovation systems, and curtail the challenges presented by the current global crisis?**

Implications for Socially Conscious Engineering

Social consciousness is closely related to ethics in engineering. Already in the early 1990s, Boeing's forethoughtful 'Desired Attributes of an Engineer'[41] list included 'High ethical standards', and while these individual standards remain essential, today 'macroethical' issues such as the relationship between society and technology are also increasingly important due to rapid technological change.[42] In a complex, highly connected world, engineers need to understand current events and challenges (for example, have a good grasp of the SDGs), the effects and impacts of science and technology on society and the environment in a broad sense, and the 'positive and negative influences that the outcome of their prospective profession can have on human society and the natural environment'.[43]

The pace of technological change has not decelerated during the global pandemic this year, while ongoing environmental and social issues have been highlighted. However, many engineering higher education institutions do not incorporate ethics, social issues, or sustainability into engineering curriculum. **Can the current global situation be leveraged to include these elements in engineering education? How can universities and industry work together to accomplish this?**

[35] (Atwater, 2020)
[36] (Bar Am, Furstenthal, Jorge, & Roth, 2020). See (AFP, 2020) and (Sachan, 2020) for examples of innovations during the global pandemic.
[37] (Dahlander & Wallin, 2020)
[38] (Knowledge @Wharton, 2020) See Lou Gerstner's book *Who Says Elephants Can't Dance?* for an example of a company (IBM) successfully going through dramatic change.
[39] (Dahlander & Wallin, 2020)
[40] (Bar Am, Furstenthal, Jorge, & Roth, 2020)
[41] (McMasters & Komerath, 2005)
[42] (Harris Jr., Pritchard, & Rabins, 2009)
[43] (Kamp, 2020), p. 41

Conclusion

Much has changed since the first edition of the GEDC Industry Forum in 2017. 2020 has been a particularly disruptive year, with the Covid-19 pandemic adding to ongoing pre-existing global challenges and impacting individuals, organizations, and entire economies and societies simultaneously at a level perhaps not seen since World War II. While there have been many devastating consequences of the global pandemic and the ensuing economic and social crises, 2020 opens a window of opportunity to make long-lasting, systemic changes.

For the Industry Forum, this means for example **completely rethinking the roles of universities and companies in society, and how they collaborate**. It also means answering the fundamental question that underlies all of the topics the Industry Forum is addressing: **How can we learn from the current global crisis and our responses to it, actively consult and partner with current student stakeholders, and then apply those lessons to other pressing global challenges?**

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