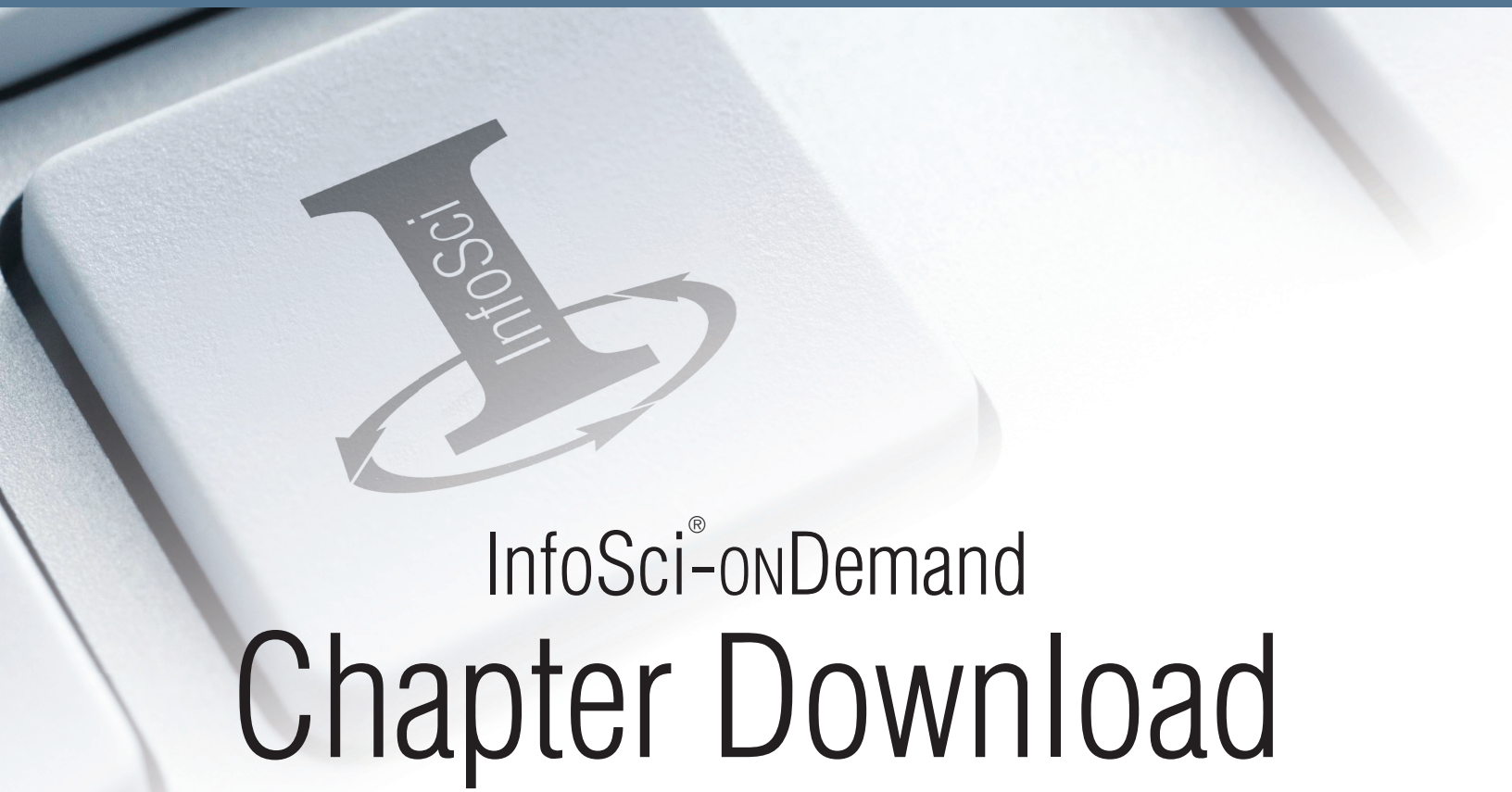

# Women and technology: disrupting leadership in engineering education

# Women and technology: disrupting leadership in engineering education

Loy, Jennifer. 2019. Women and technology: disrupting leadership in engineering education. In Schnackenberg, H.L. and Simard, D.A. (ed), *Challenges and opportunities for women in higher education leadership*, IGI Global, Hershey, Pa., pp.252-267.

DOI: 10.4018/978-1-5225-7056-1.ch015



# Chapter 15
# Women and Technology:
## Disrupting Leadership in Engineering Education

**Jennifer Loy**
*University of Technology Sydney, Australia*

## ABSTRACT

*This chapter looks at challenges for women in leadership in technical disciplines, specifically mechanical and civil engineering. It considers strategies being employed to correct the gender imbalance and highlights the particular challenges faced by women working in these disciplines. The chapter responds to these challenges by building on the need for changes in thinking highlighted by thought leaders in the 21st century, to suggest a way forward for creating change that directly relates to the role of women in leadership in the discipline. The chapter is relevant for scholars researching gender equality and also for university leaders in developing strategies for adopting women in leadership initiatives in a changing educational landscape. It will also be of interest to academics within these and related disciplines as well as academics involved in the delivery of professional development courses for women in leadership.*

## INTRODUCTION

*"I asked for the man in charge," said Pascoe coolly. "Did you indeed?" said the woman in sympathetic motherly tones. "Were you perhaps shell shocked in the first world war? They let us women out of the kitchen now, you know, and we've even got laws to prove it." (Hill, 1978, p.29)*

However far women's suffrage and economic integration may have advanced over the last forty years, struggles for equality in the workplace are ongoing, built on the historical positioning of women in societies. In the UK, for example, women over the age of thirty only gained the right to vote in 1918 (men were already entitled to vote at twenty-one) and the century since then is arguably a relatively short time, culturally and economically, for social change. It is therefore not surprising that the dominant majority remains reluctant to relinquish control into a fairer division of labor in most fields. Whilst there has been some progress, women in leadership positions across the corporate board remain outnumbered in

DOI: 10.4018/978-1-5225-7056-1.ch015

2018, and in higher education strategic initiatives have had to be introduced even in the last ten years to help redress the gender balance in STEMM (Science, Technology, Engineering, Mathematics and Medicine) and of the professoriate. Certain academic groups remain particularly intransigent. One such is Engineering.

Whilst the struggle for diversity in academic disciplines particularly steeped in tradition (including engineering) continues, the world around higher education is changing, and these changes, such as the evolution of digital communication technology, impact the delivery of education irrespective of the status quo. For women, this could provide new opportunities that the existing hierarchy will be less able to control. Over the last twenty years a digital revolution has occurred with the development of new digital tools, including for communication and monitoring, data analysis and digital fabrication. The integration of these tools into new systems continues, but even so, they are creating significant changes to business convention and customer interaction. These are demonstrated by examples such as the rise of music streaming services and share-economy businesses, for example city share-bicycles. The future of work, business organization and industry face a potential paradigm shift, and learning for the twenty-first century needs to adapt in anticipation. As Gore points out in his book The Future (2013, p.xv) "there is a clear consensus that the future now emerging will be extremely different from anything we have ever known in the past. It is a difference not of degree but of kind".

These changes are difficult for any leadership in higher education to address, but it is particularly so where long-established academic disciplines have entrenched ideas and understandings. For engineering, thinking about the future will mean challenging the accepted practices of the past that inform and validate current educational norms and values. The past in engineering is solid for inveterate academics. Not so the future. This chapter presents an alternative perspective on the educational environment that women in engineering in higher education face in the twenty-first century, in light of the rapidly changing digital context. It provides an argument for a reversal in strategy for women in leadership positions in engineering, suggesting that rather than fighting for greater acceptance in this discipline, women are ideally placed to respond to the changing educational and professional imperatives, and instead lead the discipline in a new, more apposite, direction.

## Background

Engineering is long-established, built on centuries of academia and real-world applications, and therefore has a significant body of knowledge and practice to draw on for education. As a result, the understanding and culture of the academic discipline are equally long established, and intrinsically linked to the profession, which has been dominated by men for centuries. In a recent survey conducted by the Association of Professional Engineers, Scientists and Managers (2017, p.6), the results showed that "Female engineers accounted for only 9.9 per cent of respondents, with males making up the other 90.1 per cent. This broadly reflects the gender imbalance in the engineering workforce which is 11 per cent female and 89 per cent male." Yet recent research, for example by Baron, Schmader, Cvencek & Meltzoff (2014), has shown the extent that implicit associative biases are "governed by and thus likely to develop in ways that are distinct from explicit beliefs" (Baron et al, 2014, p.109). Engineering education has been closely aligned to the needs of professional practice as it has been perceived by an incumbent, dominant majority. Industry bodies, Engineers Australia, for example, accredit degree programs, and industrial practice and internships are embedded in most programs internationally. Because of this, it is difficult to divide the academic discipline from existing professional practice. Women have been discouraged from leadership

in higher education generally until relatively recently (with the necessity often to relocate for academic advancement a factor), but for engineering academics in particular there have been systemization characteristics linked to the identity of the discipline that further preclude women and men who do not fit a particular profile from succeeding in the discipline. The research of Simon Baron-Cohen (Baron Cohen, 2006) highlights the dominance of men with a 'systemize' preference profile, both in the engineering profession and higher education. The researcher concludes that conventional practice and pedagogy for the subject, established to ensure students focused on the traditional mathematical requirements for the profession, have created a paradigm where 'systemizers' at the more extreme end of the Asperger's autism quotient achieve more readily within the current system, than those further towards empathy on the quotient. They are also identified by incumbents as more suitable candidates for the challenges involved in both teaching and the profession. Baron-Cohen (2006, p.869) also highlights that "fathers and grandfathers of children with autism are twice as likely to work in the occupation of engineering (chosen as a clear example of a systemizing occupation), compared to men in the general population".

This re-enforcing of systemizing characteristics through engineering epistemology has served to effectively exclude those who do not conform to this view of the discipline as requiring "narrowly focused intellectual gifts", described by Baron-Cohen as "an engineer's brain". At the same time, research, such as conducted by Javid Abdelmoneim (Hoyle, 2017) in the BBC TV series "No More Boys and Girls: Can our kids go gender free?" demonstrates that young females, even in the twenty-first century, are conditioned away from activities that engage them at a young age in developing understandings and confidence in areas that involve qualities valued by the engineering disciplines, such as spatial awareness and construction, whilst males are conditioned towards them. In this way women are discouraged and disadvantaged in relation to acceptance into the profession right from the start by society and, arguably, genetics - not because of innate abilities (although there are arguments made by researchers such as Baron Cohen (2006) on this issue based on experiments with rats, testosterone and maze tests), but because of the characteristics favored by the dominant majority as suited to their framing of the profession based on historical attitudes. These preferences have influenced the development of tools used in university education selection for engineering:

*Another piece of evidence comes from the Physical Prediction Questionnaire (PPQ), a method for selecting applicants for engineering. The task involves predicting which direction levers will move when an internal mechanism (of cog wheels and pulleys) of one type or another is involved. Men score significantly higher on this test, compared to women. (Baron-Cohen, 2006, p.867)*

Gaining acceptance in an ingrained, male-dominated culture like this, forged over generations, is an uphill battle that has resulted in a significant gender imbalance. Based on a survey conducted by Jones, Ruff, & Paretti (2013) completed by three hundred and sixty-three first year general engineering students:

*Results indicated that there were differences between men and women for gender stereotype endorsement and engineering ability perceptions, with men more likely to hold negative stereotypes of women's engineering abilities and women more likely to report higher perceptions of their engineering abilities. Engineering identification was a significant predictor of persistence in engineering, and engineering ability perceptions were significant predictors of achievement; the relationships were stronger for women than men. The fact that neither gender identification nor gender stereotype endorsement were related to*

*achievement or persistence in engineering indicated that they were less important factors for first-year women engineering students than engineering identification and engineering ability perceptions.*

Before women can become more widely accepted in leadership roles within Engineering academia, there needs to be a change in culture, enabled by a critical mass of diversity in the student population and faculty within the discipline as a whole. This includes for undergraduate education, postgraduate study, postdoctoral opportunities and initial employment within a department. Only then will women – and men who do not fit the standard profile - be accepted and supported into leadership positions. Targeted initiatives will have to be actively promoted by universities to attain that critical mass.

*Given the ongoing gender disparities in recruitment and retention in engineering programs in spite of concentrated efforts, clearly, we have more to discover about the way gender schemas potentially influence how students themselves construct and experience gender within the educational environment. (Kelley and Bryan, 2018, p.23)*

The Athena SWAN Charter is an evaluation and accreditation program aimed at enhancing gender equity for science, technology, engineering, mathematics and medicine (STEMM). It provides a framework for institutions to follow to support women, and other under-represented groups, in disciplines that it highlights are traditionally male-dominated. Since its official inception in 2005, building on the earlier Athena project begun in 1999, there have been approximately 100 institutions accredited in the UK and the Charter has expanded internationally, though in 2017 out of 587 department awards only 10 were at the highest level (gold). Overall 699 awards have been made to departments, universities and research institutions (www.ecu.ac.uk/equality-charters-swan/2017-statistics). This initiative was deemed necessary because of the lack of diversity, and in particular the under-representation of women in STEMM disciplines. It recognizes that it there are such endemic attitudes and behaviors in STEMM in higher education that, rather supporting the independent promotion of individuals within existing systems, require holistic, cultural change to address. The success of individuals who have learned to adapt to the prevailing workplace culture arguably re-enforces that culture, rather than challenges it ((though this is a point of contention). Athena SWAN provides an example of a strategic attempt to embed change in departments as a whole, to foster gender equity at all levels. The intent is that this will support diversity in relation to appointments, build the critical mass needed to maintain the careers of women who join STEMM disciplines and foster their evolution into leadership roles. This is a worthy cause, and a sound strategy that over time should create genuine change to ingrained cultural practice. Yet, whilst the goal of acceptance remains at the forefront of the efforts of women in leadership, it is possible that they are kicking the ball towards the wrong end of the field.

## ENGINEERING FUTURES

*National policies, regional strategies, and long accepted economic theories are now irrelevant to the new realities of our new hyper-connected, tightly integrated, highly interactive, and technologically revolutionized economy…. the global economy is being transformed by changes far greater in speed and scale than any in human history. (Gore, 2013, p.4)*

In his book, The Future, Gore (2013) describes the recent emergence of drivers for radical global change enabled by developments in integrated digital technology. In particular, Gore underlines the significance of the integration of thought that mass communication creates. The extent of connectivity in disparate populations and the sheer volume of connected data, along with the development of sophisticated data analytics, the interconnection of global markets, and the use of analytical software for trade, rewrites relationships between people, systems and products, and creates changes to the world order. Yet, as Hajkowicz (2015) observes in his research into global megatrends, this is difficult to do:

*We need to think about the future for ourselves. But the future is slippery and hard to grasp. It's a fascinating space where emotion mixes with logic and it becomes difficult to neatly separate imagination from evidence. To think about the future, we need a mental model to give structure to our thoughts. That means we need to think, at a deeply conceptual level, about the passing of time. (Hajkowicz, 2015, p 11)*

According to Cameron (2017), the future of work and industry faces unprecedented disruptions that will mimic the impact of earlier industrial shifts, from the Industrial Revolution to the collapse of heavy manufacturing in the 'rust belt' in the US, but concurrently and at a global scale. He argues that this is not only because "technologies are difficult to understand, and their impact is unpredictable" (Cameron, 2017, p.7), but also because there is "no obvious location on the political spectrum" for the type of discussion he feels is needed to plan to address the emerging challenges brought about by digital technology development, including robotics and machine learning. Cameron (2017, p.11) argues that

*on any reading of the situation, our leaders need to prepare for a period of perhaps unprecedented turbulence in labor markets. The evidence is that they aren't.*

In any discussion on leadership in higher education, the challenges facing society in relation to human development and the future of work and industry in a digital era need to be front and center. In the face of revolutionary, technological change, learning for the next generation of engineers needs to be re-evaluated. Engineering has evolved in higher education into a series of study majors, including mechanical, civil and electrical. With some exceptions, such as at Olin and Stanford, the majority of universities still run programs that are based on building mathematical capabilities in the students in their first few years, and then broadening their experience out to more real-world applications. Yet just as computer algorithms have been developed (Cameron 2017) that can replicate the work of paralegals, and journalism has been fragmented through open access internet communication and story generating 'bots', so too does the future of engineering look very different in a digital world. At a disciplinary level, the evolution of civil engineering study over the last hundred years into a narrowly mathematical and analytical subject means it is arguably the most immediately threatened by developments in digital technology. As the adoption across industries of labor replacement algorithms continues, civil engineering is visibly in the firing line. Added to which, the development of digital fabrication technologies, illustrated in innovative digital construction architecture, as discussed by Dunn (2012) and 3D printed robotic mold-making process developed by Australian Architect James Gardiner and used by Laing O'Rourke in collaboration with FreeFab for the Elizabeth Line train station for Crossrail, challenges higher education to teach civil engineering students to be more creative. The mechanical engineering profession faces a similar paradigm shift, with increasingly accessible computer programs providing finite element analysis and

topology optimization for complex problems compounded by new digital fabrication technologies. Just as in stock broking where computer programs react to markets more quickly than a human in analyzing and reacting to the incoming data, so in mechanical engineering, the complexity of industry 4.0 enabled by ubiquitous industrial monitoring systems and machine learning takes it beyond the realm of human capability for the validation of the computer's results. This shifts the emphasis within the profession towards a reliance on the computer over the individual. Additive manufacturing also heralds a new era of production practice that challenges the mechanical design engineering rules currently taught in higher education and deems the expertise of academics steeped in conventional manufacturing no longer relevant. According to Cameron (2017, p.83) "The education and training programs required to convert workers in the current economy into candidates for these diverse new opportunities need to be effective and timely. This may be the greatest stretch of all."

Engineering needs to change, and radically, in order to respond to the changing engineering landscape in the twenty-first century. The rulebook for engineering needs rewriting. In fact, more than that, the rule book needs to become an online blog that can evolve and adapt as the landscape continues to rapidly evolve in unanticipated ways. Digital technologies need to be studied and integrated into a new, creative engineering, digital technology practice. The changes to industry and the implications for the future of work and economic priorities are pertinent to the development of engineering for the next generation. Higher education leadership in engineering needs to show the way, but there is currently little evidence of this happening in any significant way.

*Psychologically, emotionally, and in ways we frame our identity, most of us still think and act as if we are still living in the world we knew when we were young. In fact, however, where the economic realities of life are concerned, that world is receding from view. (Hajkowicz, 2015, p.5)*

## Changing Practice

New learning is needed for the twenty-first century to create graduates who are better able to be holistic thinkers, reframe problems and deal with both complexity and human machine interactions in the development of solutions. Current educational theory advocates for empowered learning strategies to foster the ability of students to become proactive learners (Weimer, 2013, Ramsden, 2003). By creating learning experiences that are authentic, that is they are based on significant issues impacting the current generation of students, educators are better able to prepare students to address new situations and scenarios that a rapidly changing work environment will bring (Dee Fink, 2013). The world economy is changing, with a move from conventional employment towards the 'gig' economy. Graduates will therefore need to be equipped to constantly upskill through their lifetime, to be comfortable with contract work, to disengage from the emotional convention of a job as providing status, and to be agile and alert to innovations in practice and technology.

This should apply to engineering education as much as to other academic disciplines, and engineering associations are highlighting the need for a shift in pedagogy towards problem-based learning (PBL) as outlined by Hirschfield and Koretsky (2018) and learning by making termed 'CDIO' in the engineering discipline (conceiving - designing – implementing – operating) aligning the discipline more to industrial design-type education. CDIO provides an educational framework that stresses teaching engineering fundamentals set within real-world problems, rather than theoretical constructs. It is a challenging change in thinking for the engineering discipline as a whole. The call for a shift of engineering education towards

CDIO provides a new direction for the discipline to move in response to the current digital technology threats and opportunities, and the adoption of the Athena SWAN principles is a positive initiative for university departments.

Optimistic as this sounds, there is little evidence that the rapid pace of change in society at this time is being matched by a correspondingly rapid redevelopment of engineering education by academics, with conventional practice based on the scientific method dominating confidence and hampering agility within the discipline. Gore (2013) highlights the dangers of an obsession with fixed measurements overshadowing an open mind described by British mathematician and philosopher Alfred North Whitehead as "the fallacy of misplaced concreteness" (Gore, 2013, p.xxvii). One of the reasons for this could be that the very status of the discipline and accepted body of knowledge and practice, built over generations, has fostered group think. Harford (2016, p.53) quotes creative musician Scott Page "if we're in an organization where everyone thinks in the same way, everyone will get stuck in the same place." He describes group think, defined by psychologist Irving Janis, as:

*a process whereby like-minded people make bad decisions without seriously examining them. Keen to maintain a friendly atmosphere within the group, they self-censor their own doubts and do not challenge each other. Since the group is full of smart people, each one feels confident that the group must be making a smart decision. Each one abdicates his own responsibility to think critically, assuming that others are doing the hard thinking for him. (Harford, 2016, p.51)*

Harford highlights the importance of recognizing the "tendency in ourselves to spend time with people who look and sound just like us" (Harford, 2016, p.62). By all accounts, engineering disciplines have exhibited poor diversity and according to Harford, when "the diversity within each group was suppressed, so the spectrum of opinion was much narrower" (Harford, 2016, p.51). Changing opinions within engineering disciplines is therefore even harder in the face of external pressures that it would otherwise be.

The University of Melbourne in Australia – an established university with long standing rather than a former polytechnic or university under fifty years old – has joined forces with a learning company associated with the Massachusetts Institute of Technology (MIT) to use block chain for a micro-credentialing system. The Pro Vice-Chancellor (Learning and Teaching), George Kennedy states that it is a response to "a future where career 'churn' and constant technical and organizational innovation are the norm". According to Gore (2013, p.6) "technology-driven changes are now playing a much larger role in determining the future of work." Kennedy argues that a micro-credentialing system will provide for professional development in the face of technological advancement, but also that it will complement existing practice in educational delivery at universities. He suggests it provides a way for employers to check on the specific skills of students gained within conventional programs, and for students to have greater ownership of the way their skills are presented. However, as Oxford University trials a block chain-enabled program that links academics directly with students on an hourly basis, it seems likely that block chain (discussed by Ross, 2016, as heralding a new protocol for the internet as it allows for the transfer of value between individuals) will have a significant role in authenticating the development of a 'gig' approach to lifelong learning. Cameron (2017, p.34), highlights the prediction made by Harvard Business Professor Clay Christensen that "within fifteen years, half the US universities and colleges may be bankrupt" because of open access online learning. Whilst MOOCs have so far failed to achieve the potential they initially promised, micro-credentialing will likely re-open the discussion on open learning.

*As we rapidly move toward a monoculture that makes imagining genuine alternatives almost impossible, we need to experiment with ways of developing new and distinctive worldviews that include different beliefs, values, ideals, hopes, and fears from today's. If our belief systems and ideas don't change, then reality won't change either. (Dunne & Raby, 2014, p.189)*

## Changing Perspective

As challenging as all these factors are, developments in engineering education, changes to the profession and technology-enabled pedagogy arguably suit women better than men on all fronts. The disadvantages that women have had to overcome in terms of stereotypical socializing and education as well as frequent breaks in careers due to carer obligations, have, ironically, better prepared them for a gig economy, both in terms of work and education. Epitomized by the ground-breaking approach of British Information Technology pioneer, Dame Stephanie 'Steve' Shirley, in setting up collaborative, flexible working for women in her company Freelance Programmers in 1962, women in leadership in male dominated technology-based disciplines, such as engineering and industrial design, need to be reframing the problem and responding differently. This should not be a conversation about acceptance, but about leadership in a changing environment for work and education. Instead of working for inclusion, start afresh in addressing the problems facing society and their implications for education.

*Women almost always comprise a minority in engineering programs and a smaller percentage of women pursue engineering than other science and technology majors. The culture of engineering departments and negative stereotypes of women's engineering and mathematical ability have been identified as factors that inhibit women's entry into engineering and cause them to leave the major. Even for women who stay, stereotype threat or the anxiety of confirming a negative stereotype can decrease academic performance. (Jones et al, 2013, p.471)*

Gaining credibility and acceptance in a field as a minority, with established prejudices long embedded hampering progression, is hard work. However, in an emerging field, there are no existing prejudices. In a new area of study, being able to develop new knowledge without the weight of convention and the need to unlearn arguably gives the practitioner a head-start. For women in engineering, it may be that rather than fighting for acceptance by the old guard, they have the opportunity to show leadership in a new direction, for the benefit of engineering in society worldwide. Without the repression of a workforce of academics comfortable in their many years of conventional engineering experience, reassured by the history and credibility of the academic discipline built up over centuries, a new digital technology engineering focus can be created that embraces emerging new ways of working and digital innovation, and welcomes women into the digital engineering workforce.

Engineering for the twenty-first century needs this leadership. Women are best placed to provide it, not only because of their exclusion from traditional engineering and preference for computer science as a specialization (Kelley and Bryan, 2018), but also because in the twenty-first century, their experience over the last hundred years has actually better prepared them for it than has the stereotypical experience and education of males. Take, for example, the shift towards the 'gig' economy discussed earlier. For those for whom their job has been wrapped up with their status and ego, moving towards a gig economy threatens more than their economic viability. Since the removal of women in the workforce following the second world war to make room for returning servicemen, men have been overtly taught to equate

their social status with their position in a company. Not so women. Just as the young entrepreneurs in Silicon Valley disrupted conventional business practice by embracing the potential of information technology irrespective of established industry practice, so women are well placed to lead in a new era of communication technology to respond positively to the opportunities it brings. Additive manufacturing (3D printing) provides a good example of the disruptive possibilities emerging at this time. The term refers to a range of technologies, around forty at this time, that form objects based on sliced 3D digital objects built in computer solid modelling systems. The scale and range of industries impacted by additive manufacturing is extensive and the changes impact business practice as well as product (Lipson and Kurman, 2013, Anderson, 2014). From construction to dentistry, to fashion, to furniture, additive manufacturing shifts manufacturing from mass production to mass customization, strict design rules to short runs of complex geometrical forms for bespoke applications. Combined with communication technologies, it allows for innovations in business practice, such as distributed manufacturing. This is where manufacturing is decentralized, with digital files sent out to different locations for production. Whilst Detroit is still struggling to overcome the impact of losing a single employer, after declaring bankruptcy with an $18 billion US debt and its population dropping from 1.8 million to 680,000 (Detroit city planner Maurice Cox, presentation in Sydney Powerhouse Museum, March 2018), a rethink of manufacturing towards decentralization, even re-ruralization seems a strategy worth taking seriously. New opportunities are emerging in digital creative engineering that no-one yet dominates. New cultural practices are emerging around those opportunities that are open for engagement by anyone, of whatever minority, as discussed by Neil Gershenfeld (2005). In fact, when considering the background and training for roles in leading digital creative engineering, women are arguably better placed than men. Digital immersion suits the training women have received to date, as does the rise in social media and communication tools, allowing for distributed employment.

*In the past, the workplace was a massive determining factor of where to live, ensuring that your daily commute would not consume hours each day. What happens, though, when work has turned fluid and spreads everywhere and nowhere? Never before in history have we had access to more international contacts in order to make ends meet. Even interpersonal relations are becoming more flexible, with divorce rates at their highest in human history. (Beekmans and de Boer, 2014, p.19)*

The need to embrace flexibility in working hours and types of contract work throughout a career suits the training women have received to date, equally shared jobs and those that require teams of people collaborating to present a single united front that is serviced by the team as one has been demonstrated as a successful approach for employing women who are combining work with carer responsibilities (such as with the Stephanie Shirley organization of work example). The shift to holistic thinking that is driving the intent behind the developments in CDIO by associations such as Engineers Australia responds to the way women have been encouraged to think about the world over the last hundred years. The blurring of boundaries also suits the way women have been trained to operate in society over the last hundred years, the lack of demarcation between roles and activities and the lack of hierarchy that digital communication facilitates, contrasts with traditional business structures predominantly led by men. The shift towards a greater understanding of human interaction in engineering projects suits the role women have been stereotypically trained for more than the stereotypical fostering of skills and understanding in the training of males in society. Co-design and participatory design builds on skills that are traditionally valued in females more than they have been in males to date. It also suits the emerging

millennial generation, whose upbringing in a digital era is in direct contrast to that experienced by the current leadership in hierarchical engineering higher education systems, and creates a very different view of living and working in the online future:

*This new perspective of city life, one not based upon being in a fixed space but based upon a psychological perspective that 'the city' consists of a worldwide network of disparate yet connected urban centres, comes from a very real sense of hyper-connectivity…. These technological developments have led to changes in the way we think, behave, and interact with spaces. It is difficult to imagine but humanity is changing at a fundamental level as you read this…Children are now growing up having never experienced a world without touchscreen devices, resulting in a visually-oriented society. (Beekmans and de Boer, 2014, p.16)*

According to Hajkowicz, global megatrends influencing the world at this time include digital immersion, sustainability (termed planetary pushback), and the demand for a personalisation of experiences. Digital technology dominated spheres of communication design have traditionally been female dominated, including at a leadership level, in higher education. In creative education, such as interior design, fashion design and animation, women can succeed, though sadly there is evidence that men are still dominating in fields such as architecture, based on, for example, the lack of women in the high-profile Dezeen design magazine's awards list of 2017. Females achieve in mathematics at a high school level but have a negative view of the field as male in higher education which prevents them choosing related subjects to study (Kelley &Bryan, 2018). Blickenstaff (2005) identified the absence of female role models as one of nine common explanations for a lack of women in STEMM. Engineering needs to change and faces many challenges in doing so. Instead of focusing on breaking down this bastion of male thinking to foster women in leadership in the disciplines, women leaders in higher education generally should be actively supporting women in engineering to look instead at the current megatrends and creating a new, level playing field in digital creative engineering in response. Women in leadership in higher education are making breakthroughs in changing the expectations of leadership, moving towards authentic leadership. Where female role models are emerging in engineering education, authentic leadership should positively engage with the external influences on education, rather than model existing leadership behaviors and attitudes both because it is those attitudes that have created negative views on STEMM in the past, and because of the need to look forward rather than backwards for the profession.

## Changing Futures

*Our leaders need to being to think on new, fast-moving timetables. The education/skills training implications of engaging seriously with the disruption scenario we are discussing stand out as immediate challenges for policymakers thinking ahead. The industrial economies have never experienced anything like it. (Cameron, 2017, p.83)*

Unshackled by the prejudices and preconceptions of long established, well respected disciplines led by those who best epitomize their traditions, and with the millennials beginning their university education, it is time to take an objective view of societies and the future of work and industry. The culmination of technological innovation in the digital revolution of recent decades is creating a change, as Gore (2013, p. xv) says, not in degree but in kind. When considering the leadership role of women in technology in

higher education, there is an argument for pausing in the current direction and taking time to decide if there is another approach worth considering. Women in leadership roles in STEMM are currently focusing on the Athena SWAN approach of creating a more accepting, supportive workplace environment within which women can achieve. This is an uphill battle in engineering, and whilst the work of both women and men in supporting this cause is admirable – and worthwhile - it is worth taking time to question if acceptance into this bastion of tradition is in fact the best option in the current era.

Hajkowicz (2015, p.14) identifies megatrends that have a significant impact at a particular point in time, He describes a megatrend as a "profound trajectory of social, economic, environmental or technological change occurring over the coming decades. The pattern of change is gradual at first but will express itself with explosive impact". In engineering, the traditional boundaries are blurring – and need to be blurred because of the changing societal issues and challenges - as digital technologies and new ways of working and creating cutting across electrical, civil and mechanical disciplines. Research by Dunne and Raby (2014, p.169) raises a concern that "the social dimension to big thinking has vanished, replaced by science, technology and logic." They question "Where can new worldviews be developed? How can they be used to generate new visions for everyday life?" For the social dimension to return, the humanities need to be integrated more effectively into a holistic, relevant engineering education. The experience and education of women, rightly or wrongly, has prepared them to lead such a shift in emphasis. In addition, as in design disciplines, there are women in leadership in the humanities who can support women in engineering building this change.

According to Cameron (2017), the lack of action by leaders to the changes the current radical developments in integrated digital technologies are creating is because the changes are too rapid and too extreme, with the implications too complex for individuals to be able to comprehend without a more collective engagement strategy. He argues for new thinking and highlights the inability of companies in history to recognize and respond effectively to the paradigm shifts digital technologies create, such as the experience of Kodak, described by Hajkowicz (2015, p.27) in their response to digital imaging:

*The rise of a digital world was a megatrend that the US print film company, Eastmann Kodak, missed. At first it was gradual as people started to experiment with digital cameras. But then the pace of change accelerated. By the early 21st century people had mobile phones which could capture, store and send images. Kodak responded but it was too little too late. It acquired a website called Ofoto, later renamed Kodak Easy Share Gallery. People could upload images and buy hardcopy prints. But that wasn't really capturing the digital revolution. People weren't paying for prints.*

With regards to higher education, Cameron (2017) argues that academic leaders are not acknowledging the threat to universities that digital technologies are creating. Whilst academics are recognizing the need to revise pedagogy in response to digital technology enabled delivery, the tendency is to see digital technology as a supplementary way of providing learning experiences, rather than central to changing the nature of the learning itself.

As the global imperatives for the twenty-first century continue to emerge, such as the environmental sustainability imperative, addressing the ageing population, the rising cost of healthcare, the changing nature of work and industry, the structure of cities and the evolution of smart cities, engineering education needs to be relevant. The current challenge is to rethink traditional understandings of what constitutes disciplinary practice in engineering and initiate discussion on what could or should constitute disciplin-

ary practice going forward. Arguably women need to show leadership in driving this change because they have less invested in the traditions of the discipline than the existing leadership.

*Just like ocean currents, the social, economic, political, technological and environmental drivers of global change – the megatrends – are powerful forces. They are continually at play reshaping our world. We ignore these forces at our peril and typically fail if we try to swim directly against them. But we also fail if we let these forces take us where they will. To find a better place we need to read the currents and anticipate likely destinations. Then we need to design and implement a strategy. A strategy embodies those actions that give our company, community, society or ourselves the best possible chance of achieving our objectives and reaching our design destinations. That means making the right choices at the right times. It also means accurately reading and understanding the megatrends heralding profound change. (Hajkowicz, 2015, p.3)*

## SOLUTIONS AND RECOMMENDATIONS

Engineering faculty needs to demonstrate an ability to look outside existing conventions in their disciplines. An objective review of the context their students will be graduating into, and also of the profile of students in high schools, embracing diversity, is required to provide engineering futures that are better aligned to the emerging realities of the twenty-first century. For women in leadership roles in higher education, there is the continued battle for acceptance into this academic arena. However, there is also the opportunity to work with forward-looking university leaders to propose a new approach to engineering in the twenty-first century as discussed in this chapter. The least controversial approach would be for women in leadership roles in engineering to create a new major within existing engineering programs that builds on the preference of females to specialize in computer science to respond to the opportunities of the digital era. There is evidence of new thinking in this respect in the approach presented by Kara and Bosia (2016), in the book Design Engineering Refocused. In this publication Professor John Oschsendorf of the Massachusetts Institute of Technology (MIT), argues for structural engineers to take advantage of the "powerful opportunities for engineers to serve as collaborative synthesizers in the endless frontier of design…exemplifies the burgeoning potential for the structural engineer in the twenty-first century" (Kara & Bosia, 2016, p.11). He suggests that "Brunel would be impressed" and it is arguably a return to the holistic practical and social engineering approach that were the foundations of Brunel's work that is needed at this time and is also becoming possible at this time because of the opportunities that customized digital fabrication, ubiquitous computing and the integration of smart objects in the environment (Kuniavsky, 2010), complex analysis and global communication are providing. However, although possible in open-minded institutions, this approach is likely to be fraught with difficulties within a more conventional engineering department in higher education, and the lack of critical mass of females in leadership roles to ensure sufficient support for the new program. In light of the issues discussed in this chapter, the recommendation of the author is for women leaders in higher education across engineering, design and the humanities to propose a new discipline area that is sufficiently differentiated to allow a degree of freedom from traditional engineering, in order that it can be developed without engaging opposition from any engineering academics and practitioners who might feel threatened by the approach or are simply unwilling to change their attitudes. As Goodwin (2009, p.699) observes in relation to arguing for designing for the digital age:

*If your organization is even remotely successful with how things are being done now, you're likely to face considerable skepticism about the need for more investment in design. People discount your argument as empire building on your part or ignorance about how the organization works. Even if they begin to see the point of your argument, many people will shrug and say that this is just how things are at (insert your company's name here). They'll tell you there's no way you'll change the attitudes of the engineers, marketers, or executives. Denial is normal. If you don't see any signs of denial you may very well wonder if people are really listening to you.*

Based on the intransigence of many academics in engineering, it may be that new directions will be dismissively underestimated, allowing the new disciplines to mature on their own. The key will be the supportive collaboration of women in leadership roles in higher education across the university so that there is the critical mass needed for change, and the defining of appropriately relevant and optimistic epistemology and pedagogy for the millennials and subsequent generations.

## FUTURE RESEARCH DIRECTIONS

Based on the approach outlined in this chapter, future research into the conscious uncoupling of engineering from existing gender preconceptions is required. Strategies for women to adopt in demonstrating leadership in higher education as a collaboration across faculties is needed to support women in higher education who currently lack role models within their disciplines. Research mapping the proposed creative engineering digital technology practice as curriculum in response to designing twenty-first century learning imperatives needs development, as well as the rethinking of pedagogy to foster lifelong learning.

## CONCLUSION

The world is constantly changing, but according to advisors such as Cameron (2017), the pace of change has increased dramatically in recent years. As Hajkowicz (2015, p.181) states "It's not whether change will happen that matters, but when and how you respond". Learning for the twenty-first century needs to evolve. Engineering as a discipline is struggling to embrace problem-based learning and suitably integrated double degrees. For more women to be employed in engineering, there needs to be a reprioritizing of the skills and abilities shortlisted towards those that women in current educational and societal systems and cultures are likely to have had enough opportunity to experience in to bring. Shortlisting via the H-Index and grant funding ignores the way the bases are loaded to begin with. Industry and academic networks, both formal and informal, are dominated by men and the incumbent gender controls the inclusion of minority newcomers into any system. Attitudes need to be addressed to counter old-fashioned ideas, such as engineering is a 'dirty job' and therefore unattractive to women, or that women cannot 'think like an engineer' even with education. As according to Baron et al. (2014, p.109) gender roles are established at an early age, they need to be challenged by society at an early age before they become embedded:

*Gender is among the earliest social group distinctions young children make, and soon after children learn to categorize others based on gender, they begin to associate different traits and attitudes with male and female. Once entrenched in long-term memory, these associations can be easily and implicitly*

*activated in the minds of perceivers or targets, acting as an unseen force, pushing and pulling the levers of behavior to subtly steer men and women to different roles and activities.*

Recent sports marketing campaigns in Australia have addressed a similar bias, countering with advertising initiatives such as the 'run like a girl' campaign. Women's sport has long faced gender bias challenges, with female athletes paid less in competitive sports, including tennis, cricket and soccer. A recent breakthrough has occurred with women's Australian Football League, as the anticipated failure of the sport to attract spectators has not materialized.

According to Legge (2012, p.1) "there are leaders and there are followers. What might seem radical to one generation is considered normal by the next. In many cases the leaders, innovators, inventors and entrepreneurs simply see a gap between what is and what could be". The role of women in leadership in engineering needs to be about challenging preconceived ideas, narrow thinking and negativity to reframe the profession for the twenty-first century. They need to be informed by the realities of the current context and unhampered by the conventions of the past and create the breeding ground for a diverse breed of engineers, ready for the new world.

## REFERENCES

Anderson, C. (2014). *Makers: The new industrial revolution*. New York: Crown Business.

Association of Professional Engineers, Scientists, and Managers. (2017). *Women in engineering: Realising productivity and innovation through diversity survey*. Melbourne, Victoria: Association of Professional Engineers, Scientists and Managers.

Baron, A., Schmader, T., Cvencek, D., & Meltzoff, A. (2014). The gendered self-concept: How implicit gender stereotypes and attitudes shape self-definition. In P. J. Leman & H. R. Tenenbaum (Eds.), *Gender and Development* (pp. 109–132). Hove, UK: Psychology Press.

Baron-Cohen, S. (2006). The hyper-systemizing, assortative mating theory of autism. *Progress in Neuro-Psychopharmacology & Biological Psychiatry*, *30*(5), 865–872. doi:10.1016/j.pnpbp.2006.01.010 PMID:16519981

Beekmans, J., & de Boer, J. (2014). *Pop-up city: City making in a fluid world*. Amsterdam: BIS.

Bhatnagar, K., Srivastava, K., & Singh, A. (2010). Is faculty development critical to enhance teaching effectiveness? *Industrial Psychiatry Journal*, *19*(2).

Blickenstaff, J. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education*, *17*(4), 369–386. doi:10.1080/09540250500145072

Cameron, N. (2017). *Will robots take your job?* Cambridge, MA: Polity.

Cox, M. (2018, March 20) Learning from Detroit. *Powerhouse Museum Sydney*. Retrieved from https://www.nabo.com.au/whats-on/event/learning-from-detroit-maurice-cox-powerhouse-museum

Dee Fink, L. (2013). *Creating significant learning experiences: An integrated approach to designing college courses.* San Francisco, CA: Jossey-Bass.

Dunn, N. (2012). *Digital fabrication architecture*. London, UK: Laurence King.

Dunne, A., & Raby, F. (2014). *Speculative everything: Design, fiction and social dreaming*. Cambridge, MA: MIT.

Goodwin, K. (2009). *Designing for the digital age: How to create human-centred products and services*. Hoboken, NJ: Wiley.

Gore, A. (2014). *The Future*. London, UK: WH Allen.

Hajkowicz, S. (2015). *Megatrends: Seven patterns of change shaping our future*. Melbourne: CSIRO.

Harford, T. (2016). *Messy: How to be creative and resilient in a tidy-minded world*. London, UK: Little, Brown.

Hill, R. (1987). *A pinch of snuff*. New York: Harper Collins.

Hirshfield, L., & Koretsky, M. (2018). Gender and participation in an engineering problem-based learning environment. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1). doi:10.7771/1541-5015.1651

Hoyle, A. (2017, August 15). What happened when a primary school went gender-free. *The Telegraph.* Retrieved from https://www.telegraph.co.uk/women/life/happened-primary-school-went-gender-neutral/

Image & Data Manager. (2017, May 5). Melbourne university pilots blockchain for student records. *Image & Data Manager*. Retrieved from https://idm.net.au/article/0011494-melbourne-university-pilots-blockchain-student-records

Jones, B., Ruff, C., & Paretti, M. (2013). The impact of engineering identification and stereotypes on undergraduate women's achievement and persistence in engineering. *Social Psychology of Education*, *16*(3), 471–493. doi:10.100711218-013-9222-x

Kara, H., & Bosia, D. (2016). *Design engineering refocused.* Hoboken, NJ: Wiley. doi:10.1002/9781119164838

Kelley, M., & Bryan, K. (2018). Gendered perceptions of typical engineers across specialties for engineering majors. *Gender and Education*, *30*(1), 22–44. doi:10.1080/09540253.2016.1262007

Kuniavsky, M. (2010). *Smart things: Ubiquitous computing user experience design.* Burlington, MA: Morgan Kaufmann.

Legge, K. (2012). *Doing it Differently*. Sydney: Place Partners.

Lipson, H., & Kurman, M. (2013). *Fabricated*. Hoboken, NJ: Wiley.

Ramsden, P. (2003). *Learning to teach in higher education* (2nd ed.). London, UK: Routledge Falmer.

Ross, A. (2016). *The industries of the future*. New York: Simon & Schuster.

Smith, P. (2015). Change: Embrace It, don't deny it. *Research Technology Management*, *51*(4), 34–40. doi:10.1080/08956308.2008.11657512

Weimer, M. (2013). *Learner-centered teaching: Five key changes to practice* (2nd ed.). San Francisco, CA: Jossey Bass.

## KEY TERMS AND DEFINITIONS

**Additive Manufacturing:** Commonly known as 3D printing, this term refers to a range of technologies that build objects layer on layer from a 3D computer model.

**Athena SWAN:** Is an organization founded in the UK that recognizes advancement in gender equality.

**CDIO:** A framework for engineering fundamentals within the context of conceiving, designing, implementing, operating.

**Megatrend:** Is significant activities or opinions recognized globally as having an impact on attitudes, behaviors, and ideas over time.

**Problem-Based Learning:** Student-centered learning where student work on an open-ended project.

**STEM:** Refers to an education focus on science, technology, engineering, and mathematics.

**STEMM:** Refers to the extended scientific education focus to include science, technology, engineering, mathematics, and medicine.

# InfoSci®-Books

A Database for Progressive Information Science and Technology Research

## Maximize Your Library's Book Collection!

Invest in IGI Global's InfoSci®-Books database and gain access to hundreds of reference books at a fraction of their individual list price.

The InfoSci®-Books database offers unlimited simultaneous users the ability to precisely return search results through more than 68,000 full-text chapters from nearly 3,000 reference books in the following academic research areas:

Business & Management Information Science & Technology • Computer Science & Information Technology
Educational Science & Technology • Engineering Science & Technology • Environmental Science & Technology
Government Science & Technology • Library Information Science & Technology • Media & Communication Science & Technology
Medical, Healthcare & Life Science & Technology • Security & Forensic Science & Technology • Social Sciences & Online Behavior


### Peer-Reviewed Content:

- Cutting-edge research
- No embargoes
- Scholarly and professional
- Interdisciplinary

### Award-Winning Platform:

- Unlimited simultaneous users
- Full-text in XML and PDF
- Advanced search engine
- No DRM

### Librarian-Friendly:

- Free MARC records
- Discovery services
- COUNTER4/SUSHI compliant
- Training available

**To find out more or request a free trial, visit:**
**www.igi-global.com/eresources**

IGI GLOBAL
DISSEMINATOR OF KNOWLEDGE
www.igi-global.com