

Engineering education systems **that are fit for the future**

Summary of an event held on 24 and 25 September 2018
at the Royal Academy of Engineering





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1. Foreword

Over the past three years the Royal Academy of Engineering has organised annual two-day engineering education events exploring the skills gaps and different approaches required to improve engineering education globally. On 24 and 25 September 2018, senior educators, industry representatives, funders and professional engineering institutions from around the world convened at the Academy to explore a systems approach to engineering education. Participants included past and present awardees of the Academy's Higher Education Partnerships in Sub-Saharan Africa (HEP SSA) programme, GCRF Africa Catalyst programme and the Industry Academia Partnership Programme (IAPP).

The thought leadership conference adopted a systems thinking approach, outlining the different stages of an engineer's educational stages to address the conference's aims:

- outlining the role of engineering to engage more young people of primary and secondary age with the skills and knowledge to take up engineering as a career path
- the role of higher education institutions in developing their approaches to education, training and student learning
- the need to upskill and continuously develop the current workforce to address the global challenges and needs of industry for the future.

Engineers make 'things' that work or make 'things' work better. The need to solve society's biggest challenges such as the growing need for sustainable energy generation, population growth, the outcomes of the communications revolution and an ageing population, will increasingly rely on innovative technological solutions. These challenges also offer exceptional opportunities for economic growth to those nations that can deliver them. When coupled with the vastly accelerating pace of technological advancement and disruption, the need to tackle global challenges means that the engineers of today are increasingly required to respond to ever-more diverse demands while the products and services that they provide become increasingly commonplace.

There is a growing concern globally that the education system responsible for producing engineers is failing to keep pace with the inherent dynamism of this situation, or with the increasing need for engineers. For example, maths and physics are essential precursors for undergraduate engineering courses, yet there is an acknowledged global shortage of secondary school teachers in these subjects. In universities, the structure and content of engineering courses has changed relatively little over the past 20 years despite dramatic changes in technology and the engineering landscape. Longer life-expectancy and improved quality of life into old age are likely to be experienced by many parts of the world. This will elevate the need for accessible continuous learning opportunities, particularly because automation will require the workforce of the future to have high levels of technical literacy and engineering skills.

Employers, the teaching and learning community and the government must work together to help grow the supply and quality of engineers. By convening senior representatives from across this global landscape, this conference adopted a systems approach to addressing the engineering skills gap. It looked at how education systems might be redesigned in terms of pedagogy and structure so that they are better able to produce more people – at all levels - who think and act like the engineers that society needs if it is to confront the challenges and meet the demands of the future.

This report is not a verbatim record of the event; rather, it seeks to highlight some of the issues raised by the conference and to contribute to further discussion. It gathers together the discussions around potential barriers to improving engineering education systems, including diversity, and institutional and financial challenges. It also pulls out areas where institutional innovations are needed to further improve the global population of engineering professionals, as described by the expert speakers and attendees at the conference. Fundamentally the report seeks to present the balance that is needed between knowledge, skills and mindsets at each stage of learning in the engineering education system.

2. Engaging young people with engineering



Dr Hayaatun Sillem, CEO, Royal Academy of Engineering

Young children are instinctively little engineers. However, education systems do not sufficiently develop the habits of mind of young people to encourage them to pursue further study towards engineering careers. The primary school system almost extinguishes any opportunities for students to flourish as engineers and in secondary schools the qualification systems force early specialisation. These systems mean that teachers unintentionally discourage potential engineers through the way they teach science, mathematics, and design and technology.

This session advocated “Exploring through fiddling, toying, messing, pottering, dabbling and fooling about with a diverse range in things that happen to be available in a creative and productive pursuit to make, mend and adapt” ([Tinkering for Learning](#)). Practical strategies were also highlighted for teaching and

learning that nurture interest, engagement and attainment from a young age in the subjects that are essential to embed an engineering mindset in students.

The current education models for primary and secondary schools do not foster the engineering skills we are born with. At a very young age we use some of the basic principles of engineering, such as toying and fiddling, to engage with and provide meaning to the wider environment around us. To represent this, the University of Manchester have collaborated with [The Science and Engineering Innovation and Research Hub](#) to create the [Tinkering for Learning website](#). This teaches children basic engineering skills and competencies as well as facilitates learning sessions for teachers to use in their lesson plans. The aim of the organisation is to ensure that engineering education is credited as a core module for all primary school students in the same way that maths, English or science are in the UK. To act as a further guide and resolution for primary school institutions, Tinkering for Learning has created the [seven principles of primary engineering education](#) that follows engineering processes such as problem solving, taking ownership, embracing failure, and encouraging curiosity.

Children of primary school age and younger have an innate ability and interest to solve problems that can be harnessed to provide more stimulating lessons in early education. For example, instead of asking children ‘what they want to be’ educators could ask ‘what they want to solve’ to inspire a mindset that is more curious and flexible.

Globally there are many different barriers preventing engineering education being integrated into early years and primary school learning. One conference participant explained how in Indonesia engineering is perceived to be a less lucrative occupation than other science disciplines, so parents often discourage their children from pursuing interests in the field from a young age. Another example came from the UK, where there is a low uptake of engineering career paths by girls and young women. The organisation Women in STEM believe this challenge is largely because young girls lack exposure to enough female engineering role models and so relate to the industry less well than other industries with better female representation.

Evidence shows that children are influenced from a very young age by messages about what they may want to do in later life. If they are exposed to harmful gender stereotypes from as young as six, for example the message that ‘girls shouldn’t work on cars’, it can shape very damaging ideas about engineering and STEM fields, negatively impacting uptake of these fields by women and girls. Changing the messages given to children about careers in these fields will help to change mindsets, which in turn will impact the way that they learn and the choices that they make.

To tackle this issue, Giuliana Huerta-Mercado, Founder and President of United Technologies for Kids (UTK), outlined the important role that social innovation plays in helping to inspire young children into engineering. Engaging children to tackle local social problems, stepping away from traditional forms of STEM education, and exposing young children to role models who reflect their background and culture increased interest in STEM subjects. “Karen is like me... she was also a shepherd, and look at what she has achieved. I can be like her and study engineering” (student, San Juan Apostol School, Peru). UTK supported schools in Peru and reported that 96% of students engaged in the UTK project increased their interest in science and engineering, and 26% changed their preference to pursue STEM careers.



Professor David Bogle FEng, conference chair and Dr Rick Miller, keynote presenter, President and First Employee, Olin College

3. Enhancing learning, teaching and training

The industries of tomorrow will benefit hugely from engineers who are ambassadors of their technological areas. These ambassadors will combine specialist expertise with an ability to operate across boundaries in increasingly complex environments and do so with a spirit of creativity, innovation and leadership. Developing groups of engineers with such broad skills will require a shift in incentive structures. It is necessary to move away from the current research-focused progression and audit-oriented accreditation systems and towards one that recognises and rewards time and energy invested in educational innovation and change.

This session aimed to provide a strategic reassessment of the goals of engineering education. It questioned the type of leadership and engagement required to instigate coherent, structural yet adaptive educational change. The session also discussed how to ensure that the skills obtained during the degree remain relevant and how the personalities being developed by university courses can be suitably holistic and resilient to meet increasingly complex, interdependent needs of society and industry.

Dr Allyson Lawless FEng, Managing Director of the South African Institution of Civil Engineering, described in her keynote presentation that within the South African Development Community (SADC) there is not a shortage of engineers, but a shortage of experienced engineers and employable graduates. Dr Lawless explained that graduates have not been given the appropriate education and training necessary to work in industry. This message was echoed by Charles Mukwase, President of the Namibian Society of Engineers, who said that “the government is paying millions in tuition fees for engineering students, yet it is not

providing an environment for those students to practice once they complete their studies and enter the job market”.

Professional engineers are expected to investigate, solve, implement and take responsibility for their solutions, but there is not sufficient training available for graduates to transition into the workplace. Dr Lawless argued that formal graduate support is urgently required in combination with a ‘flipped classroom approach’ to ensure SADC region graduates are employable and meet the demands made to experienced engineers.

It is clear that new approaches to engineering education are needed to meet this demand. Dr Deepak Garg, Chair of the Computer Science Engineering Department at Bennett University, India, advocated making deep learning and AI skills mainstream in India to fulfil the trilateral needs of entrepreneurship, industry-academia partnership and application-inspired engineering research. He argued that this will create a collaborative approach to ensuring graduates hold the skills necessary for the future. Innovative education models are needed to fully implement and realise engineering education in school-based curricula.

Another example was described by engineer Oduwa Agboneni, of the Nigerian Institution of Mechanical Engineers (NIMechE). She discussed how the NIMechE Innovation Challenge, funded by the GCRF Africa Catalyst programme, hopes to provide solutions to some of the biggest challenges and problems in Nigeria where 75% of the population are unemployed and 52% of all young people are illiterate. The NIMechE Innovation Challenge builds capacity through outreach, training, and an innovation prize that hopes to inspire young people to take up a career in engineering.

Dr Diane Harris and Dr Maria Pampaka, University of Manchester, discussed how it is important to understand why young people do choose to take up engineering as a degree. Insights into positive choices can inform teaching, policy and practice. To understand the factors that influence pupils’ decision to study engineering it is important to reach out to young people’s influencers and build projects such as the Learning Gain Pilot Study by the University of Manchester, which aims to increase understanding of what engineering is.

In a discussion on how individuals learn the delegates emphasised the importance of “learning by doing”, and celebrating and learning from failure. There was a belief that there is an overemphasis on theory and assessment within engineering education globally, rather than hands-on practical experience, or activities that delegates described as “getting stuck in”.

Delegates described how some countries, for example India and Kenya, have separated teaching and research in universities. Improving the relationship between research and teaching should be encouraged to improve teaching quality, particularly because the practical experiences gained through research can be inspiring for students and promote the perception of engineering as an interesting career option.

It is also important to ensure that educators hold the necessary knowledge and latest teaching approaches to ensure graduates are equipped with the skills needed for jobs in industry. Dr Kevin Hall, Hicks Endowed Professor of Infrastructure Engineering, University of Arkansas, showcased the ExCEED Teaching Workshop, a six-day ‘practicum’ that provides engineering educators with an opportunity to improve their teaching abilities.

One clear issue highlighted by the conference was the lack of recognition and support for technicians. The delegates highlighted a German model where a positive image of technicians is encouraged from an early age, support is available for individuals who choose technician career paths to excel and earn a competitive wage, and technician jobs are well respected by society. On the contrary, in many societies around the world parents may be ‘embarrassed’ if their children are technicians rather than engineers. For example, in many polytechnics in Zimbabwe Principals and Vice-Chancellors are engineers rather than technicians, which serves to project an image of superiority of the profession. It was highlighted by conference participants that when society values certain job roles over others it can dissuade young people from those

career paths. This was felt to be a major challenge for uptake to technician careers and reconfirmed the important role that habits of mind can play in effective education. Framing technicians' roles positively was felt to have the potential to encourage students into sectors, disciplines and roles that are essential to the engineering industry and society.



Dr Allyson Lawless FREng, Managing Director, South African Institution of Civil Engineering

4. Upskilling the Workforce

Engineering is almost uniquely placed in having technical routes to registration that run alongside academic qualifications. Historically the engineering profession and industries within have done much to enable talented individuals from all areas of society achieve a fulfilling and rewarding career. There is a growing interest globally in exploring such routes to help address engineering skills shortages both for young people and, increasingly, for reskilling older generations. This is especially pertinent in the context of increasing life expectancy where people will be a part of the workforce for longer and will need to continually adapt to technical change. Doing so will require a considerable improvement in the support offered by engineering institutions to overcome the practical challenges of ensuring consistent, high-quality and widely-recognised education provision.

This session explored how educators, industry and policymakers collaborate to design suitable pathways that allow more mobility between academic and technical routes to build skills at a meaningful scale and in ways that are attuned to the diverse cognitive profiles among the workforce and are accommodating of their operational constraints.

Mr Ng Cher Pong, Chief Executive of SkillsFuture Singapore, showcased the Singaporean government's successful approach to creating a skills framework to equip Singaporeans with the skills fit for the future of Singapore. SkillsFuture is a national movement that aims to provide Singaporeans with the opportunities to develop their fullest potential throughout life, regardless of their starting points. The programme provides a common skills language for individuals, employers, education and training providers. This allows individuals to assess whether their existing skills match their career interest and find relevant training where they have gaps. Employers can design progressive human resources to recognise skills and make informed decisions about how best to invest in the skills of their workforce, and training providers can develop responsive industry-relevant programmes.

The Sierra Leone Institution of Engineers, through its Young Engineers Corp, aims to upskill, support and develop graduate engineers by developing a framework for the training that will enhance their employability and competitiveness in the international job market. Eng Trudy Morgan, Director of Engineers for Change Sierra Leone, explained that one of the aims of the programme is to create a community of engineers in Sierra Leone that can drive improvements in the standard of engineering practice.

This session also drew attention to the need to ensure that engineers have the appropriate skills to tackle rapid changes in both the technological landscape and the type and scale of challenges that they must face. Alastair Taylor, CEO of the UK's Institution of Agricultural Engineers, outlined the need for professional engineering bodies (PEBs) to plan for the future of engineering. PEBs must make efforts to not only understand which technologies will be available in the future, but also identify the skills that will be needed to meet this demand. This session reiterated a message from the World Economic Forum's 2016 report, *The Future of Jobs*, which claimed that 65% of children entering primary school today will end up working in jobs that do not yet exist. Given this context, the conference discussed questions about what can be done to keep up-to-date in a fast-moving world, and whether institutions should focus more on encouraging a multi-skilled and multi-disciplinary workforce, or if highly skilled, specialist individuals are a more important group to develop. Alastair Taylor outlined how upskilling the workforce will improve the quality of work, not only in terms of better accuracy or higher quality outputs, but also in terms of improving job satisfaction and potentially ensuring higher profitability for employers.



Mr Ng Cher Pong, CEO, SkillsFuture Singapore

Conclusion

The conference convened academics, industrialists, teachers, funders and government agencies to discuss how to ensure engineering education systems are fit for the future. The conference emphasised the need to change mindsets and perceptions of engineering. There is a need to do more to change society's view of what engineering means, and what an engineer looks like. Yassmin Abdel-Magied, writer, broadcaster and engineer, explained how championing diversity in the current engineering community is one way to make sure that young people are inspired by role models who they identify with. By showcasing engineering as a career for anyone, projects that aim to increase the diversity of the engineering community must be widely supported by the profession if the future workforce is to harness the brightest and best from across society.

This can be achieved by encouraging young people into engineering from a young age by bringing on board their influencers such as parents and support networks. Providing the necessary training for teachers to change habits of mind will also have impact on the integration of engineering-style thinking amongst the workforce of the future, as depicted by Professor Bill Lucas of the University of Winchester. Furthermore, supporting initiatives such as those described by speakers from the Behavioural Insights Team that encourage underrepresented groups to participate in, and thrive within, education settings will be crucial if the global engineering community is to meet the growing engineering demands in a rapidly changing technological age.

Not only is the nature of a career in engineering changing, but the physical and social environments that engineers work within are changing as well, adding new layers of complexity to engineering projects. With advancing technology, innovations such as artificial intelligence, and environmental pressures such as climate change, the skills and competencies that engineers have must also adapt to ensure that the

community is fit for the future. Professor Rick Miller, Founding President of Olin College, explained that there is a need to fundamentally change the way engineering is taught, because current approaches may be preventing institutions from producing the innovators that are desperately needed by the profession. A new culture of learning must be developed that is centred around a more collaborative and interest-led model of learning. This can only be achieved through strong partnerships between industry, academia and governments, and by moving away from siloed approaches of addressing engineering challenges to ensure long term change to the way that engineering is taught. Collaborative mechanisms for sustained engagement are vital to ensure young people, and society as a whole, understands engineering's role as a driver of economic development and in addressing development challenges. As outlined by Professor Chris Wise RDI FREng, Expedition Engineering, long term engagement between schools, communities and industry will ensure a wider recognition of the importance of the profession and improve engagement with engineering education.

Professor Rick Miller also emphasised the paramount importance of changing mindsets to ensure that engineering education is fit for the future. In his vision, this means moving towards a holistic education system that includes learning about ethics, promotes collaboration and interdisciplinary thinking, and encourages students to be proactive in developing wider skill sets. It is important that educators consider more than just content knowledge, but instead see their role as preparing students for life in a more holistic way.

The overarching message of the conference was well summed-up by Dr Charles Vest, former President of Massachusetts Institute of Technology and of the US National Academy of Engineering, who said that “making universities and engineering schools exciting, creative, adventurous, rigorous, demanding, and empowering milieus is more important than specifying curricular details”. This can be achieved through effective analysis and evidence of the skills and knowledge gaps within society, graduates and industry. Understanding where best to channel resources so that the current shortfalls of engineering education, at all levels, are most effectively tackled will help to ensure an engineering community that it is appropriately skilled, resilient, flexible, and fit for the future.

5. Agenda

Engineering education systems that are fit for the future

Systems approach to creating the global workforce of the future

Conference Agenda		
24 September 2018, Royal Academy of Engineering		
8.30am	Registration	
9.25am	Introduction	Professor David Bogle FEng , Chair HEP SSA/ IAPP
9.30am	Welcome remarks	Dr Hayaatun Sillem , CEO, Royal Academy of Engineering
9.45am	Keynote and Q&A	Dr Richard Miller , President and First Employee, Olin College

Session 1

Engaging young people with engineering

Session Chair

Dr Rhys Morgan, Director of Education, Royal Academy of Engineering

11.00am	Thinking like an engineer: how reframing engineering as a set of habits of mind opens new opportunities for education.	Professor Bill Lucas , Professor of Learning and Director, Centre for Real World Learning
11.30am	Q&A	Professor Bill Lucas , Professor of Learning and Director, Centre for Real World Learning
11.40am	Breakout session one	
Option 1	Progressing to be an engineer	Dr Lynne Bianchi and Dr Jonathan Chippindall , Science and Engineering Education Research and Innovation Hub, University of Manchester
Option 2	Igniting STEM education through social innovation	Giuliana Huerta-Mercado , President, United Technologies for Kids (UTK)
Option 3	Engaging youth for a gender balanced fit-for-future engineering workforce	Hema Vallabh , Co-Founder, WomEng

Session 2

Enhancing learning, teaching and training

Session Chair

Professor Chris Wise RDI FEng, Director, Expedition Engineering

1.15pm	Approaches to developing tomorrow's engineering problem solvers?	Dr Allyson Lawless FEng , Managing Director, South African Institution of Civil Engineering
1.45pm	Q&A	Dr Allyson Lawless FEng , Managing Director, South African Institution of Civil Engineering
1.55pm	Breakout session two	
Option 1	Learning gain	Dr Diane Harris and Dr Maria Pampaka , University of Manchester
Option 2	Mainstreaming AI skills in engineering education	Dr Deepak Garg , Chair of Computer Engineering, Bennett University
Option 3	Entrepreneurship innovation a solution to global technological challenges	Engineer Oduwa Agboneni , Publicity Secretary, Nigerian Institution of Mechanical Engineers
Option 4	World Bank Group: African centres of excellence and international activities	Dr Graham Harrison Senior Science & Technology Specialist, World Bank Group, Education

Session 3

Upskilling the Workforce

Session Chair

Shobha Mishra Ghosh, Assistant Secretary General, Ficci

2.45pm	SkillsFuture: A national movement for everyone	Mr Ng Cher Pong , CEO, Skills future Singapore
3.15pm	Q&A	Mr Ng Cher Pong , CEO, Skills future Singapore
3.25pm	Breakout Session three	
Option 1	Lessons from the land: autonomous farming and future skills	Alastair Taylor , CEO, Institute of Agricultural Engineering
Option 2	A Sierra Leone approach to meeting a national challenge	Trudy Morgan , Director, Engineers for Change, Sierra Leone
Option 3	Using behavioural insights to support a pipeline of talent	Jessica Hunt , Senior Advisor, The Behavioural Insights Team

4.00pm	Diversity and inclusion within engineering	Yassmin Abdel-Magied , Engineer/Writer
4.30pm	Overview of the International Centre for Engineering Education under the auspices of UNESCO	Mr Kang Jincheng , Strategic Expert, International Centre for Engineering Education under the Auspices of UNESCO
5.00pm	Panel discussion	Professor David Bogle FREng , Chair HEP SSA/ IAPP
5.20pm	Drinks reception and close	

25 September 2018

Turning ideas into action: making systems thinking practical for engineering educators

Royal Society of Arts

9.45am	Welcome and round up of day one: principles of systems approaches	Professor David Bogle FREng , Chair HEP SSA/ IAPP
10.00am	Insights workshop: building models for embedding systems thinking approaches into engineering education	
11.45am	Masterclass in engineering education	Professor Kevin D Hall , Hicks Endowed Professor of Infrastructure Engineering, University of Arkansas, and Chair, Education Committee, American Society of Civil Engineering
12.45pm	Conference wrap up and close	Professor David Bogle FREng , Chair HEP SSA/ IAPP

6. Acknowledgements

We would like to thank the following speakers for their contributions to the *Engineering education systems that are fit for the future* conference.

Chair

Professor David Bogle FEng

Pro-Vice-Provost of the Doctoral School, UCL

Welcome remarks

Dr Hayaatun Sillem

CEO, Royal Academy of Engineering

Session chairs

Dr Rhys Morgan

Director of Education, Royal Academy of Engineering

Professor Chris Wise RDI FEng

Director, Expedition Engineering

Shobha Mishra Ghosh

Assistant Secretary General, FICCI

Keynote speakers

Dr Rick Miller

President and First Employee, Olin College

Professor Bill Lucas

Professor of Learning and Director, Centre for Real World Learning, University of Winchester

Dr Allyson Lawless FEng

Managing Director, South African Institution of Civil Engineering

Mr Ng Cher Pong

Chief Executive, SkillsFuture Singapore

Speakers

Dr Lynne Bianchi

Director, Science and Engineering Education Research and Innovation Hub, University of Manchester

Dr Jonathan Chippindall

Engineering Champion, Science and Engineering Education Research and Innovation Hub, University of Manchester

Giuliana Huerta-Mercado

President, United Technologies for Kids (UTK)

Engineer Hema Vallabh

Co-Founder, WomEng

Dr Diane Harris

Research Associate, University of Manchester

Dr Maria Pampaka

Senior Lecturer, University of Manchester

Dr Deepak Garg

Chair of Computer Engineering, Bennett University

Engineer Oduwa Agboneni

Publicity Secretary, The Nigerian Institution of Mechanical Engineers

Dr Graham Harrison

Senior Science & Technology Specialist, World Bank Group, Education

Alastair Taylor

Chief Executive Officer and Secretary, The Institution of Agricultural Engineering

Engineer Trudy Morgan

Director, Engineers for Change, Sierra Leone

Jessica Hunt

Senior Advisor, The Behavioural Insights Team

Yassmin Abdel-Magied

Engineer, Broadcaster, Writer

Mr Kang Jincheng

Strategic Expert, International Centre for Engineering Education under the Auspices of UNESCO

Professor Kevin D Hall

Hicks Endowed Professor of Infrastructure Engineering, University of Arkansas, and Chair, Education Committee, American Society of Civil Engineering

Royal Academy of Engineering, [National Engineering Policy Centre](#)

Royal Academy of Engineering

Engineering matters. It underpins our daily lives, drives economic growth, plays a critical role in addressing major societal challenges and helps ensure our readiness for the future, from providing a sustainable supply of food, water and clean energy, to advancing healthcare, and keeping us safe and secure.

As the UK's national academy for engineering and technology, the Royal Academy of Engineering brings together the most talented and successful engineers – our Fellows – to advance and promote excellence in engineering for the benefit of society.

We harness their experience and expertise to provide independent advice to government, to deliver programmes that help exceptional engineering researchers and innovators realise their potential, to engage the public with engineering, and to provide leadership for the profession.

Drawn half from business and half from academia, and from all branches of engineering including areas of emerging technology, our 1,600 Fellows give their time and expertise voluntarily.

We have three strategic priorities:

- Make the UK the leading nation for engineering innovation and businesses
- Address the engineering skills and diversity challenge
- Position engineering at the heart of society

We bring together engineers, policy makers, entrepreneurs, business leaders, academics, educators and the public in pursuit of these goals.

Engineering is a global profession addressing global challenges, so we work with partners across the world to advance engineering's contribution to society on an international, as well as national scale.