Transforming Engineering Education for Innovation and Development - A Policy Perspective

Dr Tony Marjoram
Guest Professor, Aalborg University
Former Head of Engineering, Department of Basic and Engineering Sciences, UNESCO

Abstract

Engineering and technology are of vital importance in innovation, social and economic development in higher and lower income countries. Development is driven by engineering applications and infrastructure, and most innovations derive from engineering. The last 50 years has seen significant change in knowledge production, dissemination and application, and associated needs for engineering, and yet engineering education has changed little over this period. This paper discusses the important role of problem-based learning and humanitarian engineering in promoting the interest, enrolment and retention of young people in engineering, and the need to develop policy perspectives on the transformation of engineering education.

*Keywords:*Engineering, education, transformation, innovation, development

1. Introduction

Engineering is of central importance and drives development around the world – our physical infrastructure is designed, built and maintained by engineers. Engineers apply knowledge and create technology - most innovations derive from engineering (Metcalfe, 2009). In terms of technological, social, economic and cultural change, engineering is the most radical profession. On the other hand, engineering is also most conservative - engineering education has itself changed very little over the last 50 years. This is one factor in the decline of interest, enrolment and retention of young people in engineering and reported shortages of engineers in many countries. These are major challenges for eng[1]ineering. This is at the time of another major global challenge for engineering - in facilitating a "greener", sustainable use of resources, in mitigating the effects of and adapting to climate change, and in humanitarian engineering and development, especially poverty reduction.

This paper looks at the importance of project- and problem-based learning (PBL) in engineering education in the context of change in knowledge and technology production, dissemination and application, and the major issues and challenges facing the world, especially poverty reduction and sustainable development, climate change mitigation and adaptation. The importance of humanitarian engineering and technology in project and problem-based learning is emphasised, along with the need for engineering to be seen as a major component in addressing global issues and challenges and opportunities, for engineering to be seen as 'cool', and for the development of engineering studies, policy and planning.

PBL is a vital innovation in the transformation of engineering education, and is complemented by the development and humanitarian engineering. With a focus on relevance and need, PBL and humanitarian engineering is crucial in the promotion of interest, enrolment, employability, mobility and the retention of students and engineers around the world, and will help to reduce the brain drain of engineers from developing countries.

2. Changes in knowledge production, application and dissemination

There have been significant changes in knowledge and technology production, dissemination and application over the last 50 years, particularly from what has been typified as "Mode 1" (academic/disciplinary) toward "Mode 2" (problem-based/interdisciplinary) (Gibbons et al 1994 and 2001; Etzkowitz and Leydesdorff, 2000). This has reflected changes in science and engineering, moving from theory toward practice, individual to teamwork, with converging bodies of knowledge, and converging professional practice and employment. Knowledge and technology production, dissemination and application also reflect waves of technological change and innovation – from the slow pace of change from hunter-gatherer to agrarian societies, to the faster pace of change beginning with the "Industrial Revolution". The first major wave of technological change in the early 1800s was based on iron and water power, the second wave in the later 1800s was based on steam, the third in the early 1900s was based on steel, the fourth in the later 1900s on oil, and the fifth, at the turn of the century, on ICTs. Each of these waves was in turn reflected in modes of education and training – from craft mentor-based hands-on approach, to apprenticeships and trade-based through to the development of technical schools, colleges and universities, with an increasing science, theory and hands-off approach. Until the 21st Century, with "post-industrial science" and the convergence of science and engineering based on interdisciplinarity, networking and a problem-solving, systems approach, with an increasing focus on applications. At the start of the 21st Century, there was increasing interest in a sixth wave of innovation based on new modes of knowledge production,

[1]Corresponding Author: Dr Tony Marjoram, Tel.: +61 437 405 412
E-mail address: t_marjoram@yahoo.com

dissemination and application. Interest is also developing in the seventh wave, based on clean technology for climate change mitigation and adaptation.

The history of the world is the history of innovation, and waves of innovation – the Stone Age was not displaced by the Iron Age because they ran out of stones (Yamani, 1973). Innovation relates to the introduction, dissemination and use of an idea, method, product or process that is new to the user or user group, although it may not therefore be absolutely new. Innovation initially referred particularly to technological innovation, although the meaning has expanded to include broader subjects – such as innovation in education. Technological innovation was first portrayed as a linear model, where basic science was supposed to lead to applied science, engineering, technology, innovation and the dissemination of technology. The linear model of innovation, from Vannevar Bush, proved to be deceptively simple and endearing, especially for the science community and policy makers in the post-war period, but was later shown to be inaccurate and misleading, although its simplicity has proved enduring. Policy analysis has since moved toward systems thinking, "national systems of innovation" and related regional and global models (Freeman, 1995; Lundvall, 1992), and also to the "ecosystem" model of science, engineering, technology and innovation. While these are more accurate for economically developed, OECD countries (where they were developed, with particular reference to Japan), they can also be misleading in the developing, non-OECD country context, where elements of the innovation system (industry, research, government) are less developed.

Educational practices slowly changed and evolved to match cognitive and professional paradigms, requirements and expectations. The dominant educational paradigm in engineering is that of "engineering science" and the Humboldt model – following the University of Berlin established by Wilhelm von Humboldt, based on a combination of theory and practice. Over time, emphasis on the practical gave way, largely on professional grounds and the desire to emulate science, to increasing focus on theory. This has had a negative impact on the interest and enrolment of young people in engineering, and consequent need for educational approaches for the next generation of engineers based on problem-based learning, projects and real-world needs.

Changes in knowledge and technology production, dissemination and application have also occasioned the need for change in associated learning approaches - toward cognitive, knowledge- and problem-based learning, and the need for innovation and development in engineering education. Engineering is a problem-based profession, and needs a problem-based, just-in-time approach to learning and continued professional development (UNESCO, 2010). The needs for the next generation of engineers are reflected in the Washington Accord graduate attributes and professional competencies (Washington Accord):

1. Engineering knowledge
2. Problem analysis
3. Design/development of solutions
4. Investigation
5. Modern tool usage
6. The engineer and society
7. Environment & society
8. Ethics
9. Individual & team member
10. Communications
11. Project management & finance
12. Life-long learning

3. Issues and challenges facing the world

One of the major overall issues and challenges facing the world is poverty. Poverty is often thought of economically, but relates primarily to the limited access of poor people to the knowledge and resources with which to address their basic human needs and promote economic, social and human development. Areas of basic human need include water supply, sanitation, housing, energy, food production and processing, transportation, communication, income generation and employment creation. Addressing basic needs in these areas consists essentially of the transfer, innovation and application of engineering and technology appropriate to the social, economic, educational and knowledge situations in which poor people live. Such engineering and technology has to be affordable, understandable and build upon local knowledge, skills and materials. This requires an understanding of the needs and knowledge systems of people living in poverty and their participation in the identification, development, adaptation, transfer and application of engineering and technology.

This also requires the provision of information, learning and teaching material using multimedia approaches and ICTs for human and institutional capacity building, and associated support services, particularly micro-finance, to promote technological innovation and application. Technology can then empower the poor by helping them to address their basic needs to reduce poverty – this is also a human right and this approach should therefore be central to a rights-based approach to poverty eradication. Specific regional and social dimensions of poverty and poverty eradication require reference to particular areas and issues – including urban and rural poverty, the problems of young people, the elderly, women and gender issues and the 'feminisation' of poverty. The poverty divide is therefore closely connected to the knowledge and technology divide, and the world can be seen to be divided into technology innovators, technology adopters, and the technologically excluded (Sachs, 2000). The number of scientific research papers and patents per capita population, for example, is in absolute reverse correlation to measures of poverty. It is the responsibility of engineering and engineering educators to address and reduce the knowledge and technology divides.

Issues and challenges facing the real world are listed below, in terms of the percentage of the world population that do not have access to the areas of basic need noted above. Engineering education, in developing and developed countries, is essential to produce the engineers to address these challenges. Addressing basic needs is an engineering issue, with engineering solutions, and project- and problem-based learning is vital to address such real and relevant world issues and challenges.

39% world population do not have safe water – 2.6 billion people
35% do not have improved sanitation - 2.3 billion people
24% do not have electricity – 1.6 billion people
20% live in poverty (<1$/day, 70% women) – 1.3 billion people
15% lack adequate housing/live in slums – over 1.0 billion people
15% lack any ICT connection – over 1.0 billion people
13% go hungry every day - 852 million people

Life expectancy - poor countries: 52 years; rich countries: 78 years.

The most well known international development goals are the 2000-15 UN Millennium Development Goals (MDGs). These consist of 8 MDGs, with 18 quantifiable targets measured by 48 indicators:

1. Eradication of extreme poverty and hunger
2. Achievement of universal primary education
3. Promotion of gender equality and empower women
4. Reduction of child mortality
5. Improvement of maternal health
6. Combating HIV/AIDS, malaria and other diseases
7. Ensuring environmental sustainability
8. Development of global partnership for development

As is common with such goals, they are aspirational rather than actual, and in reality have achieved limited success – although this was at the time of the Global Financial Crisis (only three of the eighteen quantifiable targets have been achieved). As is also common with such goals, there was little mention of how they might be achieved, or what areas of knowledge might be important or instrumental in achieving them. The role of science and technology was only mentioned in relation to MDG8, target 18 relating to ICTs (the very last target), for example, and there was no mention of engineering.

Limited success in achieving international development goals may therefore be of little surprise, given not only the scope of the challenge, but also reflects on the importance of and limited emphasis on engineering and technology in international and humanitarian development, and the generally outdated understanding of the role of engineering and technology in development by the "aid" community and associated policy makers and decision takers.

4. Development and humanitarian engineering and technology

Engineering applications, technology and innovation for development include all levels of technology, from high to low. The crucial consideration is that technology should be appropriate to social, economic, environmental, engineering and technological context. Technology should reflect social need, affordability, operability, maintainability, sustainability, from high-tec solar PV systems, to more common medium and lower tec, for example a foot-operated water pump for African farmers (an innovation as it is a technology new to the user and user-group). For a background on appropriate technology see "Small is Beautiful" (EF Schumacher, 1973). Other areas of development and humanitarian engineering and technology include biogas, water tanks, improved toilets, improved cooking stoves (fuel efficient, smokeless), biofuels (biodiesel, ethanol), biomass gasifiers and building materials.

Interest in engineering and technology for development has waxed and waned over the last 50 years, with increasing interest in appropriate technology in the 1960/70's. This declined in the 1980s/1990s with changing politics, cuts in aid in many Western countries and linkage to policies of structural adjustment. There was a reemergence of interest in appropriate technology in the 2000s, for example with the appearance of "Small is Working" (UNESCO, ITDG, TVE, 2004), and Appropedia (2006) and the development of Engineers Without Borders groups around the world. So it could not be said that appropriate technology was dead (Paul Polak, 2010), but had been resting. Appropriateness is also a feature of the increasing interest in new modes of knowledge generation and dissemination, networking (sixth wave of innovation), sustainability, greener engineering and cleaner technology for climate change mitigation and adaptation (seventh wave). Engineering and engineering education is of vital importance in contributing to the sixth and seventh waves of innovation, and the development of greener-cleaner engineering and technology will be essential for the survival of humanity and the blue planet.

This includes developed and developing countries – where much of the technological, economic and social change is taking place. This relates to a "political economy of engineering and development" – in developed and developing countries engineering applications and technology depend on knowledge, resources and funding, and in less developed countries this also relates to development assistance and aid. The application of engineering and technology in the development context depends on various considerations, internal and external to engineering:

Considerations external to engineering:
- awareness of the role of engineering/technology in development
- appropriate policy and implementation by policy-makers and decision-takers

Considerations internal to engineering:
- information and advocacy of engineering in development
- inclusion of development issues in engineering education

There are various factors for success in the application of engineering and technology for development, these include the need for:

- Information, advocacy, resources, leadership
- Appropriate policy, need for commitment, implementation of policy
- Technologies to be appropriate to local social and economic needs conditions
- affordable, operable, maintainable, sustainable
- Engagement and involvement of local community and engineers
- Drive by the engineering and technology community, popular champions

Focus on various communities:

- engineering organisations and education institutions
- policy, planning, development in government and private sectors
- NGOs, international and intergovernmental organizations

5. Issues, challenges and opportunities – cool engineering?

As discussed above and reported elsewhere (UNESCO Report, 2010), particular issues and challenges for engineering include:

- Decline of interest and enrolment of young people in engineering (due to negative perceptions of engineering and engineering education)
- Shortage of engineers, technologists and technicians (reported by many countries)
- Brain-drain of engineers from developing countries and serious impact on capacity and development
- Need for investment in infrastructure, capacity, R&D (Obama, 2008, 2013) (following Global Financial Crisis, 2007-8)
- Climate change, mitigation and adaptation, move to lower-carbon future

The decline of interest and enrolment of young people (especially women) in engineering appears to be mainly due to negative perceptions that engineering is uninteresting, 'nerdy', 'geeky' and boring, that university courses are difficult and hard work, that engineering jobs are not well paid, and that engineering has negative environmental impact. There is evidence that young people turn away from science at age 10-12, that good science education at primary/secondary level is vital, and that teachers can turn young people on and off science and engineering (National Science and Technology Centre, Australia, 2007). The image of the nerdy engineer is epitomised in the "Dilbert" cartoon strip, and by Mr Bean (although Rowan Atkinson has a degree in engineering). The overall message in this context is that engineering is uncool!

To address this situation there is a need to counter specific negative perceptions of engineering as boring and uninteresting, and a need to promote public awareness and understanding of the important role of engineering in development. To counter the perception that engineering education and university courses are hard work there is a need to make education and university courses more interesting and relevant for problem-solving, that emphasise a problem-based learning (PBL) approach. To counter the perception that engineering jobs are not well paid there is a need to promote pay parity and the perception of pay parity with similar professions and levels of qualification (although, following the law of supply and demand, it is already apparent that salaries have increased in areas of shortage). Finally, to counter the perception that engineering has a negative environmental impact, there is a need to promote engineering as a part of the solution to sustainable development, climate change reduction and mitigation, rather than part of the problem.

Overall, there is a continued need to address and present an overall picture of engineering to:

- Emphasise engineering as the driver of social/economic development to get engineering on the development agenda
- Develop public and policy awareness of engineering
- Develop information on engineering highlighting the need for better statistics and indicators on engineering
- Promote change in engineering education, curricula and teaching to emphasise relevance and problem-solving
- More effectively apply engineering to global issues such as poverty reduction, sustainability and climate change
- Develop greener/sustainable engineering and technology - the next wave of innovation

It is also useful to note some perceptions of recent trends in academia relating to declining standards, funding, overloaded academics. These have been linked to increasing bureaucracy, corporatisation, public relations and increasing focus on revenue, efficiency, profile and position, based on indices of academic ranking (Hill, Richard, 2012).

6. Positive linkages and opportunities – cool engineering!

Fortunately, many of the above issues, challenges and opportunities facing engineering are linked in the provision of positive solutions. When young people, the public and policy-makers see that engineering is a major part of the solution to global issues, for example, their attention and interest is raised and young people are attracted to engineering. They are also attracted by relevant and innovative pedagogical approaches, such as problem-based learning, and to relevant and appropriate technologies to address global issues, such a sustainability and poverty reduction. To achieve this, there is a need to promote transformation and innovation in engineering education, to include theory and practice that was a core of the original Humboldtian model – to promote fun and fundamentals. It is also important to provide examples of engineering relevance and appropriate technologies for development.

The promotion of relevance in the context of engineering problem-solving to address global issues such as poverty, sustainability and climate change, is exemplified in such initiatives as the Daimler-UNESCO Mondialogo Engineering Award that ran from 2003-2010, attracting 10,000 student participants from 100 countries (Mondialogo, 2010). The Mondialogo Engineering Award was a problem-based, project design exercise involving international student cooperation focused on global issues around a diversity of technologies, including water supply and sanitation, cooking stoves and prosthetic feet. The interest in such issues is also reflected in the rapid growth of Engineers Without Borders (EWB) groups at universities around the world over the last 20 years – which have been shown to attract students, and which several universities have supported in the enrolment and retention of students. Such activities promote engineering and appropriate technology as highly relevant in addressing global issues, ensuring positive feedback, promoting public interest and understanding and conveying the important overall message that engineering is cool!

7. Transformation and innovation in engineering education

To address the issues and challenges noted above, the main goals of transformation and innovation in engineering education are to respond to rapid change in knowledge production, dissemination and application, moving from the traditional, formulaic, engineering curricula and pedagogy toward a cognitive, knowledge-based approach, emphasising experience, problem-solving and insight, with a more just-in-time, hands-on approach, as exemplified by project and problem-based learning. This is also in response to the changing need for engineers to be better attuned to knowledge change in terms of synthesis, awareness, ethics, social responsibility, experience, practice, applications and intercultural sensitivity. Because of rapid change in knowledge production and application, engineers have an increasing need to learn how to learn, in terms of lifelong and distance learning, continued professional development, adaptability, flexibility, interdisciplinarity and multiple career paths. There is also the need for relevance regarding pressing global issues and challenges – including poverty reduction, sustainability (environmental, social, economic and cultural), climate change mitigation and adaptation. These graduate attributes and professional competencies are reflected in the Washington Accord.

Engineers are problem-solvers and innovators, and need to innovate in engineering education toward a curricula focused on project and problem-based learning, with particular reference to real world, relevant issues and problems, cleaner and greener engineering and technology appropriate to social, economic, environmental and cultural context. Curricula should reflect formal and informal learning trends, especially the use of ICT resources for student-centred learning, with limited lectures and staff acting more in a role of learning facilitators. There should be a focus on development and the assessment of graduate attributes, and the provision of suitable learning and work space to facilitate student interaction. The focus on real world, relevant issues and problems also serves to promote engineering as essential, exciting and rewarding (Beanland, 2012).

Transformation is partly a political process, and as such may encounter resistance and barriers to change. Universities and academics usually have a focus on research, rather than education, are conservative and resist change, and have a culture and space for lecturing, rather than learning. Universities in general focus on staff performance in terms of papers published and grants gained, and have higher rewards for researchers than effective educators, and university leaders rarely see the need for transformation. Other constraints and barriers relate to accreditation authorities, who tend to be conservative, slow to change, often averse to an output-oriented, graduate attribute approach, and often do not effectively enforce attribute achievement at the individual student level. Despite the rhetoric of excellence, quality, innovation and creativity, there are real concerns, as noted above, regarding declining standards in these areas.

8. Transforming engineering education

There is a particular need to recognise changing needs for engineers, in terms of knowledge, learning, graduate attributes and professional competencies. These include a problem-solving, problem-based learning approach and link to global issues - poverty, sustainability, climate change. There is also a need to promote information, evidence, examples of good practice and advocacy on the need to transform engineering education targeted at engineering organisations, accreditation bodies and universities, to facilitate government support and enlist champions for change and transformation.

It is possible to identify areas of 'transformative action' that are crucial for change. In the case of transforming engineering education, these relate particularly to:

- Knowledge systems – in engineering, science, technology
- Ethical issues – in engineering, science, technology
- Data and information – in/on engineering, science, technology
- Engineering and science education and educators
- Engineering and science professions, institutions, employers
- Policy and politics – decision making and decision-taking
- Society and social context for engineering, science, technology

Guidelines for transformative action in these areas include the need to develop and disseminate a better understanding of the knowledge system of engineering – how knowledge in engineering is produced, applied and disseminated in social, economic and ethical context. This requires data and information on engineering to support evidence-based advocacy for change. This needs to be directed toward engineering and science educators (at tertiary and secondary level), the engineering profession, institutions and industry, policy makers and politicians.

Several areas of transformative action crucial for change in engineering education have been identified. These relate particularly to engineering information, knowledge and ethics, the engineering profession, institutions and industry, engineering educators, engineering policy, planning and decision-making, and the wider social and ethical context for engineering (UNESCO Report, 2010; Beanland and Hadgraft, forthcoming). Specific guidelines for transformative actions include the following:

- Use of the Washington Accord graduate attributes as overall objectives for engineering education, and assessment based on these attributes.
- Use of curricula to develop professional competencies, emphasising student-centred, Problem-Based Learning and ICT resources over lectures to encourage motivation and engagement, especially in first year (for example, the EWB Challenge in Australia).

To facilitate such transformations, actions required include the development of:

- Curricula, establishment of student goals and assessment based on Washington Accord graduate attributes.
- Student-centred, Project Based Learning curricula, featuring use of ICT resources, student learning rooms, e-portfolio personal learning environments and staff as learning facilitators rather than lecturers.
- University-industry cooperation for project activity, work and professional experience, exchange and promotion of engineering as a career.

Possible resistance and barriers to change, and how to address them:

- Universities are conservative – need information, advocacy for change
- Universities focus on research – need more emphasis/reward for education
- Universities focus on lecturing – need to emphasise learning
- University space is for lecturing – need for student learning space
- Accreditation authorities - need to recognise WA graduate attributes

Engineers and educators can help facilitate change by:

- Recognising, promoting and supporting the transformation of engineering education to universities, government, through example, research, information, advocacy
- Working with industry on projects, professional experience and exchange and facilitate transformation
- Working with accreditation authorities and universities to implement Washington Accord graduate attributes, professional competencies and development.

The transformation of engineering education is required to attract and retain young people in engineering, to address the shortages of engineers increasingly reported around the world, and associated brain drain from developing countries, and to keep up with changing needs for engineers, changing modes of knowledge production and application and changing needs in the world. These include the increasing need for sustainability, climate change mitigation and adaptation, and humanitarian engineering to reduce poverty and promote social and economic development – challenges that concern and appeal to many young people, and attract them to engineering.

The transformation of engineering education needs to be student-centred, with a focus on graduate attributes, professional competencies and relevance. This transformation will not only benefit students and engineering, but also universities, industry and the wider public. Other professions, such as medicine, have transformed toward 'patient-based' learning, when there was no enrolment need to do so, wheras engineering has enrolment and retention issues that transformation will address. These issues are internal and external to engineering, and require internal and external incentives to change, including a move from teaching to learning, and a better balance of reward between learning and research at universities. Student-centred, problem- and project-based learning has been shown to facilitate such transformation at various universities around the world (Aalborg, Olin College, Singapore University of Technology), with many other universities taking an interest. Accreditation authorities and governments need to recognise, support and help facilitate the output-oriented, graduate-attributes approach and transformation of engineering education.

9. Engineering studies, policy and planning

The background to the transformation of engineering education relates particularly to government and academic interest in science and science policy and planning, which has neglected engineering. Engineering studies, policy and planning needs to be developed to facilitate the transformation of engineering and engineering education. Interest in science and science policy and planning developed particularly after 1945. Reflecting this interest, courses and then departments focusing on science and technology studies, policy and planning were established in the 1960s at universities around the world. Business schools also developed an interest in science, technology and innovation. Most of this interest focused on science or 'science and technology' policy, with little reference to engineering. The study of engineering, and engineering policy, remained a neglected area of interest and emphasis. This is reflected in the limited public, media and policy awareness, perception and understanding of engineering today. The main reasons that science and technology policy has a focus on science rather than engineering relate to classical economics, public and research policy, and the popular perception and 'linear model' of science and innovation.

In classical economics, technology is regarded as residual, subordinate to the three factors of production - land, labour and capital. Science policy developed from public and research policy, and the principle that decisions regarding the allocation of research funds should be made by researchers rather than politicians – thus favouring science rather than engineering. In the 'linear model' of innovation, basic science research is imagined to lead, through applied science and engineering, to technological application, innovation and diffusion. This model was promoted by Vannevar Bush in the postwar period, and has endeared and endured with scientists and policy-makers on grounds of simplicity and funding success, although many science and technology policy specialists now regard the 'linear model' as inaccurate and misleading. This is partly due to the recognition that many innovations derive from engineering rather than basic science. Interest in the role of science, engineering and technology in international development also evolved towards the end of the colonial period in the 1960s, with the development of universities in developing countries, again with a focus on science, rather than engineering, replicating universities in developed countries.

Given this background, and the rapid change in knowledge production, dissemination and application, there is a particular need to develop a more holistic view of science, engineering and technology, better integrating engineering into the narrow, linear model focusing on the basic sciences. To achieve this, there is a need to emphasize the way engineering, science and technology contributes to social and economic development, and the vital role engineering will plays in promoting sustainability, climate change mitigation and adaptation. There is also a need to better integrate engineering into science and technology policy and planning, and of better integrating engineering, science and technology into development policy and planning, to provide a more useful and accurate reflection and model of reality. This also applies in the development context - engineering, science and technology drive development, are vital in promoting sustainability and poverty reduction, and need to be placed at the heart of policies addressing these issues, at the national and international levels. As noted above, engineering is vital in addressing basic human needs in water supply, sanitation, housing, energy, food production and processing, transportation, communication, income generation and employment creation. Development policy and planning would benefit from a broader approach and 'evidence-based' analysis of the way engineering and technology drives development and reduces poverty. These considerations also relate to the need to transform engineering education to facilitate innovation and development, and the important role of PBL and humanitarian engineering in encouraging the interest, enrolment and retention of young people in engineering in developed and developing countries.

10. Concluding remarks

There is a particular need to recognise the changing context of knowledge production and application, and changing needs for engineers in terms of learning, graduate attributes and professional competencies, as indicated in the Washington Accord. These include a problem-solving, problem-based learning approach and link to global issues – especially poverty, sustainability and climate change. There is also a need to develop and promote information, evidence, examples of good practice, and to enlist champions for advocacy regarding the transformation of engineering education, focusing on engineering organisations, accreditation bodies and universities, with the goal of facilitating government and private sector support for transformation.

To conclude, it is useful also to consider the consequences of failure to address the challenge to transform engineering education. This includes continued shortages of engineers around the world, continued impact on social and economic development, continued brain drain and impact on developing countries, a world of borders without engineers. This is the potential backdrop to the need for engineering education to transform itself to interest young people, promote enrolment and retention, reflecting changing knowledge, production, dissemination and application, changing societal, economic conditions and needs.

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