2018 International Conference on Multidisciplinary Research
Track 1: Science, Technology, Engineering & Mathematics
https://doi.org/10.26803/MyRes.2018.13

From Sustainable Engineering Education to Knowledge Transfer: A Preview

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Abstract
Science, as discovery, reminds us to praise the Creator for the divine, implausible, magnificent beauty and intricacy of His Creations. Engineering, as invention, helps us to unfold the creations further by developing products using the existing materials and the forces of nature to serve humanity. To do so without compromising the ability of future generations to meet their own needs, sustainable engineering concepts are required. Hence, the engineering education needs to anticipate and adapt itself to the socio-technological ever-evolving challenges in order to contribute towards the sustainability of the globe in an effective manner. A sustainable engineering curriculum would be one that is comprised of a good blend of engineering, scientific, technological knowledge, plus managerial, innovation, economic, communication, and more importantly ethical and moral knowledge and skills. This paper highlights the evolution of engineering education and emphasizes on the significance of ethics and moral values, managerial skills, emotional awareness, training and development, technopreneurship and knowledge transfer in engineering education.

Keywords: engineering ethics, emotional intelligence, knowledge society, technopreneurship, technology transfer.

Introduction
To seek knowledge is elemental. Applying and imparting the acquired knowledge with proper principles is what would contribute towards the transformation of the society in a constructive and positive manner. The process thereby knowledge is

being nurtured can be termed as education. Sustainability, on the other hand, can be broadly defined as the ability of doing something in a constant and renewable manner. The mechanism to achieve sustainability is called as sustainable development (herein referred to as SD). According to the United Nations' Our Common Future, also known as the Brundtland Report (Brundtland, 1987), sustainable development is a type of development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Literature indicates that SD is a multifaceted, multidisciplinary and inter-temporal complex concept which encompasses three dimensions namely, social, economic and environmental (Griggs et al., 2013; Holden et al., 2017; Lehtonen, 2004; Lélé, 1991; Omer, 2008). Sustainable Engineering Education (herein referred to as SEE) is therefore an infusion of the SD concept into engineering education to support the global visionary knowledge society. The latter has been defined in numerous forms: it is a society about creating, sharing and using knowledge to bring prosperity and a sense of well-being to its people (Al-Hawamdeh, 2002); it is a society in which the knowledge sector represents the most significant share of the economy (Rohrbach, 2007); it is a society fortified by a up-to-date information as well as well-built physical infrastructure allowing participation in the different socio-economic and political activities (Lor et al., 2007), inter alia.

"Engineering is that profession in which knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind". - Engineers Council for Professional Development (*1961/1979*)

Engineers are therefore intellects that apply interpersonal judgment to analyze, design, construct and operate the products and services. The know-how of creative problem-solving under restrictions, the insights of extent to compromise, the wisdom to develop intuitive communication, the aptitude to identify risky or failure scenarios and act responsively – these are the features required to make a reliable engineer, combining not only math, natural sciences but also social sciences, creativity with ingenuity and the universal characteristics, moral values and ethics. Engineering has an intrinsic relationship with the society unlike science which is not bound by the immediate needs of society and is driven by curiosity or inherent dedication to solving nature's elaborate complexities and/or seeking answers to natural phenomena. Considering the ever-growing challenges worldwide, engineering-oriented solutions are critically demanded. Traditional engineering education has to be properly tailored with respect to technological advancement without compromising any standards or professionalism. As a consequence, the branches of engineering have expanded into scores of different engineering expertise compared to other subjects. Fields ranging from agricultural to aeronautical, electrical to telecommunications, civil to naval architecture, chemical to biochemical and many more have been established in the academia. Furthermore, the areas of specialization are narrowed to specific applications at degree level by means of minor technical modules. It is undeniably, that numerous technological-driven institutions are already emphasizing on engineering sustainable development in terms of economic and environmental contributions, but does our actual engineering curriculum instill satisfactorily essence of ethics and moral values and their significance in the society? Does the pedagogical approach inform engineering apprentices of the essentials matters in sustainability of mankind and its development? Are our graduates ready to identify and manage their own emotions in this world filled with odds? Does engineering education provide ample opportunities for training and development for interpersonal skills? Do we, the Higher Education Institutions (HEI) which is considered as the beacons of hope, amity, and ideas are promoting the spirit of technopreneurship? Are academicians transferring knowledge effectively to the society? This preview intends to highlight these philosophical viewpoints as an impulse towards SEE.

Transformation in Engineering Education

"The only constant in life is change."- Heraclitus

A timeline of the future global visions for engineering education and trends in industry is shown in Figure 1. It can be noticed that eras of engineering education and trends in industry have been evolved from 1900 up to now and are still being developed. The eras of engineering education have been changed from practice-oriented into engineering science based content and we are now moving towards integrative and innovative era. Froyd (Froyd et al., 2012) shared five major shifts during the past century: (1) a shift from hands-on and practical emphasis to engineering science and analytical emphasis (2) a shift to outcome-based education and accreditation (3) a shift to emphasizing engineering design (4) a shift to applying education, learning and social-behavioral sciences research (5) a shift to integrating information, computational and communication technology in education.

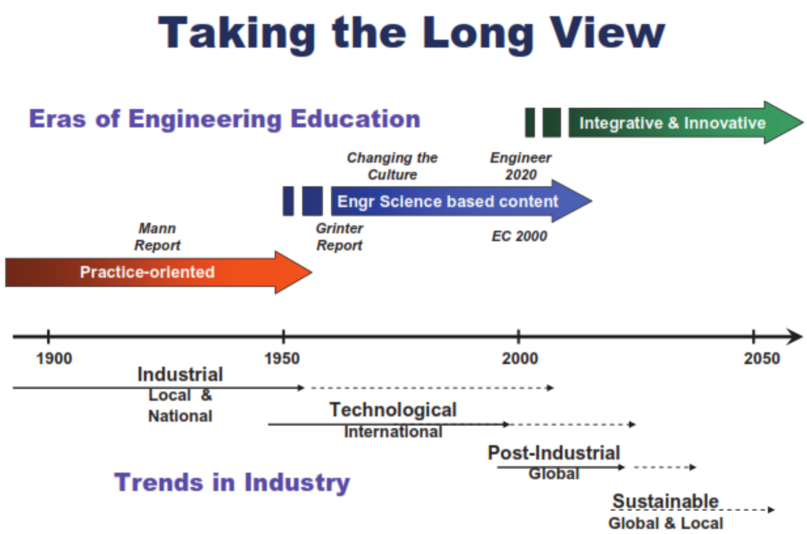

Figure 1: Long view of engineering education (Sunthonkanokpong, 2011)

While the first two shifts have been realized already but continue to have implications up to now, the last three shifts are still being implementing. The first shift is about mathematical modeling and theory-based pedagogy. The second shift concerns internationalization of engineering curricula and engineering practices that are regulated by the Washington Accord. It gives international recognition to the degrees of engineers for member countries enhancing the employment opportunities of their citizens across the world. The accord requires that member nations set up suitable accreditation standards which would ensure a minimum quality of attainment for their engineering graduates. This improves the overall standard of training across all engineering schools to match the international standards set. It also works as quality framework that responds to difficulties that graduates face after their studies. It is worthwhile to mention that engineering technology degrees are now being run by institutions in many countries and graduates are rather referred to technologists rather than engineers as the students learn more through hands-on training as opposed to theory. The Sydney Accord is the mutual recognition agreement (MRA) which pertains to four-year engineering technology programs accredited by its signatories in their jurisdictions since 2001. The incorporation of design courses is usually achieved by a cumulative project during the first year of the curricula. The fourth shift can be noticed that it is directly related to work-integrated learning (WIL) which is a way of equipping graduates with attributes that make them work-ready by going through a compulsory work-place learning form (WPL). Qualities such as work diligence, qualitative efficiency, quantitative efficiency and teamwork are simultaneously being fostered in the engineering interns. WPL focuses on developing competencies. Lastly, the fifth shift is about the impact of information, communication and computation technologies (ICCT) on engineering education. Examples are content delivery methods, personal response systems, intelligent tutors, simulation software, remote laboratories amongst others (Froyd et al., 2012).

Gaps in Engineering Education

Although during the past 100 years, numerous challenges in engineering education have been tackled by the global community of educators and researchers, either enthused by the development of new technologies or the need for a restructuring the engineering curricula based on suggestions for more effective approaches to teaching and learning, some gaps still exist and hence SEE cannot be fully realized. Quite some time ago, in 1997, Nichols and Weldon (Nichols, 1997) argued that engineering education process and professional societies pay insignificant attention to the relationship between engineering and the society. They proposed a Venn diagram (Figure 2) which shows the engineering relationship with societal needs, scientific knowledge and creativity with different regions intersected. Region A solely describes the domain where capabilities of solving scientific problems lie. Region B shows the innovative capacity in engineering domain. Together, intersection of region A and B creates region C, where engineering design are a result of real world problem solving from the merging of engineering science and creativity. Region D illustrates the domain where region A, B and societal needs meet. This region exemplifies the ideal role of engineering and the individual engineer.

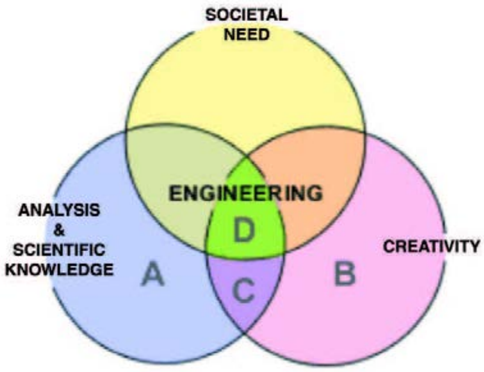

Figure 2: Venn Diagram of the relationship of engineering to societal needs, scientific knowledge and creativity (Nichols, 1997)

Engineering education has to be therefore in harmony with the society in order to ensure its sustainability. Socio-behavioural development of young professionals is the key for a better and safer modern future world. Apart from the scientific understanding of engineering science, the engineer has to be able to appreciate and prioritise the society's needs, propose optimum solutions, subjected to the available resources and time. It is hence essential to reform the way that an engineer thinks, decides, and deals with members of his society. This is dictated by the ethics and moral values and shall be reminded and inculcated in our engineers' mind. Key qualities are integrity, discipline, dedication, responsibility, transparency and commitment. If not, negative emotion such as ego will be developed. In their paper entitled as "Linking Ego and Moral Development: The Value Consistency Thesis", Levine et al. (Levine et al., 1992) addressed the relationship between ego and moral development, as represented by the theories of Erikson and Kohlberg. Engineering ethics which is the study of the moral issues and decision confronting individuals and organizations involved in engineering (Catalano, 2010), should be embedded into the curriculum. As a result, it will increase the ability of engineers to confront the urgent moral questions raised by technological activity, boost the ability to identify, formulate and solve engineering ethical problems, and improve the ability to communicate effectively with personnel of other related disciplines. The programmes should initiate awareness on moral autonomy, defined as the ability to think critically and independently about moral issues and to apply this moral thinking to situations that arise in the course of professional engineering practice. Proper, intensive, and practical- oriented training and practice of ethical decision-making approach is imperative. There is an urgent need to have qualified, well-informed engineers who will voluntarily, effectively, and wholeheartedly implement SD principles in its entirety. A revolution in ethics is needed to improve the chance of success for SD in engineering education. Decision makers that include engineers, the community, and society needs to redefine, address, and prioritize the real issue facing this generation and future generations. The difference between public interest, self-interest, organizational interests, society's interest, and future generations' interest should be clearly and explicitly dealt with in relevant courses. Al-Rawahy (Al-Rawahy, 2013) has stressed that this is an important area where young engineers need to be exposed to and rehearsed on. Conflict of interest is and will continue to be a sticky problem for decision makers who are not fully aware of the distinction between these paradigms. Engineering code of ethics require engineers to consciously place the public interest above all other interests. It is primordial to incorporate practical examples and incidents that will practically teach students of the reality that is practiced by working engineers. Besides engineering ethics, it is thought that spirituality also contributes to the development of the engineer's personality philosophically, sociologically, and psychologically.

Contemporary themes addressing the essentials issues in sustainability of mankind and its development need to be made conscious to engineering students. These may include industrial and economic development, environmental impacts, globalization, population growth and its general impact on resource use, availability, and environment, the social-cultural-political-ethical-and moral impacts of development, global crises and problems that confront mankind and the wider environment, and their relevant impacts on society and future generations. This will further enable them to see beyond technical issues to the societal implications of technology, adapt to the rapid fluctuations of the consumer market and new technologies, solve interdisciplinary challenges, and combine a depth of knowledge of a subspecialty with the breadth of understanding required for real-world engineering (Al-Rawahy, 2013; Albu et al., 2004; Crawley et al., 2007; Mills et al., 2003).

Even though it is asserted by universities that an engineer's role in a company is one of leadership and implicit management, some engineering education curricula still lack the management skills component. Emotional Intelligence, coined as EQ, is a concept that was developed by Salovey and Meyer (Salovey et al., 1990) and later expanded by Goleman (Goleman, 1996). He identified that IQ is less important for success in life and work than EQ – a set of skills comprising of five characteristics that are not directly related to academic ability, namely self-awareness, self-regulation, motivation, empathy, and social skills. He thought that these qualities can be taught to engineering students as preparation for their professional working life. Moreover, Goleman (Goleman, 1996) stated that emotional intelligence abilities were about four times more important than IQ in determining professional success and prestige, even for those with a scientific background. He mentioned that engineering education has ignored this range of skills in the past, skills that incorporate communication and collaborative abilities, teamwork, selling an idea, accepting criticism and feedback, learning to adapt, and leadership. The professionals involved in international business will need to be equipped with new and expanded competences and skills from an intercultural perspective. Technical skills alone are no longer sufficient in this brave new world of globalisation and digitalisation; intercultural awareness and EQ skills are prime components that will facilitate the adaptation of future engineering graduates. The engineer's requirements continue to expand and evolve beyond the basic technical engineering knowledge and therefore universities need to recognise that the skills base now needed in the knowledge era has extended to greater emotional awareness. EQ tests should be performed with students. A person who owns high EQ test has the ability to self-assess, knows the strengths and weaknesses of themselves and others, has empathy and understanding of others' feelings. He/she will always know how to keep calm and optimistic in life even in the most difficult challenges. Regular mentoring activities should be conducted to further strengthen the relationship between lecturers and students, thereby recognizing the fact that we are first and foremost, all human beings, irrespective of our qualifications and achievements in life. Interpersonal skills, such as team building, communication skills, conflict management, persuasion skills, affirmation skills, adaptability and negotiation skills may be addressed. The activities may also assist mentees in discovering their interests and talents, how they learn best, possibilities of a career path, and how to make decisions and start planning. In short, the curricula should have attributes of human touch as well.

Training and development programmes are often considered as a pivotal human resource aspect to achieve sustainability in this dynamical business environment. Imparting codified knowledge and technical skills-knowledge would fulfil the requirements of academia-industry-government while maintaining the standard of the organisation internationally. Upgrading engineering students through add-ons training, such as soft skills, business standards, and manufacturing operations amongst others can accelerate their performance, mould their thinking and ensure they are sufficiently energised to meet the objectives, hence mission and vision of the organisation they will be working for. The establishment can stay competitive in today's ever-changing marketplace whilst ensuring its future engineers are being up-to-date with the current state-of-art management and technologies. They should gain the intellectual skills needed for lifelong learning. Upon graduation, the engineers should have vision, innovation, creativity and the spirit of technopreneurship. The importance of technological entrepreneurship needs to be addressed to engineering students by the faculty through approaches such as:

- Developing of modules in technopreneurship;
- introducing of new postgraduate courses on entrepreneurial engineering;
- Organising workshops and certified trainings in conjunction with consultancy firms;
- Forming a research group exploring on technological entrepreneurship;
- Implementing of an entrepreneurial centre for enhancement of entrepreneurship for graduated engineers;
- Promoting of alumni-industry collaborations.

Knowledge Transfer

Knowledge transfer (KT) is the process in which ideas are being shared and/or commercialise from the academic environment to the outside realm (industry/community) to generate a knowledgeable and high income nation. In other words, it is a process of knowledge creation and application, knowledge mobilization and exchange, information search and transformation as well as the learning process at and outside the workplace (Awang et al., 2009). The importance of technology transfer and its relevance in the formation of a knowledge-based economy has nowadays been recognised to altered extent by nations. Universities and research councils already have Technology Transfer Offices (TTO) in order to provide platforms for transfer of technologies being developed within institutions to industries. It is the role of these offices to collect invention disclosures from engineers and technologies, to assess the disclosures for merit, to propose the category of intellectual property protection that is most relevant, to ensure the proper filings or registrations are carried out, to market the inventions to potential commercial partners through licensing efforts, to monitor the patent filings and license agreements and screen revenue generation and distribution from licensed technologies/services amongst others. However, many innovations that are being generated at research organisations do not find their way to the market for various reasons including as outlined below:

- Not market-focused: solutions do not meet the society's demands;
- Lack of Technology Transfer managers: well-versed personnel to facilitate technology transfer, in terms of invention disclosure assessment, IPRs, marketing technologies, negotiation of deals, basics of license agreements and spinout company formation are scarce, which causes delay in transferring the knowledge;
- Missing of direct indicators of impact: Many governments and organisations across the world have been utilising metrics that are not true indicators of success in measuring the impact of technology transfer. Such a gap can be seen in many countries where the numbers have only led to the disappointment of impact seekers. Greater effort needs to be deployed in measuring the true impact of technology transfer and to determine its spillover effects to an economy.

Considering the above second point, it should be understood that formation of Technology Transfer Managers (TTM) is necessary to accelerate the rate of transferring technology. Do the actual TTM really focus on commercialising the outcomes of university research? Do they satisfy their key responsibilities which are:

- To work with academic researchers thereby commercialising new university technologies;
- To identifying commercial strategies for transferring technologies to industry, including supporting proof-of-concept activities and marketing to potential end-users;
- To negotiate appropriate licensing contracts, in conjunction with legal experts;
- To manage the creation of spin-out companies and supporting a culture of entrepreneurship within the university and local innovation ecosystem;
- To ensure technology transfer activities support the generation of research impact by university researchers.

In addition, successful technology transfer managers should also demonstrate proven competence in:

- Grasping technical concepts quickly, and translating these into commercially viable proposals;
- Working effectively with key stakeholders, assertively influencing them and where appropriate showing tenacity and persistence in business development situations;
- Deploying excellent interpersonal and communication skills, both verbally and in writing;
- Successfully negotiating and licensing commercial contracts with industry;
- Working successfully within a close-knit team;
- Managing a large portfolio of complex projects to a successful commercial conclusion.

Most technology transfer platforms are lacking trained and accredited individuals with the skills mentioned above to deliver on knowledge and technology transfer requirements. The lack of expertise is crippling the transfer of knowledge and innovations from research organisations to the industry. It has further resulted in reduced commercialisation rate in terms of the number of innovations that are protected and the number of innovations transferred to industry or another entity for further development and commercialisation. The development of skill set relating to technology transfer and commercialisation should become a pressing need to developing countries. Governments should push their national agenda towards innovation and commercialisation which can spur talent development in the industry.

While implementing the New Economic Model for Malaysia which is a blend of high income, inclusiveness and sustainability for a better quality of life, a Knowledge Transfer Programme (KTP) has been initiated in such a way that:

- It recognises a broad range of activities to support mutually beneficial collaborations between universities, industries and communities (government agencies/ non-government organizations/ public sectors);
- It provides the platform for the exchange of tangible and intangible intellectual property, expertise, learning and skills between academia, industry and the community;
- The forms of interactions may include joint research, consultancy, education, training, graduate development, conferences, sharing of physical facilities and student placement.

KTP's objective is to recognise and promote the transfer of knowledge via the exchange of creative and innovative ideas, research findings, experiences and skills between IPTA, research organizations, industries, government agencies and the wider community.

Conclusion

Engineering turns knowledge into technology which is vital in addressing global challenges such as sustainability, climate change, poverty and the other humanity-oriented goals. Yet, as technology advances, the engineering education needs to ensure conformity with the economic, environmental and social domains in order to realise sustainable development of the society, or rather knowledge-society. The first two aspects are undoubtedly being encouraged sufficiently by academic institutions but relatively less attention is given to the contribution of engineering to the society. Propositions such as an engineering ethics dosage with a touch on spirituality is required in the curriculum, contemporary topics to educate the engineers about sustainability of the society has to be addressed, the emotional intelligence concept has to be integrated during formation to nurture self-awareness, self-regulation, motivation, empathy and social skills, and finally training and development programmes including technopreneurship workshops should be conducted to address and confront the new set of realities whilst simultaneously ensuring revised standards and norms are being met, as innovation and creativity are crucial to the global competitive arena. Overall, an engineer should (1) be technically adept, broadly knowledgeable and a lifelong learner (2) be ethical and sincere (3) exhibit a technopreneurial spirit, innovative, and understand world markets (4) be pro-active and possess emotional intelligence (5) know how to translate technological innovation into commercially-viable products and services thereby contributing towards the betterment of mankind. Knowledge transfer programmes should be initiated and steadily encouraged to improve the quality of life whilst ensuring high income, inclusiveness and sustainability.

Acknowledgements

The authors would like to thank the Ministry of Higher Education of Malaysia for their financial support through the Fundamental Research Grant Scheme FRGS/TK05/UPM/02/7 No. 5524896.

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