THE NEED TO REVIEW ENGINEERING EDUCATION FOR ACHIEVING SUSTAINABLE DEVELOPMENT

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Abstrak

Pembangunan lestari merupakan satu frasa yang popular. Ianya cuba mengimbangi pemuliharaan terhadap alam sekitar selaras dengan pertumbuhan ekonomi dan menjanjikan kaedah yang mampu menyediakan kehidupan yang selesa untuk penduduk di muka bumi tanpa memusnahkan ekosistem di sekeliling kita. Kejayaan pembangunan lestari akan banyak bergantung kepada jurutera. Aspek-aspek utama yang perlu ditekankan termasuklah penggunaan tenaga yang lebih efisien melalui kaedah-kaedah pemuliharaan dan penggunaan sumber yang boleh diperbaharui, pengurangan sisa, meningkatkan penggunaan semula bahan-bahan dan mengitar semula, penilaian ekonomik/alam sekitar yang lebih komprehensif dengan menggunakan analisis kitar hayat serta pengurusan sumber yang lebih sempurna. Kertas ini menyungkil beberapa aspek-aspek penting untuk keperluan agar kurikulum pengajaran di dalam bidang kejuruteraan dan latihan diubahsuai supaya dapat memenuhi aspirasi untuk mencapai objektif pembangunan lestari.

INTRODUCTION

The world population now is increasing at the rate of about 1 billion people per decade, having increased from 3.5 billion in 1970 to 5 billion in 1990, to an estimated 7 billion by 2010, with the great majority living in developing countries (UN, 2002). Studies have also shown that 1 billion people are consuming almost three-quarters of the world's resources and creating the bulk of its pollution, devastating the global ecosystem such that a quarter of the Earth's species may be extinct in 50 years because of habitat destruction. On a system wide level the environmental problems, from global warming to the destruction of the rain forest, are getting worse.

Thus, there is an urgent need to reform the world from its wasteful ways and raise living standards in the developing world without fatally overloading demand on the planet's resources by adopting sustainable development principles.

The term "sustainable development" first came into use in the report "Our Common Future" from the UN World Commission on Environment and Development (WCED, 1987), which defined it as "meeting the needs of the present without compromising the

ability of future generations to meet their own needs". The report framed much of the debate at the highly publicized UN Commission on Environment and Development conference held in Rio de Janeiro, Brazil in June 1992 - the so-called Rio Summit producing one of the important documents known as Agenda 21, a 450-page "operational plan" for implementing sustainable development in the 21st century (Earth Summit, 1992). Following the Rio Summit, global collaboration was intensified in addressing two major issues: how to strike the right balance between our need to develop and improve human quality of life and the imperative to preserve the environment; and, how we can achieve the goal of sustainable development.

Without doubt, engineers will be the central players in deciding success or failure in the pursuit of sustainable development. Amongst the important aspects to look at are the development of efficient energy use through conservation and replacement with renewable energy sources, waste minimization and pollution prevention, adopting recycling strategies, more widespread environmental assessments employing holistic life-cycle assessment and better management of natural resources.

Impact on the Engineering Community

Reformulating and reviewing the engineering curriculum to include sustainability is essential. All engineering graduates should be environmentally conscious and not just knowledgeable about end-of-the-pipeline issues. They need to be taught to view environmental impact and compatibility as part of the decision process and in a holistic manner. In the engineering community, a number of world engineering bodies such as the World Federation of Engineering Organizations, the International Federation of Consulting Engineers and other groups have continued policy-formulating activities on the issue of achieving sustainable development (Ministry of Environment, 1990).

Examples of the action principles to guide the role of the engineer in sustainable development include the call on engineers to become more engaged in shaping decisions, educate themselves and the rest of society on sustainable development, consider systematically the aggregate consequences of decisions and alternatives, help develop new environmental-economic measures and analyses, create and adapt sustainable technologies and processes, and pursue expanded multidisciplinary partnerships.

For engineers, implementing the concept will involve changing their mind-set, whereby they will practise their profession with an additional ethical component. The practice of engineering over the past years requires engineering to the protection of public safety as a goal integrated into every discipline. Subsequently engineering's future goal would have to integrate the principles of sustainability, so that an engineer would have to design not only a safe and cost effective project, but also a sustainable one.

The Importance of Environmental Education in Engineering Curriculum Reform

As we find ourselves entangled in the diversity of environmental crises and their technical and political intricacies, many underlying concerns are likely to escape our serious attention. In many cases, these are the truly fundamental details leading to the apparent problems which can only be discovered following a thorough and neutral analysis of the problems. Unless the roots of the enigma are identified and treated, the journey to sustainability would face obstacles (Amlir & Megat, 1999).

Concerted effort in improving and reforming the engineering curriculum would enhance local and global efforts in producing engineers committed towards achieving sustainable development. However, promoting environmental education in engineering curriculum reform requires a stronger incorporation of the matter in the curriculum to succeed. Thus, the engineering curriculum should be reformed to include a clear and consistent definition of the required outcome of environmental implications in engineering education (UNESCO, 1978). Environmental education should be incorporated in the curriculum as a cross-cutting issue, as specific topics under each subject or as a separate subject. The curriculum reform should open up for a more learner-centered/outcome based teaching. The guiding principles agreed for programs in education for sustainable development based upon these goals and objectives emphasize that environmental education should (Tbilisi Intergovernmental Conference, 1977):

- Consider the environment in its totality - natural and built, technological and social (economic, political, cultural-historical, moral, and aesthetic).
- Be a continuous lifelong process, beginning at the preschool level and continuing through all formal and non-formal stages.
- Be interdisciplinary in its approach, drawing on the specific content of each discipline in making possible a holistic and balanced perspective; and
- Examine major environmental issues from local, national, regional and international points of view so that students receive insights into environmental conditions in different geographical conditions.

Incorporating Sustainable Development into the Curriculum

Sustainable development requires a broader view of environmental issues, ensuring that natural resources are sustainable but that necessary development continues to occur. It seeks to ensure that a stronger stand on environmental protection is taken while accomplishing economic growth (Palmer, 1995).

In theory, sustainable development means not using more resources than are renewable. Given that such resources are finite, as the population increases

inevitably we see living standards go down. While sustainable development is a great improvement and a positive first step, however, by itself it is not the ultimate solution. From the engineering standpoint, a sustainable system is one that is either in equilibrium, operating at a steady state, or a system that changes at a rate considered to be acceptable. Models for sustainability should emulate natural ecosystems such as hydrologic, food and climate cycles- "closed loops" that change only very slowly and allow for natural environmental adaptation- in contrast to the "linear approach" humanity has so often taken up (as in Figure 1 and Figure 2).

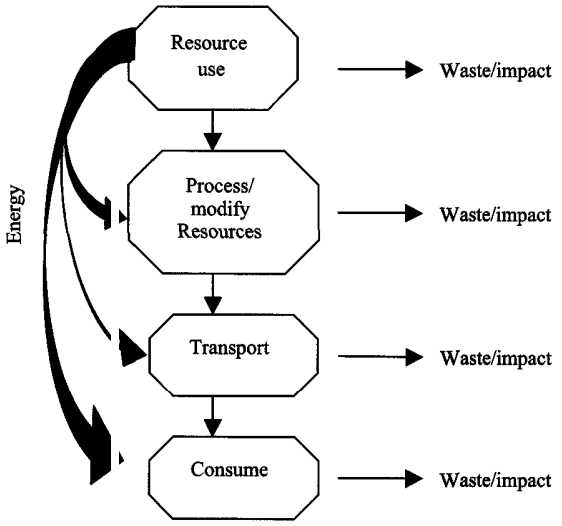

Figure 1: Linear approach

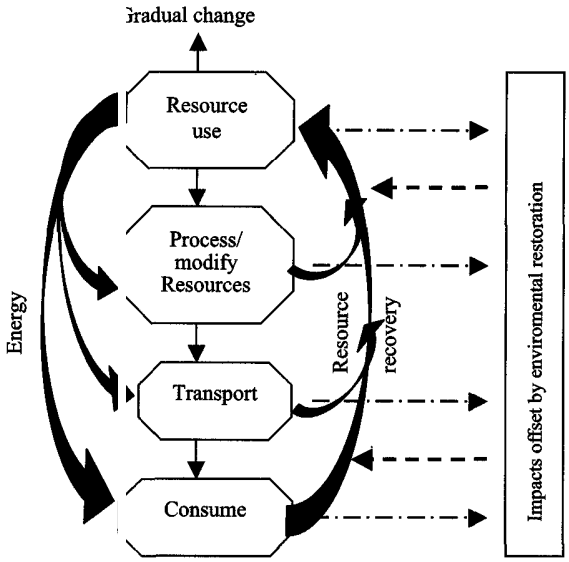

Figure 2: Sustainable system

Reviewing Curriculum Development

In reviewing curriculum development, firstly, there is an essential need for developing the metrics of sustainability. In other words, ways have to be found to evaluate a proposed project or design in totality. Defining sustainability is one of the first goals. Basically defining sustainability involves "global sustainable development metrics" which can provide a basis for social, political, economic and technical discussions relating to sustainability. These tools hence enable integration of environmental and sociopolitical conditions into market economics (Prendergast, 1993). Also needed is a set of "specific sustainable-development metrics" to plan, design, construct and use products and projects. These encompass the complete life cycle of a project, from initial needs assessment through eventual upgrade or project replacement.

Once a methodology is developed, it must be applied in critical sectors: energy, water and transportation/urban development. How long that will take depends on the resources available. There are potential big paybacks in the developing world in terms of increases in potable water and source reduction in the municipal waste pollution stream.

Although education is a critical component, it cannot be limited to the studying period of an engineer. Realistically, it will take a graduating engineer about 15 to 20 years to get into a position of power; hence the focus should also be on practising engineers. Individual engineers need to become more generally informed on social, economic and environmental problems and participate in interdisciplinary and multidisciplinary projects. They should also work and integrate with others, perhaps through worldwide networking programs or capacity building efforts such as assisting developing nations.

Concurrent Integration

An engineer's task in society in this century takes on a much expanded dimension. For example, the mid-twentieth century demanded that engineers choose from two or three aspects of manufacturing: making a product well, making it quickly, and making it inexpensively. In this new century, it is necessary not only to satisfy all three criteria but another two more-making it safely and making it environmentally benign. A new paradigm for making things thus develops: applying intelligence, or cognitive expertise (human or otherwise), across all dimensions of the manufacturing process; integrating across all dimensions concurrently; and diffusing or deploying technology perpetually into the societal infrastructure (ASEE, 1994). Hence this expanded responsibility suggests that tomorrow's engineer will have to be functionally literate across a number of disciplines, not merely well-educated in one.

Engineering now assumes a tighter partnership on the wealth-creation team of an increasingly idea-driven society. The engineering process can be considered as one of five elements which must be integrated concurrently (instead of serially as in the past) in order to innovate effectively and create shared wealth with regard for environmental

fragility. These elements are: scientific inquiry, engineering integration, available technology, economic context and public policy (Froyd & Ohland, 2005).

Thus engineering is essentially an integrative process and engineering education, particularly at the bachelor level, should be designed toward this end. Present undergraduate curricula require students to learn in unconnected pieces, in separate courses whose relationship to each other and to the engineering process are not explained until late in a bachelor education. Current engineering education generally proceeds 'bottom up'. Students study mathematics and science before being 'allowed' to frame an engineering problem, let alone proceed to build anything. Engineering education is usually described in terms of a curriculum designed to present the set of topics engineers 'need to know', leading to the conclusion that an engineering education is simply a collection of courses (Figure 3). The course content may be valuable but this view of engineering education ignores the need for integration which many believe should be at the core of an undergraduate engineering education.

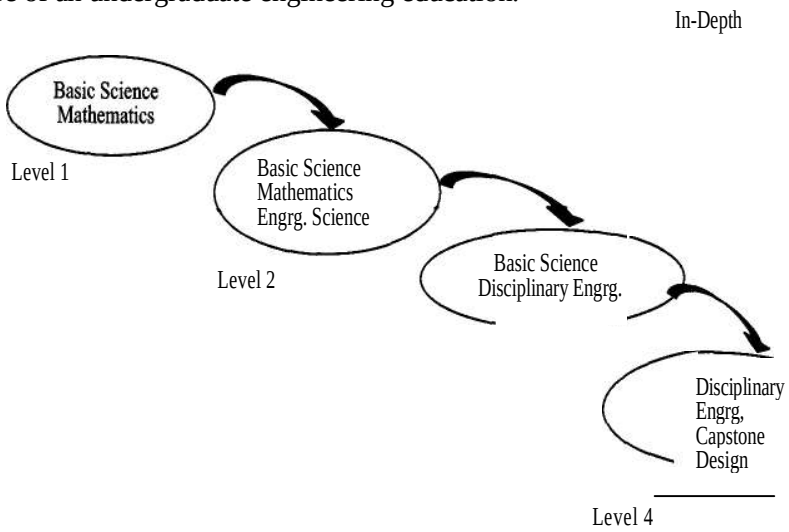

Figure 3: The typical sequential engineering curriculum

Table 1 identifies the suggested components of a holistic bachelor engineering education.

The tasks are to educate engineering students to understand that creation of knowledge and its integration go hand-in-hand as a framework for organized cultural, intellectual, political and social evolution. The overall objective is to develop functional literacy or lateral depth across elements of engineering education. The concept of lateral depth in this attempt to develop integrative capabilities is in sharp contrast to the in-depth or vertical depth effort needed for good research. For an integrative task, lateral depth is concerned not only with investigating a number of areas in depth, but also developing the connections among them. Both are needed in tackling open-ended problems and opportunities, the kinds of activities engineers usually face as professionals.

Table 1

Suggested Holistic Bachelor Engineering Curriculum for Achieving Sustainable Development

Vertical (in-depth) thinking	Lateral (functional thinking)
Develop order	Correlate chaos
Solve problems	Formulate problems
Develop ideas	Implement ideas
Understand certainty	Handle ambiguity
Abstract learning	Experiential learning
Reductionism	Integration
Analysis	Synthesis
Research	Design/process/manufacture
Independence	Teamwork
Techno-scientific base	Societal context
Engineering science	Functional core of engineering

This context suggests that emphasis on course content must shift to a more comprehensive view focusing on developing human resources and the broader educational experience in which the individual parts are connected and integrated. Using these principles as a base, the task before us is to develop more provocative approaches to engineering education. Thus, a vision of engineering education for the twenty-first century can be based on the notion that the engineer's essential role in organized society is an integrative one, i.e., emphasizing 'construction of the whole'. The primary goals of an engineering education should therefore be to develop, in as individualized a way as possible, certain capabilities in each student (Workshop on Engineering, 1988).

Toward Comprehensive Curriculum Planning

The most significant change in approach in sustainable development addresses advance planning before projects are identified. The various aspects that need to be instigated for comprehensive curriculum planning for a more sustainable engineering education would include:

(i) Integrative capability

The recognition of engineering as an integrative process in which analysis and synthesis are supported with sensitivity to societal need and environmental fragility.

(ii) Analysis capability

The critical thinking that underlies problem definition (modeling, simulation, experimentation, optimization) and derives from an in-depth understanding of the physical, life and mathematical sciences, as well as the humanities and social sciences.

(iii) Innovative and synthesis capability

The creation and elegant implementation of useful systems and products, including their design and manufacture that is least burdening to the environment and society.

(iv) Contextual understanding capability

The appreciation of the economic, industrial and international environment of engineering practice and the ability to provide effective societal leadership

CONCLUSION

Educating for a sustainable future is not so much about a destination as about the process of learning to make decisions that consider the long-term economy, ecology and equity of all communities. Its goal is to build an enduring society. This involves learning how to anticipate the consequences of our actions, envision a sustainable future and create the steps needed to achieve the vision. Individuals and societies will perpetually have to make choices. How those choices are made and the information and ethical discernment used in making them will determine whether our visions of a sustainable future are achieved. Hence the incorporation and re-evaluation of sustainability and conservation values and issues in the formal education curriculum must be realized particularly as there are still opportunities for improvement and development.

Focusing on a value-based education curriculum reform may offer a solution, at least to an extent for achieving sustainable development. Incorporating technical, economic, political and legal realms may be narrowed down to a common root of a holistic, integrated curriculum that reflects worldview and development in totality. While technical knowledge and skills are important, the future engineers have to acquire generic skills to assume leadership and influence in society. Engineers have to learn to be creative and innovative, possess interpersonal, business and management skills and acquire a global outlook. Thus, the breadth of an education in engineering is very important in creating well-rounded engineers (New Straits Times, 2003).

The engineers we produce in this country should be creative and innovative in their approach to design. A model curriculum integrated with sustainable development principles is essential for producing engineering and industry leaders. Even though the journey towards a comprehensive and effective curriculum reform is more often than not a long one, it is worth it, if Malaysia is to achieve sustainability in the long run.

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