Moulding Cutting-Edge Engineers for the Borderless Century: The Constructive Role of the Social Sciences

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Abstract

The rapid pace of technological advancement of the 21st century provides a challenging landscape for engineers. The role of the engineer has seen a significant shift from the more conventional practices towards added responsibilities necessitating new knowledge. Apart from possessing the technical competence, engineers of the 21st century are expected to acquire life-long learning capacity, critical thinking, communication and behavioral skills, business acumen, and solution synthesis ability. Such changes entail a fresh look into existing engineering curriculum to incorporate subjects from the social sciences. The paper discusses Universiti Teknologi PETRONAS efforts to produce well-rounded engineers through the design of a new curriculum to cater for the changing industry needs. The university's academic programs and the associated education delivery methods are looked into. In order to gauge the university's progress, a study was conducted to identify the impact of the academic programs on students' behavioral competencies. The behavioural anchors employed in the study include 'goal and action management abilities', 'people management abilities', and 'analytical reasoning abilities'. Among others results showed that "written communication" and "oral communication" were rated highly by both students and external assessors. Both self and external assessments agree on "quantitative analysis" behavior being low in students. The empirical data from the research is presented as a platform for future research directions.

Keywords: Engineering education; Well-rounded model; Soft skills

1. Introduction

The overwhelming role of science and technology in our everyday lives needs no further elaboration. We are becoming more dependent on technology in our daily and work activities. The on-set of the 21st century offers much more of the same. Society is experiencing an onslaught of new technologies notably in the field of information technology. The rapid pace of technological advancement has led to a changing landscape of our work lives. Institutions and corporations have to reorganize themselves to meet the new challenges of the borderless century. The force of technology is so strong that it is beginning to be the most dominant cultural form. Many countries are trying to harness the power of technology for their economic benefit. Governments, through various institutions and academic establishments, are also encouraging research to be conducted. In fact, it is through the higher education system that the interface between government and science and technology occurs to discover new technologies. Society is presently more conscious of technical change and the effects it has on our lives. Undoubtedly, in many developing nations, technology is regarded as the panacea to growth and development. Technology has greatly contributed to economic modernisation by way of business efficiency and competitiveness. Manufacturing and construction development based on new technologies is crucial for a country to keep afloat in the global market. Engineers of the new century, therefore, require skills and knowledge far beyond the technical competence provided by conventional engineering programs in order to play an effective role in society.

Technology operates in a social setting. The introduction of a new technology demands people to reorganise themselves to suit the technology. In educating and training engineers in a rapidly changing technology driven borderless century we must develop approaches for students to be proactive, versatile, and global in outlook [1]. Also, the engineering students of

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the new millennium must be able to comprehend and solve problems from different dimensions and perspectives requiring a broader knowledge base compared to the conventional engineering paradigm. The engineering curriculum has to be broadened in a manner to include subjects in the social sciences (sociology, psychology, management, business and accounting, communications, languages, culture and humanities) in order to prepare the students for the job market.

2. The Changing Face of Engineering Education

The technological upsurge and its outcome on humanity require us to conduct a critical assessment into the present engineering education curriculum. The world of engineering work has drastically changed with the times. In engineering, team-based learning, problems with open-ended solutions, hands-on projects, business and management knowledge, and communications, are the demands of the day [2]. We are in the heart of a technology revolution far greater than history has ever witnessed. Its impact on the university and engineering instruction is enormous. Rapid change is, for the most part, disconcerting for tertiary education due to out tradition-bound and conservative attitudes. Despite the appearance of the white marker board and the overhead projector as teaching tools, professors have continued to function very much the same as they have piously carried out for decades.

Both students and prospective employers, the major stakeholders in higher education, are exerting their demands on universities. These calls are not confined to the field of engineering alone but also other disciplines. The secondary school students who formed the majority of undergraduates are no longer of the same mould compared to students of former times. The present generation of secondary school students who join the universities grew up with computers and computer games. Many are quite adept at programming even before joining the university. The current age group of students can alter the ending of a computer game depending on how the game is played. Academic programmes and education delivery methods have to be revolutionized in order to cater for the needs of these students and the employers. Despite the challenges, opportunities are abound. The new age of technology has created a great demand for engineers. It has the potential to be an exciting time for engineering education. A wide range of opportunities is available to make the teaching of engineering more challenging and interesting. The future of engineering education lies in emphasising problem solving, communication, change management, and lifelong learning skills [5].

3. The Universiti Teknologi Petronas Model

The hallmark of the Malaysian government's policy pertaining to higher education is the repeated emphasis on science and technology. This is in line with its policy as acknowledged in the Vision 2020 to achieve the status of an industrialised nation. The education policy underscores the country's need to compete economically at the global level. In its quest to remain competitive in the world market, industries and the associated service sectors have to be supplied with skilled labour to ensure that there is an effective and prompt response to changing industrial structures. Apart from reaping the benefits of technology transfer, the academia and research institutions are also encouraged to produce local innovation. The universities, including Universiti Teknologi Petronas, have been charged with a direct and positive role in Malaysia's industrial development in order to respond to rapid global scientific and technological changes and to help meet the government's objective of increasing the share of manufacturing in Malaysia's total output and to move more and more into high-tech, high value-added, information based industries.

3.1 The Well-Rounded Graduate Model

Bearing in mind the critical importance of technology for the industrial development of the country, Malaysia needs technically qualified, well-rounded graduates who can lead the successful development of key industries. The success in key industries is undoubtedly one of the keys to sustained growth and development. In particular, success in a range of technology-driven industries will be vital. Apart from the industries associated with telecommunications, technology plays an increasingly important role in a wide range of industries. This trend towards technology as the basis of sustainability is likely to continue.

Success in these industries will be contingent upon the ability of leaders who can apply and manage the technologies, which underpin the industries. For these leaders, the competence to rapidly grasp the commercial possibilities of a range of new technologies will be more important than deep skills in particular technologies. Moreover, these leaders will require a broad range of skills, not just technical skills. Among other things, they will need to be able to communicate and to harness the energies and talents of Malaysia's broadening base of tertiary-educated workers. Primarily these leaders will

come from engineering backgrounds, although they must be equipped with a set of competencies which differs from those generally associated with engineers. UTP's purpose is to address the need for a new generation of well-rounded engineers.

Admittedly, the 'well-rounded' model is not new and many universities profess a mission of producing well-rounded graduates. However, not all succeed. It takes more than a clear sense of purpose to produce high-quality, well-rounded graduates. In order to succeed, universities must have (and carry out) strategies, which lead to the alignment of processes, organisation, and resources to deliver the desired results. To succeed, UTP must do some things differently to most other universities. It must undertake specific actions to create the strength required to move from the ordinary to a well-rounded outcome.

The well-rounded graduates as defined in UTP consist of seven qualities or attributes. These seven qualities were basically distilled from the stakeholders. Stakeholders of UTP include the government, industry (including PETRONAS), students, academic staff, other universities, and professional associations. The university is deemed successful if it fulfils the balanced needs of its major stakeholders. The seven attributes of the well-rounded graduates are as follows:

1. *Technical competence:* Possessing a fundamental understanding of science and technology; Capable of applying knowledge in real life situations.
2. *Lifetime learning capacity:* Capable of managing their own professional development; Skilled at rapidly developing new competencies in response to changes in their careers and the environment; Inquisitive and creative.
3. *Critical thinking:* Capable of thinking critically about their own and others' proposals; Possessing analytical capabilities.
4. *Behavioural and Communication Skills:* Able to articulate their own thoughts confidently; Able to draw out the thoughts of others. Demonstrates teamwork, leadership, and knowledge sharing.
5. *Business acumen:* Fundamental understanding of and belief in business values, principles, and ethics; Possessing an entrepreneurial spirit; Ability to assess and manage risk.
6. *Practical aptitude:* Ability to operate effectively in real-life operations; Recognition of the value of practical experience in their careers; Committed.
7. *Solution synthesis ability:* Able to understand the issue requiring solution; Able to draw together knowledge from multiple areas to create a practical solution [3].

In a study conducted by Universiti Teknologi Petronas prior to its operation in 1995, it was found that stakeholders are satisfied with the technical competence of graduates from overseas and local universities. However, what were lacking are the other attributes such as solution synthesis ability, practical aptitude, business acumen, communication and behavioural skills, critical thinking and lifetime learning capacity. These six attributes, which are lacking in conventional engineering programmes, can be placed under the social sciences and humanities. In other words, while the graduates are excellent in their technical competencies, the 'soft skills' are glaringly inadequate (Figure 1). In order to achieve its vision, UTP focuses on six critical differentiating strategies. These are i) Academic programmes and education delivery ii) Academic staff iii) R&D iv) Linkages and partnership v) Organisation and management vi) Facilities. However, for the purpose of this paper only Academic Programmes and Education Delivery will be discussed.

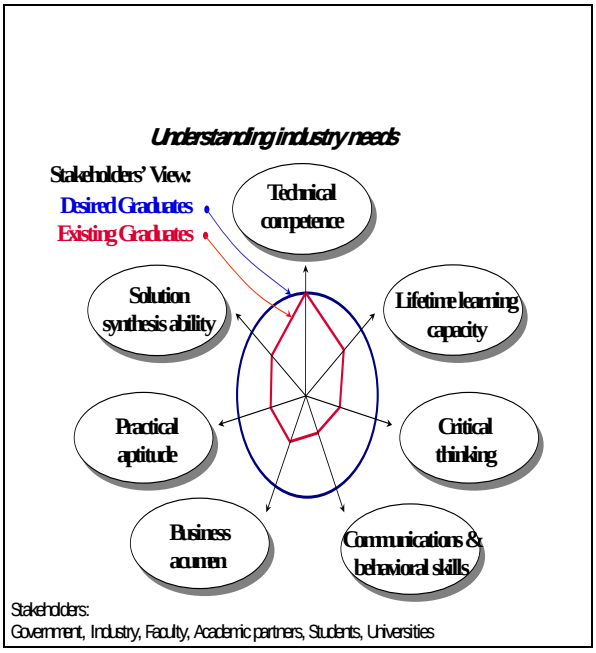

Figure 1. UTP Well-Rounded Graduates Model

3.2 Academic Programmes and Education Delivery

UTP's academic programmes differ from traditional engineering programs to mould well-rounded graduates. Academic programmes are geared toward the development of technical competencies balanced with an understanding of, and an ability to communicate with, the world within which these competencies will be applied. UTP's curriculum includes a range of common and discipline-specific courses to provide a solid, broad

technical grounding for graduates. The curriculum includes a balanced mix of social science and humanities courses, thereby helping to develop a wide range of qualities among students.

Four modes of learning are utilized to create a learning environment, which closely resembles the world of work. New education delivery techniques is utilized to accelerate learning in a conducive environment and to support continuous learning. UTP's academic programmes consist of a common spine and degree-specific topics, delivered via a changing mix of four modes of learning. The need to implement different modes of delivery to the students is well supported by research. In terms of retention rate, the conventional lecture approach exhibits the lowest level of retention (5%) among students. Reading accounts for 10% retention while audio-visual chalked 20% retention. Demonstration, discussion groups, and practice by doing accounts for 30%, 50% and 75% respectively. The highest retention rate of 80% is through teaching others/ immediate use of knowledge gained.

Programme changes includes the introduction of more non-technical topics, broaden the base of technical knowledge, introduce modes of learning akin to the work environment, and the application of new educational delivery techniques. Currently, approximately 20% of the curriculum is non-technical in nature. Taken over a period of five years (One year Foundation and four-year degree) the courses in the humanities include those providing essential skills such as Critical thinking and Writing Skills. From the social sciences and liberal arts courses include Technology, Society and Development, Cultural Anthropology, Economics, Finance and Accounting, Management, Organizational Behaviour and others. Apart from these academic courses, co-curricular courses emphasising non-technical aspects are also offered to students. These courses include Dance and Movement, Peer Group Counselling, Sports Science, Modern Music, Drama and Theatre, Recreation and Adventure, Traditional Music and a whole host of other courses.

In terms of modes of learning noted earlier, there is a shift from the traditional single topic, formal/ rote learning and individual learning model towards multiple topics taught simultaneously within a practical or project framework and a mix of individual and team-based learning. Undergraduates' learning experience consists of a changing mix of the four modes of learning [3]. The four modes of learning currently employed in UTP are:

1. *Formal:* Face-to-face teaching/ lectures.
2. *Independent:* Tasks undertaken by students on an individual basis and unscheduled so that students have to set their own goals and manage their own time.
3. *Project:* Tasks undertaken by students in groups where they learn teamwork and how to manage group responsibilities in a project.
4. *Practice:* Tasks undertaken by students in an operating industry setting with work jointly supervised by university and industry staff.

It should also be noted here that wherever possible, topics would be integrated to create courses that encourage simultaneous learning of theory, practice and synthesis. In many traditional engineering schools, the supporting disciplines of mathematics, physics, computer science, etc., are taught in isolation of the engineering topics that require that knowledge. More effective learning by students can be achieved by introduction of the knowledge from the supporting discipline concurrent with the engineering application. Modern delivery technologies makes this "just in time" approach much easier to organize.

4. Pilot Study: Quantitative Evaluation of Students' Behaviours (QUEST)

In order to gauge and monitor the university's progress in producing the well-rounded graduates a pilot study was conducted in 2001 to serve as feedback to the university [4]. The study known as QUEST was based on the "well-rounded" model developed by Prof. Richard Boyatzis for the Weatherhead School of Management. The objective of the study is to identify the behaviour profile of UTP graduates against the "well-rounded graduate model" as developed in the UTP Master Plan. This study is also an initiative to identify the impact of UTP's academic programs on its students' behavioural competencies, which are exemplified through the 'soft skill' areas. The mission of UTP, based on its Master Plan, is "to produce well-rounded graduates who are creative and innovative with the potential to become leaders of industry and the nation". Additionally, UTP aims "to nurture creativity and innovation and expand the frontiers of technology and education for the betterment of society". The Behavioural Anchors of the Boyatzis Model are as follows:

1. *Goal and Action Management Abilities*
   a. Efficiency Orientation
   b. Planning
   c. Initiative
   d. Attention to Detail
   e. Self-control

f. Flexibility

2. *People Management Abilities*
   a. Empathy
   b. Persuasiveness
   c. Networking
   d. Negotiating
   e. Self-Confidence
   f. Group Management
   g. Developing Others
   h. Oral Communication

3. *Analytical Reasoning Abilities*
   a. Use of Concepts
   b. Systems Thinking
   c. Pattern Recognition
   d. Using Technology
   e. Quantitative Analysis
   f. Social Objectivity
   g. Written Communication

4.1 Method

Basically, the study involves the use of the questionnaire designed by Boyatzis to assess UTP students' specific behaviours. It contains the 21 behavioural anchors categorized under the three broad groups. Five (5) levels of ratings were used, 0="Not Shown", behaviour not seen, or no opportunity to show it; 1="Seldom", behaviour seldom shown; 2="Occasionally", behaviour occasionally shown; 3="Often", behaviour frequently/ most of the time shown; 4="Consistently", behaviour consistently/ always shown. Questionnaires were distributed to students to assess self (i.e., self-assessment) and to lecturers and Industrial Training Supervisors to assess graduated students (i.e., external assessment). Students assessed were UTP 'Pioneer' 2001 graduates (n=143; 94% of population); on self and by lecturers and industrial training supervisors. UTP 2001 entry students (n=348; 90% of population); on self-only. Assumption based on 'cross sectional' method. Entering students 2001's qualities are similar to graduating students' when they first entered. This assumption is substantiated by the fact that UTP did not change the criteria or standards of acceptance.

It is admitted the Boyatzis model through its 21 behavioural anchors is not a perfect fit to the UTP 'well-rounded' attributes. However, it does support most of the attributes. It can serve as an indicator for well roundedness even though a specialised or customised questionnaire to capture the UTP attributes would be ideal.

4.2 Interpretation of Findings

As illustrated in Figure 2, the high ratings on self by graduating students may suggest some true development or cognitive dissonance. Cognitive dissonance occurs when people try to rationalise certain outcomes to specific purpose or efforts undertaken. For example, "spent so much time, effort, and money, so must be learning and changing". Accordingly, the progression in behavioural pattern from Entering to Graduating students may suggest true development. However, at this juncture, we cannot say for certain whether this development can be ascribed to the program or to 'natural development'. The fact that these patterns are similar in shape may suggest the latter than the former. It is interesting to note that both Entering and Graduating students thought that "Quantitative Analysis" competency is of their lowest "skill". There may be a need to revisit this competency to ascertain this because the general belief is that this competency is the most exercised in current education system.

The significant difference in perspective between 'self' and 'others' shows that we cannot depend solely on self-assessments to describe the students' behaviours. Not only do the external assessments provide a lower rating on the students, they also provide a different behavioural pattern, one that is less 'rounded' (see Figure 3).

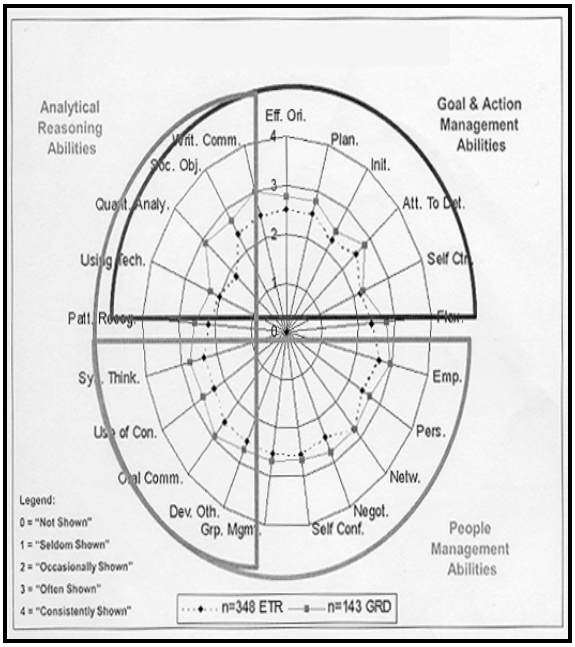

Figure 2. Entering 2001 vs. Graduating 2001

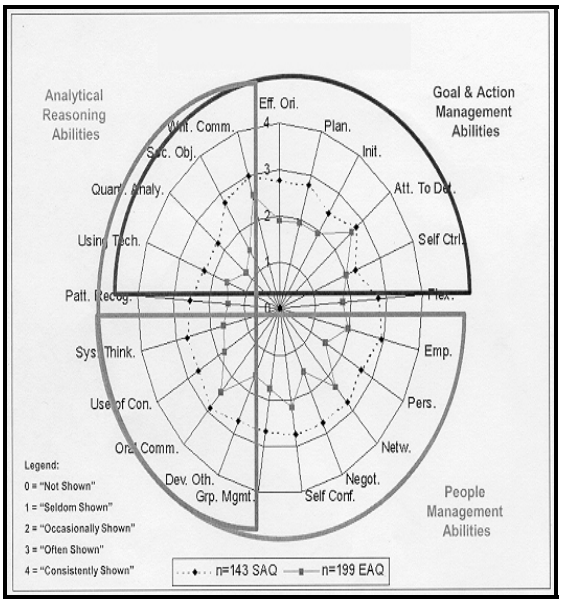

Figure 3. Graduating 2001 – SAQ vs. EAQ

The fact that "Written Communication" and "Oral Communication" is the top rated behaviours by both 'self' and 'others' shows some consistency between the two groups. It also follows from the general belief that the current educational system focuses on these skills through report writing and presentations. The question to ask is how profound these reports are and this would depend on other 'analytical' factors, which, based on the results, are not really high. Consequently, both self and external assessments agree on "Quantitative Analysis" behaviour being low in students.

5. Conclusion

The changing technological and societal scenarios of the 21st century requires new approaches to university level teaching and demands new ways of thinking. In training engineers for the 21st century UTP has taken steps to combine the strengths of a variety of disciplines embracing the technical, social sciences, humanities and the liberal arts to produce well-rounded graduates. Engineers will be better equipped if they recognize fully that they work within and for society. The changing global scenario also demands academicians to change their mind set to meet the new challenges in providing a broad-based, innovative curriculum to produce the well-rounded graduates.

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