Mechanical Engineering Education and Its Challenges

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Abstract. The paper addresses historical development in Engineering Education in the country, its evolution till present day efforts toward the formation of Professional Engineers (PE). Of particular interest is the proposed recognition of more than one pathways towards PE Certification amongst member countries of the International Engineering Alliance (IEA). However, Engineering Education of Gen Y poses challenges at maintaining relevant benchmarks at the basic degree level. The widespread use of sophisticated software for simulation work in any undergraduate programme has its sacrifices with respect to emphasis on depth of knowledge. A definite mismatch between what is perceived by the educators and the actual performance of graduates had been identified in a forum and an employment survey conducted by the Institution of Engineers Malaysia (IEM). Suggestions as to how this can be addressed include the setting up of a Board of Educators to regulate the education industry.

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1. Introduction

Earning an Accredited Engineering degree is one of the assured pathways towards professional registration as a Professional Engineer [1] in Malaysia. Whilst the option rests with the individual engineering graduate as to pursue this pathway or otherwise, the subsequent postgraduate work-experience defines whether one is up to the mark to be certified or not. Redmill F [2] presented a paper on strategic perspectives on engineering education focussing mainly on aims of curriculum in targeting the kind of graduates and hence professionals for the professing. The paper had its weaknesses in that the strategy should also focus on the educators and the relevant skills they need to have so that the graduates have a chance to start with.

At the recent IEA meeting in New Zealand, Katy Turff [3] from the Engineering Council of United Kingdom (UK) shared with those attending the meeting the good practice in competence-based registration of professional engineer. Her presentations included both academic pathways as well as non-academic pathways in the development of professional engineers. Development of engineering education in UK is quite innovative to the extent that one is sometimes at a complete loss as to which is the best pathway to follow. Recognition of the diversity of students some of whom are not academically inclined, dreamers, late bloomers to the academically brilliant ones is the way forward in strategising any curriculum. The knowledge profile for Graduate entry to the UK engineers register may follow one of two discernible pathways. These are via formal programme or via a series of informal on the job learning.

Knight J et al.[4] highlighted a professional pathway for UK students who would like an accelerated entry into the workplace for allied professions. Rather than attending full time study the computing students are permitted to sit for the same exam but attending classes one day a week having successfully completed the first year of the course. This philosophy is well reflected amongst university entry requirement in New Zealand where for certain courses a good command of English (IELTS score exceeding 6.5) is sufficient.[5] The graduate should be able to undertake a journey of discovery albeit under guidance and close monitoring of the mentor.

The historical development of Engineering Education in United States of America is well documented by Mark and Buchanan [6] highlighting the central role played by American Society for Engineering Education over the past 120 years. It started with the Morrill Act 1862 also known as the Land Grant College Act and the subsequent numerous engineering schools set up are broadly classified into one of two camps namely the school culture which stressed on theoretical education and the shop culture which stressed on hands on learning in the laboratory. Further reforms saw the setting up of a body known as the Engineering Council for Professional Development which evolved to become the present Accreditation Board for Engineering and Technology (ABET).

This year the Institution of Professional Engineers New Zealand (IPENZ) celebrated its Centenary (1914-2014). Formal engineering education has similarly evolved from technical education along similar route as the USA with early Learned Engineering societies similarly evolving into the present form of an IPENZ. [7]. The Engineering Council of South Africa (ECSA) is a statutory body set up under the auspicious of the country’s Engineering Profession Act (2000). Its core functions are the accreditation of engineering programmes, registration of persons as professionals in specified categories and the regulation of the practice of registered persons. [8]

In Malaysia perhaps one of the more comprehensive summary of development in Engineering Education is by TT Chiam [9] who traced the foundation for education in Malaysia began with the founding of three trust-english-medium schools namely Penang Free School in 1816, Singapore Free School (renamed Raffles Institution) in 1823 and the Malacca Free School (renamed Malacca
High School) in 1836. After the Second World War, the establishment of Technical College in 1949 provided an opportunity for Malaysians to obtain sub-professional technical education locally. The original University of Malaya was established in Singapore in 1949 and with it the Department of Engineering formed in 1955 within the Faculty of Science. A Faculty of Engineering was established in Kuala Lumpur in 1958 and UM was divided into two divisions, one in Singapore and the other in Kuala Lumpur. The UM in Singapore evolved to be present day National University of Singapore whilst that in Kuala Lumpur remained as University of Malaya.

Megat et al [10] traced the beginning of formal 4 year engineering education in the country offered by major Public Universities and the subsequent reduction to 3 years instead of 4 in 1966 since universities in the United Kingdom were doing just that with the same entry qualifications. The system at UM then was still a 3 term system in a full academic year although Institute Teknologi MARA (presently Universiti Teknologi MARA) conducted a three year Diploma programme with those attaining good grades proceed to the Advanced Diploma programme for an additional two and a half years. The entry qualification to this programme was at the SPM level and was accredited initially by The Institution of Engineers on a regular 5 yearly basis. The desire to establish a suitable basis for 3 or 4 years education led to the Institution of Engineers Malaysia hosting of a forum during the Presidency of Dr Ting Wen Hui [11] to decide on the appropriate equivalent credit hours of engineering and non engineering studies needed for an engineering graduation. The main reason for this development was that whilst the oldest university still runs a 3 term per academic year programme, most of the other government sponsored universities have migrated to the American Semester based system.

Although Institut Teknologi MARA (ITM) was amongst the earliest institutions to introduce the semester system in the country in 1976 by dividing the 8 subjects per academic year into 4 each for each of the semester (half year) programme, the ongoing discussions then did not affect ITM as it run a two-tier system and maintained as such until the institution changed its status to that of a University at the turn of the century. The IEM forum resulted in general agreement that at least 120 credit hours of study with at least 80 hours for engineering subjects for graduating engineering students would be sufficient to be equated to the 3 term one academic year system but no timeline was set for the duration for the study which is normally completed comfortably within 4 years.

In the 90s numerous private colleges offered twinning-type engineering degree programmes with established overseas universities. The initial setup of the National Accreditation Board (LAN) in the 90s and its subsequent migration to Malaysian Qualifications Agency (MQA) presently led to the widespread upgrade of private colleges and the promulgation of private universities beginning with the three industry led giants namely Universiti Tenaga Nasional (UNITEN), Multimedia University (MMU) and Universiti Teknologi PETRONAS (UTP). Accreditation of programmes were conducted by LAN for private Institution of Higher Learnings (IHLs) only but the then accreditation conducted jointly by BEM and IEM continued with appropriate representation from LAN and the Public Services Department (JPA). The joint committee is the start of the Engineering Accreditation Council (EAC) which subsequently saw the inclusion of stakeholders such Malaysian Council of Engineering Deans (MCED) and additional engineers from the industry. Numerous innovations were introduced by the Engineering Education industry and this lead to widespread development in engineering education.

2. Educational preparation
Under the present educational system, varsity entrants are supposed to be equipped with the depth and breadth of physical and mathematical sciences. Any inadequacies at the preparatory level shall have to be addressed at the university level in order to maintain benchmarks. The
semester system of education permits such corrections by allowing candidates to repeat and re-
sit the subjects for which they have yet to achieve the required benchmark.

**Where does the education process begin? At Home? At the Kindergarten? During Primary Education? Lower Secondary?, Upper Secondary? Finally, at the Universities and Colleges? Continual Education till the day we drop dead?**

Let us begin with education at home. I would like to share an experience which I had with a granddaughter. Her mum decided to raise her with lots of Positives rather than Negatives. Words like “Cannot”, “Don’t”, “No” etc. are banned from our dictionary when replying the little girl at her formative ages less than 5 years. It takes quite a transformation within the family to cope with such a change. Adults have to innovate for appropriate responses to questions and along with the innovative responses, the child is observed to be equally innovative in her subsequent actions. When this pathway is reinforced at the Kindergarten school and subsequent Primary, Secondary and Tertiary levels, one certainly makes learning interesting and educational activity fill with innovative responses. Unfortunately somewhere along this journey more than one word of “NO” shall contribute towards derailing the entire spirit and perhaps put off any further interest in whatever the subject may be.

We have witnessed the traditional methods of teaching science and mathematics shifting gradually from prescriptive to student-centred learning at schools and universities with evaluation focussing on use of tools rather than hard memories of multipliers etc. to the extent that one uses a calculator to do simple multiplications for an answer. What is the significance of this development? A lack of mental arithmetic or lack of depth of fundamentals and how it works? Naturally there are lots of arguments for this “natural” development because we now use IT tools in a digital world. Even the English language as we know it is transformed by Short Message Services (SMSes) to a “sound” version such as C U B4 6 etc. There is a clear difference in the SMSes between a Traditionist (born between 1922-45), the Baby Boomers generation (40s-50s), X-generation (60s-70s) and Y-Generation (80s-90s) as we know it. A consequence of Y-Gen is that more information can be stored and made available to the user at any instant but the negative side of this is the lack of basic understanding of fundamentals at all levels for the average student.

### 3. Mechanical engineering crossroads

Peck Cho [12] commented that the arrival of the information age at the turn of the century saw a paradigm shift which changed all aspects of education. These changes were with respect to Access, Certification, Content and Organisation. The same time, same age and same place educational window can shift to any time, anyone, any place manifested in the form of Continuing Education, Distance Education and a Learning Society. With regards to Certification, rather than treating an accumulation of sufficient credits and grade points, the shift has been towards assessment of acquisition of specific skill sets such as those in an OBE system. A corresponding shift in acquiring (static) knowledge which can be cumulative, permanent, transmitted and cognitive towards information (dynamic) which is transient, transitive, transacted and affective. A manifestation of these development is the student-centred learning (SCLs), problem-based (PBLs) teaching and lifelong learning which we hear today.

Traditional curriculum which addresses 5 out of 11 Programme Outcomes (POs) of the original ABET Engineering Criteria 2000 had left out the remaining six which focussed on “soft” skills etc. Present day driving forces from the industry require emphasis of soft skills amongst graduating engineering students under a false assumption that the core skills are not compromised. Together with proliferation in specialisation within each subject matter, the task
of identifying what is really needed and what is irrelevant has become more formidable. It is also worthwhile to note that a Mechatronic programme is neither Mechanical nor Electronic but an integration of certain elements from each added to it the Assembly level software programming skills.

Recent development with Washington Accord graduate attributes speak volumes about what skills an engineering graduate should have. When it comes to registration of engineers with the Board of Engineers Malaysia (BEM), therein lies the frequent debate of what e.g. an Electrical Engineer does and must acquire in the formative years, etc. Whether the industrial development in this country is ready to employ e.g. Mechatronic graduates is another subject for debate. How about Mechanical Precision Engineering Programme and the list of options is never ending. The main purpose for accreditation of engineering programme within Washington Accord or IEA Signatories is to maintain some sense of Substantial Equivalence (yet to be defined since its inception). As an example, Engineers Canada defined “Substantial Equivalency” to mean comparable in program content and educational experience. It therefore implies reasonable confidence that the graduates possess the academic competencies needed to begin a professional practice at the entry level but such programmes may not be absolutely identical. Taking it one step further, is there a need to BEM to register all disciplines of engineering? Perhaps Singapore PE board has got it right by registering those disciplines whose work has direct impact upon safety of the Public.

Presently the EAC 2012 Manual [13] spells out clearly the core subjects required for a programme to be classified under the Mechanical Discipline. These are reproduced here in Appendix. The question is how do we establish/measure or have an inkling of the amount of emphasis given to understanding of fundamentals underpinning the formation of a mechanical engineering graduate even with the form of accreditation exercise we now conduct. I do feel that the examples of the types of courses listed in the Appendix should be reanalysed only for core requirement for the registration of Mechanical Engineers whose work affected public safety. Stifling further evolution and innovation in development of any programme shall severely handicap graduates in facing future technological challenges.

The accreditation process conducted is largely a peer review process dependent upon the calibre of peer reviewers as well as the time available to do a simple audit. The proof of employability is with the market which the next section shall address. The specifications for relevant must-have-ingredients are listed in an accreditation manual hosted by the BEM. It is done not only for the Mechanical discipline but also Electrical, Civil, Chemical and Electronic Engineering disciplines and implies the need to define an overall basic core knowledge for those disciplines whose subsequent work has an impact upon public safety. Are these “requirement” restrictive towards meeting future market needs? Can we afford to move forward without such a mechanism? The answer may be both yes and no.

4. Technological challenges
Do the core competencies spelt out in Appendix for Mechanical engineering programme adequately prepare graduates to meet current challenges? At a recent meeting of HVAC engineers in Seattle, USA, a Technical Plenary presentation by Dennis Hayes [14] which entitled a building which lives like a tree indicated the possible options presently day technology could provide. Short of producing the much desired oxygen for the atmosphere, this building has most of the functions of a tree producing net positive energy overall. Do we have an energy crisis if all buildings are designed and built to such functions? Certainly the role of learned societies such as ASHRAE and the development of its Codes and Standards which focuses towards Net Zero Energy building would soon be replaced by towards net positive outcomes.

Another development which has yet to make a future impact is the magnetically levitated shaft using advanced magnetic bearing in a 800-TonsR HFC 134A compressor as highlighted by M.S Jeng [15]. The only shortcoming reported is its extra cost of 30% more than conventional bearings. Self-centering within a 200 microns air gap at all speeds and loads, it is truly a bearing of the future with minimal friction and hence better energy efficiency. One cannot help speculating further when such bearings are the norm for all road vehicles in the near future.

There is price to be paid in the supply of such products in that the Total Equivalent Energy consumed (TEE) in producing it from scratch must be tagged on at some stage. Whilst Global Warming issues have placed the blame on some green house gases such as carbon-dioxide, there are however contradictory arguments by R I Nigmatulin [16] towards this in that historically the planet has undergone cycles of global warming and cooling with or without the corresponding increases of CO2. Perhaps a greater source of basic heat, greenhouse gas, moisture and flux for the atmosphere is the ocean which has a heat capacity 1000 times that of the atmosphere and a mass 270 times as great.

Bill Coad, [17] even predicted the use of a Seasonal Ferris-wheel to overcome the cooling/heating needs globally across the tropics. The then available technology was simply too expensive to be implemented. Nevertheless use of Solar Panels and other Green Technologies (GT) should also consider the incorporation of TEEs and carbon footprints into their computation. A possible future direction for GT is to utilise energy supply at source rather than to first having to convert to electricity the process of which does not exceed 33% efficiency, burning coal or oil at source. New materials such as development of Metal Organic Framework (MOF) sponge [15] for hydrogen gas at low pressure when successful shall see more widespread use of hydrogen-fuel-PEM fuel cell powered vehicles and the brand new Hydrogen Economy albeit that in certain European countries H2 refilling stations have already been set up. With the limited resources of platinum and other metals needed for such an economy to be sustainable, a system of recycling and reuse has to be in place at the onset for it to be successful. There is a need to define adequate fundamentals in the education of Mechanical Engineering graduates for them to address these and other future technological challenges.

5. Role of learned societies
The Institution of Engineers Malaysia (IEM) hosted a National Forum on Benchmarking the Quality of Engineers on 16 January 2012 in which various stakeholders such as academics, industry practitioners, employers of engineers as well as regulatory bodies attended the forum. Several examples were cited with regards to the low standard or quality of graduate engineers entering the industry such as:
(i) Graduates with CGPA 3.5 and above were severely handicapped at drawing bending moment diagrams and shear force diagrams (in the Civil Discipline).

(ii) Electrical engineers cannot explain why birds standing on live wires are not electrocuted.

(iii) Poor understanding of design fundamentals

(iv) Mistakes in design calculations

(v) Lack of engineering knowledge

(vi) Unfamiliar with the basic codes of design

(vii) Not able to apply engineering knowledge

The consensus reached at the end of the forum was that:

(i) There is a need to raise the standard of engineering graduates.

(ii) Schools need to improve on the education delivery system to ensure quality students enter universities (some term it as “unfit” for industry and “untrainable”).

(iii) Institutions of Higher Learning (IHLs) to engage more practicing engineers to teach while lecturers should gain more industrial experience.

Arising from the forum, IEM established a Task Force on 3 December 2012 to prepare a Position Paper on this matter. The first task undertaken was to commission an Employer’s Survey targeted at engineers who are most likely in positions capable of judging the quality of fresh graduates, i.e. those of 35 years of age or older. Results from the survey shall be duly reported in the Position Document to be issued in the near future. The IEM survey points out clearly to the lack of DESIRED OUTCOMES of recent graduates. Private communications with IEM volunteers indicated that young graduates are not able to approach the design of taller buildings as he/she was trained to do a 4 storey only and vice versa. This brings up the question of whether are we conducting Educational or merely Training activities at those IHLs?

The IEM survey results further reinforced the fact that a kind of decoupling exist between education providers on measured and perceived outcomes which do not meet the desired outcomes of employers. Perhaps a fresh survey on desired outcomes of graduates should be undertaken so as to close the loop as discussed by certain accreditation panels during the exit meeting.

As an educator from yesteryear, I do perceive one commonality in that we do not produce graduates to meet the needs of any specific industry but to equip him/her with adequate academic competencies and interpersonal skills to face the “real” world. This is a tall order to achieve when the students who entered varsity also lacks the depth in analytical skills needed to solve science and mathematics problems. At the school level the over indulgence of “exam-knowledge” has led to a culture of “how to answer” examination questions rather than the inquisitive “why this is so” as commented by D Rahman [18]. Much has been written about the country’s educational blueprints, nevertheless, the important factor is the quality of an education delivered and acquired as perceived in the plans.

6. Changing landscapes and complex engineering problems

Does accreditation of engineering programmes guarantee quality? Similarly does the presence of an ISO Quality System assure confidence? How are our future lecturers tenured? The requirement of the 2012 Engineering Accreditation Manual for greater emphasis on Complex Engineering Problems as defined in Appendix has been debated and continually improved upon at International Engineering Alliance (IEA) meetings. However they do not guarantee that graduates meet the desired results from the above survey. Perhaps the inherent weakness
within the process has not been truly addressed. At a recent IEA meeting in Wellington, complex engineering problems involving current research issues faced difficulties in defining boundary conditions for the students to solve. The definition of complex engineering problems is clearly spelt out in Appendix. However to come up with such problems in undergraduate studies requires much thought and may also be a function of the amount of industrial exposure one has with real problems which are non routine in nature and job specific. This reminds me of a conversation with a past principal of Ngee Ann Polytechnic in Singapore in which he insisted that a guarantee for employment be made by each of his staff for the graduates of any new programme being proposed by them. This may be out of the norm but that is the crux of the issue, are we producing unemployment with some mandatory survey conducted as a matter of routine to establish needs for a new program?

The Peer Review Process carried out during Accreditation Exercises is dependent upon the Peer Benchmark which is predominantly transient. The IEM survey results clearly pointed out to a probable FAILed (First Attempt In Learning) system as it stands. Civil Engineers knows well the need to accurately determine platform levels based on the Ordinance Datum Level (ODLs). On a similar note, how can we benchmark graduate outcomes, based on the multitude of PBLs, Student-Centred Learning etc, in a system of marks which are given in-house albeit objectively and subjectively? Can the commercialisation of education such as the setting up of private IHLs help to sustain benchmarks? Where are the conflict of interests? Can we afford to let market forces of demand and supply determine the quality of Mechanical Engineering Graduates?

I am impressed by the present day practices of Continuous Quality Improvement (CQI) embedded within an Outcome Based Education (OBE) in which we defined clearly the Learning Outcomes and Course Outcomes which we plan to deliver with all the necessary measurements in place. Reflecting upon the IEM Employers feedback result, one wonders whether we have missed something important in the entire exercise. Perhaps an independent method of assessment is needed across all educational providers so as to maintain benchmark. Is this too difficult a call to make?

Is there a need for a Board of Educators to be set up along the lines of BEM, ensuring ethics and accountability amongst the educators/teachers? An established scheme for the development of educators so that they are professionally qualified to provide the right type of education is equally important in addition to the OBE system. Most of all is the availability of an avenue for the public to raise appropriate concerns/issues with education- providers if there is proof of negligence anywhere. At the school level is it ethical for a teacher to provide tuition classes to the same students after school?

7. Crisis and choices

Perhaps the country could look beyond Washington Accord Signatory in setting suitable benchmarks. A scheme for the tenure and continuous professional development of engineering educators is needed. Engineers Canada may have got it right in that all of the academics who teach an accredited engineering programme are Professional Engineers by registration. In such a structure, a platform is available to define and maintain benchmarks within a profession of ethical practices. Are good researchers also great educators and vice versa? How can we guarantee quality of deliverer as this is the most basic requirement for any OBE to be successful albeit with the current system well establish. Staring at the past, whatever the type of education system proposed, we need to educate graduates who are able to contribute to society via moving with the current technology and well equipped with all the relevant soft and hard (fundaments) skills.
Simply stated, it should never be a difficult task to achieve and shall not be too in the future. Use of software in design and simulations at the undergraduate level demands a good understanding of the underlying principles which govern the use of such IT tools, their limitations and mathematical limitations.

8. Conclusions
More questions than answers have been raised in this paper. A kind of decoupling seems to be present between perceived graduate attributes achieved and those desired by the industry. Even with and OBE system with CQI in-placed as required by the Accrediting Body, engineering education in the country has yet to satisfy industrial needs with respect to graduate competencies and skills. A Board for regulating Educators is proposed to assure ethical standards in place for the continual development of engineering educators. The survey results from amongst employers conducted by IEM is an eye opener to many education providers in that a mismatch do exist between what an employer sought and what is produced. Whilst there is a need to provide emphasis on appropriate fundamentals the regulatory framework in place must not stifle innovations to produce graduates who are able to face future technological challenges.

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APPENDIX

ENGINEERING CONTENT FOR SELECTED ENGINEERING DISCIPLINES AND INNOVATIVE PROGRAMMES

(a) Engineering Sciences, Principles, and Applications

An accredited programme is expected to cover the broad areas of the respective disciplines at an appropriate level. The following are examples of underpinning courses that may be introduced for the respective disciplines:

| CIVIL                               | MECHANICAL                                      | ELECTRICAL                      | CHEMICAL                             | ELECTRONICS                      |
|-------------------------------------|-------------------------------------------------|---------------------------------|--------------------------------------|----------------------------------|
| Strength of Materials               | Materials                                       | Circuits and Signals            | Chemical Thermodynamics              | Circuits and Signals             |
| Structural Analysis and Design       | Statics and Dynamics                             | Electro-magnetic Fields and Waves| Material and Energy Balance          | Electro-magnetic Fields and Waves|
| Fluid Mechanics/ Hydraulics          | Fluid Mechanics                                 | Instrumentation and Control     | Chemical Kinetics & Reactor Design   | Instrumentation and Control      |
| Soil Mechanics/ Geotechnical Engineering | Thermodynamics and Heat Transfer | Digital and Analog Electronics | Momentum Transfer                     | Digital and Analog Electronics   |
| Civil Engineering Materials         | Mechanical Design                                | Machines and Drives             | Heat Transfer                        | Microprocessor System            |
| Statics and Dynamics                | Instrumentation and Control                      | Power Electronics               | Mass Transfer                        | Programming Techniques           |

[16] Robert I Nigmatulin, Multiphase and Multiscale in Oceanology, Climatology and Economics, Proc. 14th Asian Congress of Fluid Mechanics- 14th ACFM, Vietnam, Vol 1, pp1, 2013
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Mathematics, Statistics and Computing
These courses should be studied to a level necessary to underpin the engineering courses of the programme and with a bias towards application. The use of numerical methods of solution is encouraged, with an appreciation of the power and limitations of the computer for modelling engineering situations. Wherever practicable, it is preferred that mathematics, statistics and computing are taught in the context of their application to engineering problems and it follows that some mathematical techniques may be learnt within other subjects of the course. In addition to the use of computers as tools for calculation, analysis and data processing, programme should introduce their application in such area as:-

| CIVIL                  | MECHANICAL                  | ELECTRICAL                | CHEMICAL                  | ELECTRONICS                  |
|------------------------|-----------------------------|---------------------------|---------------------------|-----------------------------|
| Computer Aided Analysis and Design | Computer Aided Design and Manufacture | Mathematical Applications | Computer Analysis and Design | Mathematical Applications |
| Economics Analysis for Decision Making | Economics analysis for decision making | Statistical and Numerical techniques | Economics Analysis for Decision Making | Statistical and Numerical techniques |
| Data bases and Information Systems | Data bases and Information Systems | Computer Applications | Numerical Methods and Optimisation | Computer Applications |
| Operational Research | Operational Research | Operational Research | Operational Research | Operational Research |
| Business and Management | On-line Control of Operations and | Databases and | Databases and | Databases and |

(b) Mathematics, Statistics and Computing
These courses should be studied to a level necessary to underpin the engineering courses of the programme and with a bias towards application. The use of numerical methods of solution is encouraged, with an appreciation of the power and limitations of the computer for modelling engineering situations. Wherever practicable, it is preferred that mathematics, statistics and computing are taught in the context of their application to engineering problems and it follows that some mathematical techniques may be learnt within other subjects of the course. In addition to the use of computers as tools for calculation, analysis and data processing, programme should introduce their application in such area as:-
Emphasis on Engineering Applications in degree programmes aims to ensure that all engineering graduates have a sound understanding of up-to-date industrial practice, in particular:

**Civil Engineering:**
- to appreciate the characteristic and structural behaviour of materials in a variety of user environments
- to be able to analyse and design structural components from these materials
- to appreciate the range of construction technology currently available and the skills which they require in people
- to appreciate the cost aspects of material selection, construction methods, operation and maintenance in their interaction with design and the delivery of civil engineering facilities and services
- to understand the whole process of industrial decision-making in design, manufacturing and use and how it must be influenced not only by technical ideas but also by the practical constraints of financial and human resources and by the business and social environment of engineering.

**Mechanical Engineering:**
- to appreciate the characteristic behaviour of materials in a variety of user environments
- to appreciate the range of manufacturing methods currently available and the skills which they require in people
- to appreciate the cost aspects of material selection, manufacturing methods, operation and maintenance in their interaction with design and product marketing
- to understand the whole process of industrial decision-making in design, manufacturing and use and how it must be influenced not only by technical ideas but also by the practical constraints of financial and human resources and by the business and social environment of engineering.

**Electrical and Electronic Engineering:**
- to appreciate the characteristic behaviour of materials in electrical and electronic systems
- to be able to analyse and design electrical and electronic systems from devices/components made of various materials
- to appreciate cost effectiveness of component/device equipment selection, manufacturing process and integration process
- to appreciate the range of manufacturing methods currently available and the skills which they require in people
- to understand the whole process of industrial decision making in design, manufacturing and use and how it must be influenced not only by technical ideas but also by the practical constraints of financial and human resources and by the business and social environment of engineering.

**Chemical Engineering**
to appreciate the characteristic and structural behaviour of materials in a variety of user environments
- to be able to adopt these materials in process design and analysis
- to understand the general sequence of processing steps for any given type of chemical process
- to calculate and analyse the material and energy flows for a given chemical process
- to understand the selection or estimation of process operating conditions, selection of process equipment, maintenance and process troubleshooting
- to analyse the various types of unit operations and processing steps and to decide their relative advantages or disadvantages on the basis of environment, economics, safety and operability
- to understand the various process control schemes for the purpose of maintaining production quality, ensuring process safety and preventing waste.

(d) Evaluating an Innovative Programme
It is a challenge for an accreditation process to promote innovation, experimentation and dissemination of good practice, while maintaining standards that can be objectively certified nationally and internationally. Innovation by its nature challenges existing wisdom, but not every programme that departs from existing norms can be said to be innovative or desirable. All fundamentals required in the programme must be maintained.

The EAC accreditation system encourages innovation by minimising prescriptiveness in how the required outcomes are attained. Programme evaluation will always focus on the intent of the criteria and on the demonstrated capability of graduates to enter engineering practice at a professional level. Clearly however, a programme which departs radically from the methods normally thought necessary – for example, by employing only a fraction of the normal complement of staff – may expect a searching examination of method as well as outcomes. The EAC and the Evaluation Panel are expected to be receptive to new approaches, and to use the best judgement available to evaluate the substance and merit of the programme.

Continuing innovation and development can be expected to lead to restatement of the criteria and policy of accreditation.

(e) Definition of Complex Problem Solving
The range of complex problem solving as required by the Programme Outcomes in Section 4.0 is defined as follows:

| Range of Problem Solving | Attribute | Complex Problems |
|--------------------------|-----------|------------------|
| 1                        | Preamble  | Engineering problems which cannot be resolved without in-depth engineering knowledge, much of which is at, or informed by, the forefront of the professional discipline, and have some or all of the following characteristics: |
| 2                        | Range of conflicting requirements | Involve wide-ranging or conflicting technical, engineering and other issues |
| 3                        | Depth of analysis required | Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models |
| 4                        | Depth of knowledge required | Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach |
| 5                        | Familiarity of issues | Involve infrequently encountered issues |
|   | Extent of applicable codes | Are outside problems encompassed by standards and codes of practice for professional engineering |
|---|---------------------------|----------------------------------------------------------------------------------|
| 7 | Extent of stakeholder involvement and level of conflicting requirements | Involve diverse groups of stakeholders with widely varying needs |
| 8 | Consequences              | Have significant consequences in a range of contexts                               |
| 9 | Interdependence           | Are high level problems including many component parts or sub-problems              |