A Basis for a New Engineering Masters Programme

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Abstract

This paper discusses some background trends and themes as a first step towards an outline for a new international masters of engineering programme. Key aspects of the programme are discussed, prior to the detailed feasibility research and planning phase which is pending funding and partners for implementation.

The perceived need for the programme stems from observations of various factors, not only relating to the core issues of engineering education and the engineering profession, but some wider issues from social, political and economic global trends. Broadly speaking, this points towards a programme with a content of technical, entrepreneurial, managerial and other skill based topics, with students and staff based in at least two universities in at least two continents. Furthermore, the boundaries between industry and academia would be purposely blurred, and include a complex work environment designed to simulate a real professional engineering work culture that is mobile, multidisciplinary, with cross-functional teams centred on the student.

The student would be heavily exposed to entrepreneurial type activities, through consulting on a main project with their industrial sponsor, as well as the possibility of a consultancy role to new potential partners whom they would seek with their supervisor. The core technical content of the main project would be the responsibility of the student, pulling in additional expertise from company and university staff in support of that core and for issues outside that core. The student would be responsible for the overall project management, and their work experience and contact with industrial partners would count towards international professional engineering qualifications.

The programme could serve as a route to senior engineering positions in fast paced multinational organisations, where there is a need to identify special projects, specific short to medium term research and development or opportunities from implementing advances in technology, bringing together project teams, and managing the project from inception to completion.

Introduction

This paper attempts to rationalise some informal personal observations made relating to the typical capabilities of undergraduates during internships and after graduation, the developing needs of employers and the wider community, and possible skills gaps even after higher degrees or other qualifications. It is not based on a comprehensive formal study, as might be expected from industry wide questionnaires, interviews and statistics from mapping the careers of graduates and the effect of further degrees on human resources in the work place. The observations do however come from interaction with multinational industry and chambers of commerce predominantly from Thailand's eastern seaboard industrial region, as well as other academic institutions and NGOs. The intention is to stimulate further comments from an international community as a next step in working towards a more tightly defined masters programme.

Background discussion

The following discusses some key issues that are seen as the current main motivation for developing a new masters programme.

Broadly speaking, undergraduate engineering education is becoming more complex, dynamic and pressured for time. From a scientific perspective, it is more complex considering the educational learning curves becoming steeper and longer in order to bridge high school science and the modern day application or state of the art of engineering and technology without losing any development of skills such as scientific rigour and enquiry. It is more dynamic considering that the modern application or state of the art can change between enrolment and graduation, making it more difficult for an approved undergraduate curriculum to keep up to date. It is more pressured for time because the range of possible and valuable topics and experiences to include in a syllabus is expanding, and it can never be squeezed into the typical timeframe of an undergraduate programme. It is debateable as to what the modern engineer with a first degree should know, or what their skill set should be. Various visions of the future of mechanical engineering education have been put forward [1,2], and seem to share much common ground, such as the need to retain a sound scientific base with the final application rapidly evolving, reinforcement of life-long learning and professional development, globalisation, merging of disciplines and evolution of traditional engineering roles. However, it is arguable that there is a need for an ever wider range of knowledge or skills that no individual graduate can possess, and hence becoming ever more reliant on the overall knowledge and skills of the new graduate population as a whole that emerges each year. The supply and demand relationships require ever closer co-operation between the institutes that receive the graduates and the institutes that produce them. It is suggested that to sacrifice the development of sound reasoning and analytical skills based in a thorough scientific foundation in order to focus ever more strongly on the final application of the science and the tools used in that application, would be a mistake. At some point the system becomes overstretched, and it has to be accepted that with the advance of engineering comes the need for more time to be spent in the education of our future professional engineers. This suggests then, that if a fresh graduate is employed by industry, that there would be an expectation of supporting their continued engineering education through formal mechanisms, and not just by on the job training. To some extent this has been verified by comments from industry that essentially indicate that fresh graduates are rarely able to seamlessly step into a job. Can this expectation be considered realistic these days? However, this seems to be a growing complaint, and not unique to any single country, industrial estate or company. When asked what they want from their new graduate employers, industry can highlight some quite specific skills or a requirement for detailed knowledge of, for example, a particular computer package or some other tool for the job. Comments can sometimes be driven by immediate needs, and it is difficult to meet such short-term needs with formal changes to a syllabus, just in time to produce graduates with those skills.

If it is accepted that graduates will not be up to speed on a wide enough range of technology, they should at least be prepared to go through an initial updating or training session with their new employer, before being let loose in a position of responsibility. Employers may not want students with higher degrees if those degrees do not come with some ability with a much closer relevance to their company specific needs, essentially eliminating or at least reducing the need for intensive skills or technology training. Hence a masters degree that moves the classroom significantly closer to the employer, that addresses the need for developing skills and technical knowledge that meets the company's immediate needs, as well as proof of the student's life-long learning ability and application, could be valuable in countering many of these problems. Sponsoring the student through a masters with a significant portion of the content being project based, specifically tailored to the sponsors needs would account for in depth training and allow greater confidence in the human resource process of hiring an engineer who can step seamlessly into the job. If this were to be achieved, it would require very close co-operation between industry and academia, with the overall programme structure allowing for the detail content to be set up between the academic and industrial supervisors of the student. This may not be workable if the administration becomes too top heavy, and would require common criteria for each student to be fulfilled, but allow for flexibility in the detail content as driven by the needs of each sponsoring company. Furthermore, it would need a strong business case to sign up sponsoring companies, perhaps under contract to support the scheme for significant lengths of time. There have been some encouraging discussions with industry that points towards some degree of willingness to support such close co-operation schemes, but still a long way to go before any firm commitments are made. It is reassuring that industry seems interested in supporting long term development of its future human resources, and the importance it attaches to education is demonstrated by two example Chambers of Commerce in Thailand. A white paper was published by the American Chamber of Commerce [3] aimed at encouraging links between industry and education at a wide range of levels, including a review of the ongoing changes in national education policy and opportunities for North American business and why they should support education. The British Chamber of Commerce Thailand Educational Committee has recently launched a scheme for sponsoring school students, and there has been some initial informal discussion with some committee members on university level sponsorship schemes.

Collaborative learning communities was one of the six strategies identified by the Institute for Alternative Futures, in their 2005 report commissioned by ASME [4]. Whilst the report emphasised collaboration through social networks and open access information, the core theme of collaboration through any medium or process is supported by learning in an environment where the boundary between the educational institute and the employer is blurred. Closer collaboration between industry and academia could leverage resources and expertise to the mutual benefit of the organisations, as well as providing a good mix of technical and professional engineering development for the student. Whilst this idea is in itself nothing new, the emphasis for the masters programme would be on taking it to an extreme. From the student's point of view, this would mean having a mind set of being an employee of the company, even if they spend some time sitting in a classroom in a traditional lecture style learning environment. The student would equate the success of their studies with success as an employee who is fully onboard with the company and even having a role of leadership and effecting the bottom line.

The other five strategies mentioned in the report were global harmonization of standards, technology innovation networks, systems thinking, attracting and educating tomorrow's engineers, and bio convergence: biology meets engineering. As with the first strategy that was discussed above, these fives strategies may not directly apply or be intended for this context, but the basic idea can be translated into the context of a new masters programme. For example, the programme would aim to be recognised internationally, not only aiming to meet a sufficient set of standards to cover a significant part of the engineering world, but to aim to play a part in evolving an agreed single international standard. The student could be positioned at the centre of an innovation network, or be the main driving force in establishing such a network for the sponsor, which would then be used in support of the project work. One element of the project work could be to meet the requirement of a company wide systems analysis to increase resource productivity, but at a minimum, any solution to any problem would be include a systems thinking approach. From a marketing point of view, the programme would have to be attractive, but would argue its case by appealing to a market group that is already motivated by the value of engineering to the wider community, and by the prospect of a fast tracked career with exciting and varied challenges. Typical career plans could be mapped out in principle as part of the acceptance of sponsorship, with the sponsorship itself making it financially attractive to the student. Bioconvergenece, and other cutting edge topics or applications or emerging disciplines could be part of the syllabus, but not necessarily with an intention of producing technical experts in these fields. Involving such topics may come through project work and building specialist teams centred on the student, where the expertise in the topic area is provided by other team members. The students draw from this expertise, learning about the topic as a practising engineer might, rather than through formal lectures throughout the programme. Hence they follow a flexible syllabus content as defined by the project, not the project content being defined by a fixed syllabus.

The picture that is beginning to emerge from the above is further reinforced by the trends in engineering education as reported in a keynote presentation at the 19th Mechanical Engineering Network Thailand national conference in October 2005 [5]. These were listed as work place based learning, research oriented undergraduate programs, entrepreneurial engineering, extended undergraduate degree programs and engineering as a profession versus an academic discipline. Some of these themes link in with the idea of learning by doing, with an example of Heat Transfer taught by a hands-on approach having been reported to and awarded by ASME [6]. The work by Ribando et al includes the use of computers as a tool in teaching as well as a vital tool in everyday engineering practise. A student was quoted as commenting "After using the software, I go back and read the book – and now it all really makes sense!" Perhaps starting with the motivation of defining the problem and working backwards down through the underpinning science and skills learning process, then back up towards applying the new knowledge to the problem is a more effective way of learning. This is further reinforced by the work on project led engineering education (PLEE), as reported by Powell [7]. PLEE was reported as being able to support an undergraduate curriculum, although needing much work to make the paradigm shift from the traditional lecture based existing curriculum. It also needed some significant start up funding. For a new masters developed from a blank sheet of paper that is closely linked to and supported by industry, these issues would not be a problem. Academic terms were organised using themes related to the project work, and staff worked in teams instead of as individuals, mimicking industrial best practice. This can be achieved by the new programme with project work embedded within the sponsoring company. The benefits reported at the student level include improved learning skills and reflection, a simulation of a professional working environment especially through teamwork and more effective preparation for taking higher degrees. Although these last three references specifically refer to undergraduate level education, it is argued that the same concepts can be applied, or even more easily and effectively applied, to a masters level programme.

At the doctorate level, the model developed at Cranfield University in the U.K. [8] has recognised the need for greater business and entrepreneurial skills to accompany the in depth technical knowledge obtained from a doctorate. The model carries the acronym "CRIE", as the student is expected to perform four main roles, these being consultant, researcher, innovator and entrepreneur. It develops management skills by drawing from an existing MBA, as well as other technical taught modules. The student is immersed in their sponsoring company such that they can identify their core research project, fully justified in a business setting. The outcome must be marketable, and hence the entrepreneurial component. It is reported as being cost effective and efficient at producing market relevant doctorate level research, as well as the development of an engineer who can link both the traditional functions of the research lab and the business boardroom, improving the communication and mutual understanding between the two.

The need for increasing the entrepreneurial ability of graduate engineers has also been commented on by industry. This may not materialise in the form of developing products or technologies to open up new sales, service or support markets, but may be other forms of entrepreneurial thinking, such as selling project ideas to company internal or external authorities for funding. This can be incorporated into the overall project management and the emphasis of project responsibility on the student, as in the CRIE model. A prerequisite to being able to identify worthwhile projects, is an understanding of the company's core and related business, its structure, work culture, its people and customers, an ability to see the big picture from shop floor to boardroom level, to understand the decision and reporting process and when that process fails. Students can sometimes feel lost within a company, taking time to find their feet and grow in confidence. The programme would therefore also aim to develop such skills and confidence. Students with a head start in this respect may be preferred, meaning the admissions criteria may include a need for some prior work experience either during their first degree or for a period of time after it. The development of these and other professional engineering skills would be a strong theme throughout the programme, and formalised as part of their initial or continued professional development through mentoring with their industrial supervisor, and recognised by an appropriate professional engineering institution.

In the modern world there is an ever greater need for high levels of professional training, conduct, codes and implementation not just within the engineering profession and industry, but also applied by engineers in the wider community. This is perhaps the highest value of professional engineering development, where the individual engineer and the professional as a whole lead the way with issues in the wider community that are linked to engineering. An example of this is the objectives of the International Association for Continued Engineering Education [9], which places an emphasis on support for developing nations. The global economy and society is driven more and more by engineering and technology, so surely the people behind it should drive up the standards and have an input to policy level decisions, requiring a strong voice from the profession. Natural disasters, rebuilding war torn nations, sustainable management of resources, fair trade, poverty alleviation, education, and many other topics on the world's political, social and economic agendas all have a significant input from engineering. An interesting example of this is the term "macro-engineering diplomacy" used by Matsuoka [10] in describing a style of diplomacy needed to solve international problems that have a complex entanglement of politics, economy, culture, and technology issues. The specific application of macro-engineering diplomacy given in the paper is that of the hope in using solar power generation in space to solve many global environmental problems. Engineering as a profession cannot afford to be detached from this level of responsibility, and tomorrow's engineers must be educated to meet these demands. The new programme would aim to produce graduates who have it in their second nature to think along these lines, and as they advance their careers through influential multinational organisations, they can guide the process of change. This may not be a full solution, but it may make a strategic difference, especially if adopted in engineering education best practise and hence reach a wider professional engineering population.

Although by no means unique to engineers, the fundamental analytical and problem solving skills of engineers are highly transferable and have been recognised by other disciplines. Focussing on the problem with a clear sense of a priority framework is an asset that helps to erode boundaries and borders, and reduce confusion or incompatibility from cultural differences. The issue of culture, whether personal, society or work environment culture should also be part of the new programme in some form, and perhaps facilitated by a requirement of being based in at least two universities in two different countries or continents. There is a growing demand for international experience, as recognised by, for example, the US based Institute of International Education [11].

The above discussion begins to point towards some key characteristics that the new programme might have. These are refined and explicitly summarised in the following sections.

Programme Overall Theme

The masters programme would aim to produce graduates with a balance of deepened technical, managerial and professional skills, who are capable of providing solutions to engineering problems through a total systems thinking approach, including environmental and community impact considerations. The graduates would be well positioned for fast track careers in, for example, multinational companies, aiming for senior positions focussed on company wide business and engineering development to meet continuously changing demands.

All students would be sponsored by industry, providing a collaborative real engineering practise learning environment, with projects set up and managed through to competition through a consulting, research and implementation process.

Mobility of all personnel involved would also be a theme, linking up institutes and industry between continents, crossing boarders and cultures, further enhancing the need for student independence, self motivation, management, maturity and professional conduct.

Top Level Content and Programme Structure

Each student may have a programme that is different in the detail, but following the same framework of aims, requirements, and tools to build the programme, with checks and clear procedures and standards.

It is proposed that the programme would run over five continuous semesters including the summer semester as the third of the five semesters. The first two semesters would be based in a university-learning environment with a balance of management and technical subjects to provide a platform to begin the project consultation process. The technical content would be aimed at giving a minimum level of competency in topics relating to the company's core business, as a first step towards any further technical training that may be required during the project phase, as dictated by the needs of the project. The management content would be aimed at developing business awareness, analytical and soft skills, such as cost/benefit analysis, negotiation, project management and entrepreneurial skills. Within this framework, there would have to be provision for topics such as sustainable development and cross-cultural studies. Overall, this would need fine tuning by selection of courses from preferably existing programmes, in consultation with the student, academic supervisor and sponsoring company.

In moving to another country/continent, the next three semesters would be based within the sponsoring company and associate university for continued academic support, along with possible sabbatical or other type of visits from staff from the first university. Immersed within the sponsoring company, the student would go through the process of site specific orientation and induction, then move into the consultation phase where potential projects are sourced. The selection is narrowed down and then fully specified with clear objectives, deliverables, resource proposal, an initial cost/benefit assessment, project plan, and other appropriate quality control styled documentation. Then the student moves through research, implementation and value assessment phases in line with the project plan. As part of the learning content, this would be carried out in a complex work culture, with cross-functional but student centred teams supported by company and academic staff as appropriate. This real life learning environment would therefore further enhance people management, negotiation and other professional skills. There may be some deepening of technical study in particular areas, but strictly for the purpose of supporting their industrially sponsored work, noting that the student would have at their disposal the technical expertise of other staff. The scope of what constitutes an acceptable project is currently quite broad, but is not defined by technical content, but rather than by the extent to which the student would be challenged and developed in order to reach a certain standard. At present, this standard is not well defined, but would be linked to the description given in the previous section first paragraph, would be influenced by the sponsoring organisation requiring the student to meet their internal staff hire standards for such a career path, and further influenced by appropriate international accreditation standards. An additional criterion might be that the project must move industry towards meeting other targets (or at least not move backwards) such as meeting higher health and safety or pollution standards, as well as the main focus of the project.

Other as yet undetermined content might be the requirement for professional academic publication and/or conference presentation, dependent on company sensitivity issues. Furthermore, there may be an opportunity for wider consulting to third parties, applying learnt concepts and skills. Dependent on the detailed sponsorship agreement, this may be done during or after the programme, and could be done with one or other of the university partners and staff.

Sponsorship

The sponsorship agreement would be primarily between the student and the sponsoring company, but must also meet the requirements of the academic institutes involved, which must be previously agreed for each student. Ideally, the company would have representation in both countries where the student will be based, allowing some personal contact and hence detailed understanding of key elements between all involved at various stages of the programme. This would also facilitate some initial orientation during the first two semesters. Companies must be fully supportive and understanding of the educational principles and value the investment in their future potential human resource capital, and the wider benefits to the engineering profession as a whole through supporting such a programme. They must also be able to identify suitable projects, and have staff that can support the programme. This would include selection of a mentor, who would be the principle industrial co-supervisor.

All aspects of the programme structure, content, administration and so on, would be set up with the sole aim of supporting the student to be sponsored, the student's ability to meet the complex challenges of the project and their responsibilities towards their sponsor. This would also include the selection of academic staff who can link in with industry and contribute to aspects of the student's development that are outside the purely technical arena. This might include requirements on their own professional engineering development background, networking, fluency in project specification and other skills.

Some Administration Considerations

With the possibility of multiple industrial and academic collaborating partners, modern technology must be used to achieve clear and transparent administration with rapid response times. Procedure, documentation, quality control, a database of registration and other student data, progress reports, communication forums and roll over updating, marketing and so on would be centrally managed.

Intake standards would take into account previous documented and verifiable industrial experience, demonstrated independence and maturity, as well as academic track record and language skills. Clear minimum requirements must be met in order for an application to be processed, with further detailed requirements that may be specific to the sponsoring organisation and base academic institutions. Hence the process will be a mix of standard academic application and industrial hiring processes. There may also need to be some assessment of the student's initial perceived weaknesses, with a special input to the selection of courses in the first two semesters.

International professional engineering and academic accreditation would be sought, aiming to optimise global acceptance, requiring significant discussion with such bodies. Professional development of the student would be supported in depth by the sponsoring company mentor system, and combined with prior industrial experience, would be a fast track to a professional engineering qualification. Accreditation would also be a basis for maintaining a membership list of participating industrial and academic partners, as well as the staff who can hold key positions, such as that of project supervisor or mentor. A pool of committed and accredited companies and academic institutions would be established to allow rapid setting up of the three elements of student, company and university, noting that more than one university would be involved for each student.

Compatibility issues, such as semester dates, which academic institutions can house which students and support what type of project, as well as language, government and other inputs are all yet to be thoroughly researched. For example, having been attached to a sponsor, the fine tuning of course selection for the first two semesters can be completed. Ideally, the courses would already exist in other programmes at the host institution, such as MBA, other engineering graduate programmes, or even advanced elective subjects in undergraduate engineering programmes. There would have to be a consultation process with the student, sponsor and academic supervisor. This does present some administrative difficulties, which need detailed consideration, and specific input from the collaborative organisations once they are onboard. Another example would be the named bodies from which the degree is awarded, ideally jointly by the universities linked with the student, but dependent on any local, meaning national, accreditation requirements. There may be a need for special dispensation, backed by multinational organisations with sufficient political and professional weight to hold that level of agreement.

The business economics of the programme are also as yet not researched in detail. Financial contributions might come from the student, the sponsor and other funding agencies that award study scholarships. The costs would be for centralised programme management, university course credit fees, additional academic staff grants, sabbaticals, consultancy or project fees, specific company project costs, and a salary or stipend for the student whilst immersed in the company. The net cost to the student may even be zero. From the sponsor's point of view, there needs to be a clear business case as to why they should invest in the student, which is alleviated if the project produces results that are quickly turned into improving the company's bottom line. From the university's point of view, the attendance of existing courses with revenue on a credit or equivalent basis would be straight forward, as long as selection of courses does not interfere with the overall expected throughput of total student numbers from the beginning to the end of those existing programmes. Participation of academic staff as co-supervisors is more often than not welcomed by those staff and seen as economical from their career perspectives, especially with the possibility of further grants, consultancy and publication. The allowance of staff time and other existing commitments are however factors to be explored.

Conclusion

This paper has discussed a range of issues that underpin a potential new engineering masters programme that would aim to produce graduates for fast track responsibility in multinational organisations suitable for the rapidly changing modern demands of engineering applied to business and its wider role in the community. A particular emphasis is placed on professional engineering and integrated business skills, facilitated through a sponsoring company specific project, being student centred in a collaborative learning environment with both industry and academia.

A process of debate with international industrial and academic engineering professionals, consolidating interested partners, then funded research and refinement is required prior to moving to a pilot scheme.

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