Global J. of Engng. Educ., Vol.7, No.1
Published in Australia

Critical Factors Relating to the Future Sustainability of Engineering Education*

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The article provides an in-depth review of a range of critical factors liable to have a significant effect and impact on the sustainability of engineering as a discipline. Issues such as image; demand; the focus of the discipline; progression; learning and teaching methodologies; the fun factor; role of mathematics; effect of E-development; the value of entrepreneurship mindset and the importance of communications are discussed. Different curriculum models are reviewed against how best to sustain the discipline. In this respect, a comparison is made of the traditional module-based programme with learning through a work-based learning programme. Curriculum content is discussed in relation to explicit and tacit knowledge and the need for skills content related to attributes such as those associated with emotional intelligence (EQ-i). The article provides an analysis of all these aspects and discusses ways to move forward that will best sustain engineering education. It is shown that there needs to be a paradigm shift away from a traditional explicit knowledge model led programme on-campus to an off-campus work-based and lifeplace learning based model. It is concluded that a complex range of factors must come together and be continuously reviewed to combat obsolescence. Another important conclusion shown is the need to change the balance of the curriculum to take account of aspects such as knowledge skills and the range of attributes characterised by emotional intelligence.

INTRODUCTION

Earlier work pointed out that traditional engineering technologies are being replaced by a range of new and emerging technologies as a means of regenerating the curriculum and maintaining relevance to industry, commerce and society [1]. However, engineering as a discipline is under both threat and challenge and the role of engineering in the society today and tomorrow needs to be carefully reviewed. The situation is well described by Dr Hawley of the Engineering Council, UK:

- *Society is becoming even more dependent on engineering and technology…*
- *…the demand for practical engineering based skills grows all the time…*
- *…the supply of such people is in disarray. This is a National issue of the utmost importance and has so far defied attempts to tackle it.*

This adequately describes the dilemma facing the discipline where industry and society both depend on and need engineering and technology, while at the same time, the image conveyed of the discipline is one that does not encourage entrants to the profession.

Some of the conflicting images that illustrate the problem are:

- Engineers make everything possible and can achieve *miracles*.
- Engineers are workaholics who mainly occupy inferior positions.
- Engineers are really just tools of society and have little or no political acumen.
- Engineers are to blame for nearly all our disasters.
- Engineers are certainly poorly paid.
- Engineers are really not natural leaders.
- Engineers are very poor communicators.

*A revised and expanded version of an Opening Address presented at the 3rd *Global Congress on Engineering Education*, held in Glagow, Scotland, UK, from 30 June to 5 July 2002.

- Engineering is a good choice for people who are simply not intellectual but are useful with their hands.
- Engineers are not good thinkers – they are good at regurgitating knowledge.
- Engineering is not the right kind of image for the 21st Century.

It is not surprising that with such branding there are serious questions that arise around sustaining the discipline. However, on the highly positive side, it is worth noting some useful facts derived from the Engineering Council, UK, in August 2001. It has been stated that:

> *The demand for engineer professionals is set to rise in the next ten years due to advances in technology and change in industry and consumer demands.*

Figures show that about an extra 270,000 professional engineers will be needed by 2009 and Department of Industry figures show that for the fifth consecutive year, engineering undergraduates can expect £3K more than the average graduate six months after graduating. It was also recorded that graduates are most likely to find permanent employment within months of leaving university. These facts clearly show that engineers are in demand and that they are not poorly paid, while for industry and society they face a crisis with real shortages of a range of engineering skills. The author previously reported action research studies conducted at different times over the past 20 years. These studies yielded a range of similar conclusions and provided additional aspects that are issues that need to be addressed to create the much needed waiting lists of entrants to engineering programmes [1].

The impact of the knowledge revolution has shifted the emphasis of education from the assimilation of facts and the ability to master processes to the ability to assimilate and apply new knowledge. In this context, the *shelf life* of the knowledge acquired during the university education is limited by the rate of development of subject specific knowledge. Modern education is therefore required to consider how it will equip young people with a skill set that will enable them to address the new knowledge world that the 21st Century presents.

ISSUES FOR THE DISCIPLINE

The following aspects need to be carefully examined:

- Are programmes really suffering from a knowledge overload?
- Are programmes able to motivate, excite, stimulate and delight students?
- Do staff, really consider learning and teaching and the learning styles of the clients?
- How much effort really goes into innovating ways to avoid underachievement in the mass education system?
- Has the image branding really been properly analysed to remove the second-class image?
- How much emphasis is given in programmes to moving from learning as an accumulation of facts – usually as many as possible within a programme's duration?
- How many programmes represent outdated technologies; is a regular portfolio review and the shelf life of programmes considered against falling entrants?
- Is mathematics and English in steady decline and what aspects of these subjects are really important to the sustainability of programmes?
- What is the effect of a widened participation mass education system and social inclusion on the discipline?
- Has the profession really solved the problems of high dropout rates via assessment and prior to assessment?
- Does the curriculum need a careful review: less technical knowledge and more teamwork, and a range of skills elements and development of capability?
- Is this lack of communication skills, such as oral and written, undermining the whole profile of engineering?
- Are staff SSRs and the workload responsible for the lack of the needed underpinning of programmes?
- Do we need to change the traditional engineering stereotype; specifically male, not especially emotionally intelligent and more likely to be manipulated by those who are?

While the list is not exhaustive, positive answers to these questions would do much to contribute to sustaining engineering and bringing clients interested in the programmes. Some aspects need to be addressed quickly to change the image and gain government support. Of particular concern is the dropout rate, which is about double the national average. While this does little for the discipline's image, it equally has the focus of governments who are increasingly reluctant to pay for non-progression.

Various reports have recorded concerns over the quality of graduates coming from a mass education system and a number of industries seem convinced that faculties are producing too many poorly motivated graduates; *...the structure of UK University engineering courses is inadequate.*

Again from the IEEE in 2001 comes the quote: *British Universities are still too slow to offer new degrees … to meet the needs of industry.*

WHERE IS THE DISCIPLINE GOING IN 2002?

Engineering educators have to focus on market demand and stop defending the obsolescent and obsolete programmes. They must address the skill shortages in business and commerce and, in particular, address the needs of the new and emerging high technology industries that are effectively facing a global skills shortage. It is a fact that high technology industries have cyclic growth needs and educators really need to be prepared to cope with the problems that cyclic business growth creates by designing a flexible portfolio of programmes that have relevance to business needs.

Alongside high technology requirements are a range of industries demanding more generic broad-based skills of graduates. Furthermore, concern has been expressed that, as technologies are transient and change quickly, engineering graduates need a set of sustainable life skills so that they can cope with technological knowledge change.

Now industry is demanding that government set a target increase of students in high technology degrees from 50,000 per annum at present to 70,000 per annum. The image has been that a gradual decline in student applications and of engineering departments closing. In reality, again, society is misled as the numbers of undergraduates studying engineering is about 6% greater than that a decade ago and entry standards to programmes have also risen. However, what cannot be denied is that the dropout rate before graduation exceeds all other disciplines despite these improvements. So at the top of the requirements to be addressed is the lack of progression and loss of students prior to assessment.

PROGRESSION AND RETENTION

Much is being done to address progression and retention in the UK; in October 2001, a conference was held at the University of Hull, Hull, England, UK, which attracted a range of papers on engineering student progression and retention [2]. The conference was part of a national project on progression and retention supported by the Funding Councils and the Department for Higher and Further Education, Training and Employment.

A range of approaches can now be identified but it will be some time before results can be analysed. However, there are now many potential ways forward that could contribute much to providing solutions to this fundamental problem. While the list is not exhaustive, the following key approaches have been identified:

- Use intensive monitoring methods and counselling of students.
- Review and analyse assessment strategies in terms of quality, relevance and quantity.
- Review and analyse *problem modules* where retention overall is unusually low against other modules in the programme.
- Monitor attendance patterns to identify as early as possible those students at risk.
- Review pre-entry preparation and advice needed by students.
- Introduce intensive, effective and efficient tutoring for students.
- Capture student interest early by introducing stimulating and interesting practical work.
- Review programme design to include module delivery methods that motivate and interest students.
- Review learning styles of students to achieve better student engagement.
- Introduce innovative module delivery methods to stimulate interest.
- Review and introduce effective induction processes for entry to first and to high-level entry.
- Review the portfolio for current and future relevance to clients and society.
- Develop effective learning services for students.
- Review and assure student advisor availability to students.
- Review conflicts developed by students in paid part-time employment and develop an innovative integration approach by credit rating skills and knowledge achieved in employment.
- Review practical work to ensure it provides stimulation and motivation.
- Review programmes, particularly level 1, for knowledge overload on students.
- Examine, review and reinforce essential mathematics skills, especially at level 1.
- Isolate aspects of programmes that cause low-level student motivation.
- Use multimedia methods to underpin student learning.
- Set up student feedback mechanisms using some form of student surgery.

- Review the effectiveness of peer support mechanisms.
- Review the modular structure and assess the effectiveness of modules presented over two semesters, particularly for levels 1 and 2.

Engineering educators can reflect on the various approaches available and some of these methods could be used in combination to achieve a synergistic result in terms of improved student retention. This, in turn, will support the sustainability of the discipline and contribute to an improved image and hence more client interest.

LEARNING AND TEACHING

Student feedback indicates that not all teaching results in quality learning. While the knowledge base is important, it is of even greater importance that students understand and can use the knowledge and thus develop capability. Many of the programmes are still based on knowledge push with little or no time given to the development of understanding.

What is meant when we say students *understand*? How do we know if students really understand the knowledge taught? This is an aspect educators must address if student interest is to be retained. To retain this interest it has been usefully proposed that the *fun* factor and *delight* factor need to be carefully taken forward as part of the engineering education process [3][4]. Published work reveals that the *fun* factor is missing with rather a great deal of stress being present in the conventional transmission model [3]. This leads to students:

- Failing to sustain attendance at lectures.
- Failing to see the relevance of the subject matter.
- Suffering in silence and just vanishing out the system.

The relevance of the subject matter taught also needs careful examination. It has been reported, for example, that many students are not motivated by base subject matter such as chemistry, physics and mathematics, having little understanding of why they need this knowledge [5]. It is a fact that knowledge growth and relevance is a problem for educators and thus they must be highly selective in knowledge content, which is, more than ever, now transient. It is not surprising that students now challenge whether the knowledge push in programmes is needed as a preparation for their career [5]. Programmes should be structured towards student centred learning where students are empowered to move forward by taking responsibility and being accountable for their work in the programme. Above all, students must be motivated. A typical successful example is described in the literature where good student involvement is achieved through the use of student-educator dialogue to improve conceptual understanding [6].

Enthusiastic and motivated educators are needed who are willing to consider novel approaches such as:

- Problem-Based Learning (PBL).
- Team working projects.
- Entrepreneurial approach.
- Work-based learning.
- Methods with variety, delight, excitement and fun.

Educators need to move away from the traditional approach that discourages reflection and student ownership of their studies.

SUSTAINABILITY THROUGH THE *FUN* FACTOR

As mentioned earlier useful work has been completed on the introduction of a *fun* approach to motivate students and consider a shift to the *delight factor* in order to solve under-achievement in programmes [3][4]. The Kano approach has been around for some considerable time but little has been done to direct this approach towards lifting achievement levels [7]. Essentially, serious learning should be ongoing, empowering and meaningful and should be stimulating and enjoyable. Successful *fun factor* case studies across Europe, North America, Africa, Asia and Australia show that such an approach can motivate students and can, with the right balance, improve the whole learning experience [3].

By allowing the *delight factor* to surface, it has been shown at the Glasgow Caledonian University (GCU), Glasgow, Scotland, UK, that this approach provides for more highly motivated students who enjoy the challenge and can take ownership;

> *Such projects force students to work more consistently throughout the semester, to learn for themselves and to push themselves into realms they did not think possible* [4].

This type of approach generates capability and competence in the students, which can make a significant contribution to lowering failure rates and sustaining the discipline.

MATHEMATICAL REQUIREMENTS

More recently, work has been published relating to the correlation between mathematical ability and student performance in programmes [8]. Other work shows problems associated with the diversity of intake where the range of mathematical skills and absence of basic skills produces a mismatch with modules and then the development of problems [9]. Others have proactively reported, on the basis of career experience, that mathematics is largely irrelevant [10]. However, the same author separates clearly numerical competence as a requirement quite separate from mathematics.

Other educators have raised fundamental questions, including:

- What kind of mathematics is needed for modern international engineering education in the new Century?
- How can mathematical abilities of the right type be delivered prior to entering higher education?
- How can good methodologies be identified for teaching and learning mathematics?
- How can the effective use of technology be correlated to the effective delivery of mathematics to undergraduates [11]?

Are the answers to those questions what educators need? No, the fundamental aspects that need to be addressed are: do all programmes need the same spectrum of mathematical skills and would some programmes benefit from numerical competence rather than mathematics?

Almost certainly the answer is that mathematics skills should be closely correlated to the requirements of the many varied programmes now available and not used on the basis that mathematics is essential for all engineers. By correlating mathematics to engineering as being essential has certainly contributed to many students either avoiding engineering or withdrawing due to lack of interest. The close link between mathematics and engineering is one significant factor contributing to *image* problems with the discipline.

So, engineering educators must be prepared to carefully analyse what mathematics, if any, are needed for specific engineering programmes. This will involve deciding on what is actually important and relevant to underpin the contents of the programme. Educators must decide what is more important: arithmetical manipulation, logical reasoning, algebraic manipulation, analysis or geometrical abilities. Is it all of them in equal amount or is it all of them but relevant amounts?

Published results claim strong correlation between mathematical skill in general and overall performance but much less correlation between arithmetical skill and general performance [8]. It is obvious that much greater understanding is needed of what amounts are really needed for different types of programmes. Perhaps educators need to accept the requirements of industry and society where a range of other key skills is more important for career survival. In proposing this view, this is not to suggest that a range of mathematical-based programmes are not still required by simply to suggest that a range of programmes exist that are not improved by filling them with mathematical skills that are not needed and are not relevant. Where a diverse intake does enter a programme, then educators will need to complete a skills audit in the early part of level 1, bring the students to a common base and thereafter move forward with a mathematical treatment. This approach is considered in a recent publication where it is proposed that subjects are taught in semester 1 of level 1 without a mathematical base in the first instance [10].

E-SUPPORT AND INTERNET

The CEO of Cisco Systems, Mr Chambers, stated in 1999 that:

> *Education over the Internet is going to be so big it is going to make e-mail usage look like a rounding error in terms of the Internet capacity it will consume.*

So what will e-support and the Internet contribute to the sustainability of the discipline? Questions that need to be considered are:

- Can the e-learning environment help to solve some of the issues facing engineering recorded earlier in the article?
- If it can, how should e-learning be used to achieve sustainable results?
- Can e-learning really replace traditional teaching methods to the advantage of the discipline?

E-learning is developing rapidly and it will not go away. So how can these developments be addressed to the advantage of students?

There are no obvious answers to these questions and there is a range of different views, some supportive of the concept and others opposing such developments. Recent published results have shown that hypermedia instruction, integrated with traditional methods, can create an environment capable of providing enhanced learning and enhanced progression rate [12]. It has been shown that it can stimulate students to proactively take responsibility for effective learning.

E-support in the form of e-care and e-guidance could help to reduce wastage rates by assisting and freeing up the time of counsellors and guidance staff. Some of the advantages available are:

- Answers frequently asked questions.
- Can address common problem areas.
- Can help to clarify career aspirations.
- Provides online, real-time academic support.
- Can support real-time study sessions such as mathematics.
- Provides both asynchronous and synchronous tutoring.
- Can provide support on communications by providing an online written communications lab.

All of these aspects assist in addressing the issues related to sustainability described in the introduction and these methods, combined with the described approaches to progression and retention, should make a major contribution to the sustainability of engineering.

THE ROLE OF COMMUNICATIONS

Generally, engineering students have a negative image in terms of communication skills [13]. It is well accepted that oral communication skills are essential for career progression and more emphasis needs to be placed on oral and written communication across the overall subject matter of engineering programmes. Oral presentation skills have been shown to be the single biggest factor in determining a graduate's career success or failure [13]. Yet most educators are still driven by knowledge push at the expense of a whole range of essential skills.

There is little doubt that ineffective communication skills have reinforced the set of images discussed in the introduction. With oral communication being a learnable skill, this should be an essential integrated component of all engineering programmes and it should be assessed. This is in contrast to the mathematical skills, which need to be matched to different programmes.

ENTREPRENEURIAL FACTOR

Students need to take responsibility for ownership of their studies and to leave the programme with a well-balanced education, which includes not only knowledge but also a capability for innovation and creativity leading to the entrepreneurial factor. On this basis, earlier work has shown that technopreneurship should be an essential component of the undergraduate curriculum where a creative and innovative mindset is established on which to build their life-long learning [14]. Entrepreneurship in the curriculum would improve the image of engineering and could generate:

- A more exciting discipline to stimulate and motivate students.
- A mindset to sustain further learning and career delivery.
- More support by government and society and a better public image for engineering.
- Attract an alternative group of students to the programmes.

Recent work reports *that entrepreneurship could lead to a new paradigm in terms of individual mindsets leading to a new way of doing things* [15].

Thus, engineering educators have yet another powerful tool available to regenerate the curriculum, improve the image of engineering and stimulate students to successfully complete their programme.

MODE 1 AND MODE 2 APPROACHES

Giddons and Hellstrom have considered the relevant mode, ie in the University (Mode 1) and at the workplace (Mode 2) [16]. Giddons proposed the following distinctions:

- In Mode 1, problems are set and solved in a context governed by the (largely academic) interests of a specific community. This contrasts to Mode 2 where knowledge is produced in a context of application.
- Mode 1 is characterised by the relative homogeneity of skills, Mode 2 by their heterogeneity.
- Mode 1 is disciplinary while Mode 2 is transdisciplinary.
- In organisational terms, Mode 1 is hierarchical and, in academic life at least, has tended to preserve its form, while in Mode 2 the preference is for flatter hierarchies using organisational structures that are transient.
- In comparison with Mode 1, Mode 2 is more socially accountable and reflective.
- In comparison with Mode 1, Mode 2 involves a much-expanded system of quality control. Peer review still exists, but in Mode 2 it includes a wider, more temporary and heterogeneous set of practitioners collaborating on a problem defined in a specific context.

Based on these considerations, the following attributes for Mode 2 were proposed:

- Knowledge produced in the context of application.
- Transdisciplinary.
- Heterogeneity and organisational diversity.
- Enhanced social accountability.
- More broadly based system of quality control [16].

Different types of knowledge can now be distinguished where codifiable knowledge is recognised as that which can be written and can be easily transferred to others. However, tacit knowledge cannot be acquired so easily and is significantly more difficult to transfer. Tacit knowledge needs to be developed in undergraduate programmes if the knowledge economy now desired by governments and society is to be realised.

Undergraduate work-based learning models have the capability to support this approach to the knowledge driven economy by providing an approach that correlates knowledge alongside codified knowledge in ways where the undergraduate is involved in the exploitation of these components of knowledge in the workplace as a real environment. In this respect work-based graduates will have greater capability to then contribute to the knowledge driven economy early in their careers. Engineering and engineers have, in the past, contributed greatly to the creation of wealth and the work-based approach now offers a realistic way to move engineers forward to participate in the emerging and evolving knowledge economy.

The basis behind a work-based programme is essentially the strategic objective of the host organisation of the student. In postgraduate terms this is easily developed through discussion with the organisation, the academic supervisor and the student. The result of this discussion is a set of objectives or goals that are specified in terms of what the student will be required to learn to deliver the strategic objectives.

The essential difference in this form of educational agreement is the specific analysis of the student's requirements to acquire and apply knowledge relevant to the problems that form part of the workplace study. Once again, in a postgraduate format this form of learning agreement, often referred to as a learning contract, is typical of a Mode 2 approach. The characteristics of a learning contract cover:

- A diversity of areas of study – it is transdisciplinary.
- An individual programme that requires knowledge skills.
- Knowledge produced in context of its application.
- Institutional accountability to the student and host organisation.

The process of delivery will be in a distance mode making use of modern technology (e-mail, net meeting, video links and telephone), as well as face-to-face contact with the supervisor. Learning goals are tackled as part of the planned process with assessment, which has been previously defined, taking place on the delivery of each goal.

An integral part of the educational process is the change in the role of the supervisor from director to facilitator. In Mode 1 structures the lecturer/supervisor directs the activity of the student along predetermined paths providing knowledge that is accepted as required to meet a specific aim. In work-based learning the aim is the development of knowledge skills that will enable the student to follow lines of enquiry until either they are able to be logically discarded or provide useful knowledge. It is precisely this form of activity that requires the supervisor to be able to discuss options with the student and suggest paths of inquiry that lead to the development, knowledge acquisition and application skills that ultimately are transferable, ie can be used in other problem-based activities.

GROWTH AND RECOGNITION OF EMOTIONAL INTELLIGENCE (EQ-I)

Some interesting results published recently draw attention to considerations relating to IQ versus EQ (emotional intelligence) [17]. That paper examined the impact of EQ on learning and engineering education and drew attention to emotional intelligence as a prime factor in the success of individuals and that it has a role to play in educating engineers. The paper's author affirmed that:

> *While University education helps establish a high IQ in graduates, other skills have been identified as necessary in the workplace, skills that are derived from emotional intelligence (EQ)* [17].

The question arising from this centres on whether traditional on-campus learning can generate jointly a high IQ and EQ in graduates and postgraduates. Alternatively, the off-campus work-based environment, and perhaps even the lifeplace environment, may be the better environment to achieve the development of a high EQ and hence the range of attributes associated with EQ.

Successful people, organisations and society can best be improved by excellence and growth in EQ-i. The five domains of EQ-i are all aspects that are essential to career progression and lifeplace development. The attributes are also linked closely to each other. Empathy, for example, is directly related to effective listening skills.

EQ-i is relatively new and first appeared in a series of academic articles by Meyer and Salovey around 1990 to 1993, but they generated little attention. It was Goleman's bestseller in 1995 that set the scene for rapid development [18]. His later publication in 1998 stimulated great interest [19].

The skill set of EQ-i is outside the traditional areas of knowledge and understanding, general intelligence, technical and professional skills and, as such, academia has given little or no recognition to these developments in revising the portfolio of programmes.

Mayer and Salovey asserted that *emotional intelligence allows us to think more creatively and use our emotions to solve problems* [20]. Mayer and Salovey also stated that:

> *The emotional intelligent person is skilled in four areas: identifying emotions, using emotions, under-standing emotions and regulating emotions* [21].

Little, if anything, has been done to correlate the understanding and development of EQ and related attributes with the work-based and lifeplace environments. If a balanced combination of IQ and EQ gives the capabilities needed of future graduates then it may be that this can be better achieved by work-based and lifeplace learning.

Consideration also needs to be given to lifeplace learning. For postgraduates, both the EQ-i and the knowledge component are best developed by the person using both their workplace and lifeplace. This raises implications for the measurement and assurance of the learning achieved. For work-based learning, there are many frameworks already available to formally measure awards from the postgraduate certificate level through to professional work-based doctorates. However, lifeplace learning can be treated in a similar way to the workplace and the outcomes assessed in novel and realistic ways that are quite different from on-campus exam-based assessment.

Work-based learning can now be most aptly explained as the environment where the spectrum of attributes of emotional intelligence can best be established and further developed both for undergraduate and postgraduate engineers. The work-based environment facilitates the whole area of non-cognitive factors, such as personality, emotional intelligence, creativity and innovation and the entrepreneurial factor. It is well accepted that the non-cognitive factors are at the heart of determining work behaviour, particularly in the rapidly changing work environments that are a feature of the early 21st Century.

EQ-i is essentially a new theory of performance in the workplace [22]. Work-based learning is also essentially about formalised learning to give a better capability and performance. In this respect work-based learning, while about knowledge development and delivery, is more about improved performance of the person through concepts such emotional intelligence.

Most work-based learning requires candidates to become involved in reflective analysis and, as reflective practitioners, reflect on their career and development to date and relate that to their required developments in the workplace. This reflective analysis deals with exactly those core aspects associated with EQ-i development.

The workplace environment is the ideal *living laboratory* for the delivery of an enhanced range of capabilities and EQ-i attributes.

The on-campus environment is the best place to establish the basis of subject knowledge. However, for a range of skills, capabilities and EQ-i related attributes that are now desired by industry and society, the workplace environment is probably a more realistic option.

DISCUSSION AND CONCLUSIONS

Engineering as a discipline can be best sustained by:

- Moving away from programmes with massive knowledge push to balanced curriculum that encourages students to achieve capability by taking responsibility and being accountable for their own learning.
- Improving progression and retention by introducing and testing various combinations of the many reported approaches available to assure that students remain on programmes until they graduate.
- Adopting innovative approaches to learning and teaching using aspects such as the *fun* factor and *delight* factor approaches.
- Careful analysis of the real level of mathematical skills needed for the wide variety of engineering programmes available.
- Putting emphasis on a broader range of attributes, creativity and innovation, such as the *entrepreneurial* factor being an essential component of programmes.
- Making sure that a regular portfolio review takes place and programmes are not overloaded with outdated knowledge.
- Introducing appropriate e-learning and the use of the Internet, alongside e-care and e-guidance.

- Making oral and written communication skills an essential integrated and assessed component of all engineering programmes.
- Educators making continuous appraisal of all of these factors on how they relate to improved sustainability in a rapidly changing global environment.
- The theoretical debate on the relationship between Mode 1 and Mode 2 models of education is still developing. However, it is clear that the two modes lead to quite different programme models. The most striking difference is associated with the differing development of knowledge skills in the participants in programmes using the respective modes. In this respect, the work-based model offers the delivery of both codifiable and tacit knowledge components to provide graduates with greater capability to contribute to the knowledge of economy.
- Work-based learning represents a paradigm of education that has been and still is developing in response to the recognition that knowledge skills are now the dominant transferable skill as well as the needs of a community that is wider than the eligible university population. As this paradigm develops and graduates of these programmes can demonstrate the knowledge skills and capabilities, employers can then maintain competitive advantage and contribute to national economic growth.
- The work-based learning model for engineering education provided the ideal environment to achieve the development of emotional intelligence attributes and a range of life-long capabilities.
- The work-based learning and lifeplace learning environments offer the ideal way to develop and grow the attributes of emotional intelligence, characteristics now identified as essential to career progression.
- Industry, government and society can be best served by the work-based delivery of emotional intelligence and capability in graduates.
- Alongside the work-based model, it needs to be recognised that lifeplace learning outside work and formal higher education learning should be given full recognition through similar lifeplace learning contract frameworks.

REFERENCES

1. Chisholm, C.U., Sustaining engineering as a discipline against present and future global technological change. *Proc 5th Baltic Region Seminar on Engng. Educ.*, Gdynia, Poland, 61-65 (2001).
2. *Proc. Progress 1 Conf. on Student Progression and Retention in Engng.*, Hull, England, UK, 1-238 (2001).
3. Meuller, B. and Riemer, M.J., Engineering the fun factor into the education process. *Proc 5th Baltic Region Seminar on Engng. Educ.*, Gdynia, Poland, 73-76 (2001).
4. Grainger, S., Ross, D.S. and Temple, B.K., Do we stretch our students enough? *Proc 5th Baltic Region Seminar on Engng. Educ.*, Gdynia, Poland, 49-53 (2001).
5. Meuller, B., The fun factor in education: engineering education in the third millennium. *Proc 1st Russian Seminar on Engng. Educ.*, Tomsk, Russia, 95-96 (2000).
6. Kolari, S. and Savander-Ranne, C., You know it, but do you actually understand it? *Proc 5th Baltic Region Seminar on Engng. Educ.*, Gdynia, Poland, 69-72 (2001).
7. Kano, N., Seraku, N., Takahashi, F. and Tsiyi, S., Attractive quality must be quality. *Quality*, 14, **2**, 39-48 (1984).
8. Page, G. and Page, H., The correlation between mathematical ability and performance on engineering degree courses. *Proc 5th Baltic Region Seminar on Engng. Educ.*, Gdynia, Poland, 122-124 (2001).
9. Mustoe, L., The mathematics background of undergraduate engineers. *Proc. Progress 1 Conf. on Student Progression and Retention in Engng.*, Hull, England, UK, 88-95 (2001).
10. Reed, E.W., The over-emphasis of mathematics at the expense of experimentation in the academic training of engineers. *Proc. Progress 1 Conf. on Student Progression and Retention in Engng.*, Hull, England, UK, 80-87 (2001).
11. Grünwald, N. and Schott, D., The Gottlob Frege Centre for Engineering Science and Design at Hochschule Wismar – an institution for developing and enhancing science in future engineering education. *Proc 5th Baltic Region Seminar on Engng. Educ.*, Gdynia, Poland, 130-134 (2001).
12. Zywno, M.S., White, W.E. and Northwood, D.O., Innovations in engineering education – Ryerson model for the 21st Century. *Proc 5th Baltic Region Seminar on Engng. Educ.,* Gdynia, Poland, 45-48 (2001).
13. Riemer, M.J., Integrating oral communication skills in the education of engineers. *Proc 5th Baltic Region Seminar on Engng. Educ.*, Gdynia, Poland, 148-151 (2001).
14. Chisholm, C.U., Factors relating to the integration of high technology entrepreneurship within the engineering curriculum. *Proc 5th Baltic*

Region Seminar on Engng. Educ., Gdynia, Poland, 94-98 (2001).
15. Chisholm, C.U., Weaver, R.Y. and Burns, G.R., Development of postgraduate studies in technopreneurship for engineering graduates. *Proc. 2nd UICEE Annual Conf. on Engng. Educ.*, Auckland, New Zealand, 71-75 (1999).
16. Giddons, M. and Hellstrom, T. (Eds), *The Future of Knowledge Production in the Academy*. London: The Society for Research into Higher Education (2000).
17. Riemer, M.J., IQ versus EQ: Emotional intelligence and the graduate engineer. *Proc 5th Baltic Region Seminar on Engng. Educ.*, Gdynia, Poland, 79-82 (2001).
18. Goleman, D., *Emotional Intelligence: Why It Can Matter More than IQ*. New York: Bantam Books (1995).
19. Goleman, D., *Working with Emotional Intelligence*. New York: Bantam Books (1998).
20. Mayer, J.D. and Salovey, P., Emotional intelligence and the construction and regulation of feelings. *J. Applied and Preventive Psychology*, 4, **3**, 197-208 (1995).
21. Mayer, J.D. and Salovey, P., The intelligence of emotional intelligence. *Intelligence*, 17, **4**, 433-442 (1993).
22. Kierstead, J., Human Resource Management Trends and Issues: Emotional Intelligence (EI) in the Workplace (1999), http://www.psc-cfp.gc.ca/research/personnel/ei_e.htm

BIOGRAPHY

Colin Urquhart Chisholm graduated with a BSc Hons in Metallurgy from Strathclyde University and with a Doctor of Philosophy from St Andrews/Dundee University in 1962 and 1968 respectively. From 1963 to 1965, he was a lecturer at Wolverhampton and Staffordshire College of Technology (now Wolverhampton University). From 1965 to 1971, he was a lecturer in materials science at Dundee Institute of Art and Technology (now Abertay University) where he researched in processes for alloy electrodeposition and the study of the structure of the deposited alloys. After spending a period as a senior lecturer at Robert Gordons Institute of Technology (now Robert Gordons University), he became Associate Head of Engineering at Paisley College of Technology (now Paisley University) and thereafter Head of School of Engineering at Glasgow College of Technology (now Glasgow Caledonian University) where he was awarded a professorship. He was Dean of the Faculty of Science and Technology at Glasgow Caledonian University (GCU) from 1993 to 2002, and, since 2002, he has taken up the position of Dean of Development. He has also been a member of the Executive Management team and is the Director of the Scottish Centre for Work-Based Learning (SCWBL), a satellite centre of the UICEE.

Prof. Chisholm is also a Deputy Chairman of the UICEE Academic Advisory Committee.

Prof. Chisholm is an acknowledged international researcher in the field of electrodeposition of alloys and leads collaboration as Chairman of Surface Technology International, which involves a group of European universities. Since 1985, he has maintained a major collaboration with a team of researchers at Eotvos Lorand University in Budapest, Hungary.

For the last decade, he has led action research and development relating to work-based learning and, at GCU, has developed an innovative Postgraduate Learning Contract Framework for work-based learning, which has been operational since 1992.

More recently, he negotiated on behalf of GCU with the UNESCO International Centre for Engineering Education (UICEE) leading to the establishment in 1998 of the first satellite centre of the UICEE, named the Caledonian Centre for Engineering Education (CCEE) at the GCU.

He was awarded the UICEE Silver Badge of Honour for Distinguished Contributions to Engineering Education at the Global Congress on Engineering Education in Cracow, Poland, in September 1998, and more recently at the 2nd Global Congress on Engineering Education in Wismar, Germany, in July 2000, he was also awarded the UICEE Gold Badge of Honour.

He has published over 200 scientific papers in refereed journals and conference proceedings and supervised over 35 PhD students. More recently, Professor Chisholm, in collaboration with the team for Surface Technology International, published the first paper regarding the successful deposition of tin-chromium and tin-zinc chromium alloys. Prof. Chisholm has also received a number of awards for published papers presented at international conferences.