2006-1929: BUSINESS AND MANAGEMENT IN THE ENGINEERING CURRICULUM

Michael Bramhall, Sheffield Hallam University
Mike is Head of Learning, Teaching and Assessment at Sheffield Hallam University's Faculty of Arts, Computing, Engineering and Sciences. He is also the Associate Director of the UK Centre for Materials Education at Liverpool University. Mike is the Editor of the British Journal of Engineering Education.

Steve Lawson, Leeds Metropolitan University
Steve Lawson is an Assistant Dean and Head of School for Economics and Human Resource Management, at Leeds Business School, with responsibility for over fifty academic and admin staff.

Steve previously worked at Sheffield Business School for twelve years where his responsibilities included Head of Division, MBA programme leader and developing and managing specialist products within the corporate and executive portfolio.

Ian Robinson, Sheffield Hallam University
Ian is Head of Undergraduate Studies at Sheffield Hallam University's Faculty of Arts, Computing, Engineering and Sciences. Technically he specialises in electrical drives and power electronics, but spends much of his time working in the area of engineering pedagogy. Internationally he is a trustee and member of the International Liaison Group for Engineering Education.
Abstract

The rate of change of the nature of employment in UK engineering industry and commerce has greatly increased in recent years. The large ‘bureaucratic’ organisations and the large public utilities of the 1970s have been replaced with small, dynamic and flexible organisations which might only exist for several years. This change clearly requires that we produce graduates who are equipped with, not only technical engineering skills, but also with skills which are business-orientated. Here, we outline the six key areas which must inform the content of our engineering curricula.

Introduction

In recent years, engineering industry has moved from a Machine Age to an Information Age where a culture of innovation is fostered, requiring an ability to manage change and develop strategies to respond quickly to competition. Clearly, with this change comes a need for a similar change in the skills of engineers. Richardson tells us that ‘traditionally engineers and scientists in the UK have seen themselves only as inventors or creators of systems and have left businessmen to worry about the possibility of their commercial exploitation’. Thus, there is now a need for a shift in the mindset of engineers, from seeing themselves as ‘just’ engineers, to being people who have a well-rounded understanding of, and an ability to make decisions within, the commercial environment. They must be businessmen and businesswomen as well as inventors and creators. It is logical, then, that if our businesses need a different type of engineer, then these new skills must be fostered, developed and learned by our engineering students. This paper aims to introduce the institutional and industrial context in which this necessity for a different engineer has developed. We then proceed to outline six factors which can be isolated as key areas for current engineering education. Of these six, two - Strategic Management and Knowledge Management - are introduced in this paper. Knowledge Management can be defined as the development and exploitation of an organisation’s information held on databases, staff skills, experience and knowledge and the inter-relationship of the different types of knowledge resource. Strategic Management can be defined as understanding where are you now, where you want to be and how you are going to get there. This paper suggests that engineers need to be developed in these areas.

Changes In Business that Call For a Change in Graduates

In the past, organisations tended to recruit from traditional universities, using the ‘knowledge base’ of the student as evidence that graduates could undertake tasks, or learn, in a ‘compliant, dutiful and reliable manner’. However, in the context of the changing nature of the engineering industry, contemporary graduates will be required to be equipped with skills to accommodate these changes. Indeed graduates will have:
increasingly flexible and truncated careers. Hence graduates have to be more ‘flexible’ in
their attitudes towards work and more ‘adaptive’ in their behaviour in the labour market.
They require a broader portfolio of technical, social and personal skills than...were
emphasised in the past.”

Therefore, the type of graduates we need to produce are those that are business-aware as well
as possessing the traditional engineering skills. However, the lack of fully efficient links
between university and industry means that we don’t always produce the type of graduates
that industry really requires. And, in fact, we have been slow to respond to its changing
requirements.

In many universities, course planning is largely an internally driven exercise, with curriculum
being designed to minimise competition with other regional Higher Education Institutions
(HEIs). Courses are often planned to attract students who are ‘initiative-’ or ‘technology-
aware’ (for example, the recent explosion of courses in Internet Engineering). It is both
difficult and resource intensive to maintain meaningful advisory relationships with a broad
range of current engineering practitioners. Therefore many HEIs prefer to simply consult a
select band of industrially-based departmental friends when proposals are all but complete.
One should therefore not be surprised that our curriculum is not always ideally suited to the
complexities of the current industrial environment.

The University’s Perspective

Throughout the rapid expansion of UK Higher Education in the 1960s and 1970s universities
were largely self-determining in the nature of their curricula. They have been described as
‘able to determine the academic criteria by which [they] will admit new activities’.

However, it is this very expansion that has, perhaps, now begun to undermine the traditional role of the
university sector as governmental and other bodies have sought to gain control over the
university curriculum.

The changing nature of both engineering business and higher education persuaded the
government of the day to commission Sir Monty Finniston in 1980 to conduct a major review
of the need for engineers; the type of engineering expertise the country required; and the
framework for the formation of engineers (The Finniston Report). This report found that
professional engineers:

‘...expect to find themselves taking part in, and responding to a more participative process of
change, through joint discussions of their work and its impact and effects at many levels. This
wider role will require that engineers develop appropriate skills in the following areas:

- the ability to express and communicate both verbally and in writing
- managing and participating in meetings
- mastery of cost and budget information’

However, UK HE institutions themselves were slow to respond to these changing demands
and some authorities swiftly recognised this. Within the HE sector, initial moves were made
to raise the importance of ‘skills for work’ within academia:
‘Meeting the needs of the economy is not the sole purpose of higher education...but this aim must be vigorously pursued...The achievement of greater commercial and industrial relevance in higher education activity depends on much closer communication between academic staff and people in business...They also help to foster the positive attitudes to enterprise which are crucial for both institutions and their students.’

And, more importantly, it was further intended that government funding be linked to such developments:

‘The Government and its central funding agencies will do all they can to encourage and reward approaches by higher education institutions which bring themselves closer to the world of business.’

Standards and Routes to Registration (SARTOR)

It is therefore not surprising that within a few years of the Finniston Report, the newly constituted UK Engineering Council (the post-Finniston successor body to the Council of Engineering Institutions) had published the first edition of ‘Standards and Routes to Registration’ (SARTOR). This document defined the roles of professional engineers, and laid down the requirements for degree and diploma courses to obtain professional accreditation. SARTOR was a prescriptive document and it stated that engineers must demonstrate:

‘the ability to give authoritative advice on innovation and change, to manage the development and implementation of new technologies, coupled with the ability to appreciate and take cost/benefit account of the financial, social and political implications of decisions taken’.

In short, engineering graduates were required to be business-minded for the first time.

By 1988, the Engineering Council was becoming more outspoken, observing that ‘education for working life rather than first job should...be the aim’. The engineer in industry must be ‘an authority on technology, a leader of others, a communicator’ and engineering courses must ‘improve working habits’.

The council was itself beginning to warm to the theme of intervention in the undergraduate curriculum, and would indeed be funding and influencing new engineering degree courses using Department of Trade and Industry (DTI) finance. The links to industry and the world of work were clearly being re-enforced.

However, it was not only industry, as the end user, who had demonstrated an interest in these wider professional skills. Students themselves were beginning to perceive the importance of studying on a course which explicitly encouraged the development of knowledge and skills firmly rooted in the business-oriented context of the modern engineering industry. In the 1992-3 Presidential Address, the President of the Institution of Electrical Engineers reviewed the trends within engineering education, and drew attention to ‘the search by students for courses which provide them with wider skills’.

The Engineering Council, in its 3rd Edition of SARTOR, continued the increasingly strong trend of basing the curriculum within the vocational arena, and argued that engineering courses must give ‘greater breadth and depth of coverage, to meet the needs of industry in management and business topics and personal skills’. In fact, the tone of this document marked a significant change in the level of control governmental bodies were beginning to exercise over the HE institutions. There were very specific guidelines about exactly what a course should include. Such as:
an awareness of quality systems in engineering; requirements and responsibilities of leadership; obligations to work safely and to apply safe systems of work; risk analysis; the financial, economic, social and environmental factors of significance to engineering; the relevant legal, statutory and contractual obligations and the broader obligations of engineers in society.\(^8\)

The ‘Nominated Bodies’ are the ‘heart’ of the Engineering Council, offering the routes through which the Council’s strategy and policy are implemented within the university sector. They are generally the Engineering Professional Bodies, Engineering Institutions or Learned Societies through which the Council is able to influence continuing professional development, and most importantly the approval, or accreditation of degree courses. Accredited engineering degrees provide exemption to their graduates from the educational requirements for registration as a professional engineer. As an example of how the overarching strategy articulated within SARTOR was implemented by an Institution, the Institution of Mechanical Engineers (IMechE) required accredited courses to incorporate:

‘...business and management covering the organisation of industry, project management, finance and human behaviour; health and safety and environmental issues’.\(^9\)

In addition:

‘...courses in business and management are essential components that should equip the graduate to progress towards a position of responsibility. The objective is to develop the student’s awareness of the organisation of industry, finance, human behaviour and the engineer’s responsibility for health, safety and environmental issues’.

The impact of the influence of governmental bodies on the curriculum outlined above is drawn from the engineering professional bodies themselves. However, in the 1990s, Government itself has once again begun to intervene in HE, in the guise of the Quality Assurance Agency (QAA) and in parallel with this we begin to see an increasing influence of the Engineering Professors’ Council (EPC). Both organisations exerting influence on the HE institutions with a greater or lesser degree of success.

**The UK Quality Assurance Agency (QAA)**

The QAA has a remit to reassure the Government’s funding agencies that the university sector has appropriate mechanisms for ensuring the academic standards of its awards. As part of this process it has developed a Code of Practice for HE, to which the universities have to demonstrate compliance. It has also published a series of National Benchmarks for various subject areas, against which institutions are required to compare themselves at the planning and delivery stages in the educational process.

The ‘Business Context’ within which an engineer works is discussed at length in the QAA Engineering Benchmark’s statement on General Transferable Skills. The definition embraces the need for graduate engineers to demonstrate abilities in Business Management, Accounting, Project Management, Quality and Marketing. This document is more detailed and prescriptive than, for example, the Institution of Mechanical Engineers Educational Base, the IMechE’s own standards document for curriculum content. This is because it describes the ‘threshold’, ‘good’, and ‘excellent’ standards for student achievement within a list of Key
Skills, and requires universities to map their course provision against the benchmarks within published programme specifications. Each institution defines its own ‘mapping profile’, allowing each programme to have its own emphasis within the overall envelope of the benchmark. However, the very prescriptive nature of this document means that universities are given very clear guidelines about what elements of a business strategy they should be including on their courses and, in the absence of little other guidance, this is welcome.

The UK Engineering Professor’s Council (EPC)

In parallel, the Engineering Professor’s Council embarked upon an exercise to define in a coherent document the Output Standards expected from all undergraduate engineering courses. The EPC work is thus rather more all encompassing than the QAA Benchmarks, but is significantly more succinct. This document also focuses on the industrial and business context both in its commentary and in the output standards statements. These include guidance to: ‘take account of risk assessment, and social and environmental impacts, in the setting of constraints (including legal, and health and safety issues)...recognise and make critical judgements about related environmental, social, ethical and professional issues’10. However, despite the recognition by the EPC that the business-context should be all encompassing, we feel that there is a lack in the specific guidance given on what aspects of business are important and thus should be included in a course.

Where are we now?

The Engineering Council’s latest guidelines for professional engineer requirements, UK SPEC11 still requires UK HEIs to include business skills within the curriculum, but with little detailed guidance. Individual professional bodies, for example the IMechE, give rather more detail. However, as we have shown, the strongest guidance comes in the form of the EPC Output Standards work and the QAA Engineering benchmarks.

The QAA statement is more prescriptive both on what aspects of business should be included and what standard it should meet. The EPC’s statement, on the other hand, does not provide a specific standard at present. Rather the EPC provide some guidance in the form of exemplars or simply state that students should work at a level appropriate to the course. The EPC statement is useful, however, in that it ‘sees’ its Key Skills as being integrated into all aspects of engineering courses, whereas the QAA statements discuss their Transferable Skills as discrete areas of programme content, an example being mathematics. In sum, we see the EPC’s statement as providing more encouragement to teachers to have an holistic strategy for the inclusion of business in its courses across a variety of disciplines, rather than placing it as external adjunct to other areas of programme content. It does, however, lack clear guidance as to the ‘thrust’ of the business curriculum.

So, engineering degree curricula are now constrained within a broad framework defined by the QAA, with which all universities must comply. Engineering departments wishing to accredit their engineering provision also have to demonstrate inclusion of topics defined by the Engineering Council and further amplified by the relevant engineering institution. The QAA, the EPC, the Engineering Council and the engineering institutions have all clearly stated the need to include an appropriate business focus within the engineering curriculum. Between them they tell us we need to look at the key themes of:
• marketing
• quality and project management
• human resources
• leadership

However, although we agree that the above themes are important, this list does not provide us with all the answers. In the next section of this paper we will examine these key themes and also seek to outline our ideal business and management-focussed engineering curriculum. This will involve the introduction of two further themes which are equally important: knowledge management and strategic management.

Marketing

An engineer may have an excellent product, but if there is no clear route to market or ability to satisfy the needs of the customer then the product will not be successful. Curtis puts it succinctly: ‘Engineers have only a white lab coat to lose and the world to gain by taking the wider business and marketing perspective’\textsuperscript{12}. It sounds so simple to say, but is it that easy? Marketing is much more than just organising events. Today’s approach needs to acknowledge competitor knowledge, innovative ideas, and satisfying the client through cutting-edge thinking. However, such thinking is not very common in many engineering businesses. Therefore, it is vital that today’s engineering curriculum should put a focus on this area.

Quality and Project Management

Closely linked with these marketing skills there is a need for enhanced quality and project management skills. Concepts such as Total Quality Management should progress from being seen purely as "add-on" tools to becoming part of an ongoing process promoting continual improvement. The pursuit of continuous improvement requires clear leadership, a focus upon the customer and staff participation in quality initiatives using the correct quality systems and tools.

Human Resources

Although the pursuit of quality has been difficult for many organisations, one of the key factors in success is the way companies have emphasised their human resources. An organisation's human and intellectual rather than physical assets are sources of competitive advantage as Becker and Huselid\textsuperscript{13} argue that rather than a cost centre, HR should be seen as an investment to develop and maintain the firms infrastructure. Staff need to be helped in learning to learn and keeping up-to-date with developments in such areas as changing ethical issues. Underpinning this is the vital ingredient of succession planning, a key factor for well-motivated employees.

Leadership

Human Resource Management has a wealth of information regarding leadership that is recognised as one of the essential components of successful organisations. As Couldstone\textsuperscript{14} reports, research commissioned by The UK Industrial Society found that organisations want:
Leaders, not bosses, with qualities to help ensure people perform well without being watched.
Flat structures where people can work with minimal supervision in a trusting environment.
A wide range of people to be able to lead projects, behave responsibly and take on leadership roles as required.
People to be responsive to customer demands and able to move more quickly when faced with changing environments.

It is interesting to note the distinction in focus between managers, who look to the specific activities of the here-and-now and leaders who have a clear vision for the future.

However, although the four themes of Marketing, Quality and Project Management, Human Resources, and Leadership are clearly important, we have not been given the whole picture. We believe that two vital themes have been missed: those of Strategic Management and Knowledge Management. These themes, together with the previous four, are represented as slices of a cake in Fig 1.

![Figure 1 Success on a Plate](image_url)

Here, the outer rim, or plate, is seen as the Business Environment, or Commercial Context within which the engineer operates. It is this 'success on a plate' which we believe all engineers should strive to achieve through understanding and ability to manage each of the six themes identified.

Why do we feel that Strategic Management and Knowledge Management are essential to the engineering curriculum? Given the changing business environment there is an increased need for businesses to be able to understand both the customer and the competition, and to develop clearly articulated strategies in order to respond quickly to changing environmental trends.
This is the process of Strategic Management. Also, we feel that Knowledge Management is a key element of this Strategic Management process because the former relates to people, that is, the employees. Arie de Geus considers that 'companies that shed their employees are also throwing out their intellectual capital' and this attentiveness to the management of knowledge as inherent in Human Resources is something we will develop in the next section of the paper.

**Knowledge Management**

Mary Chapman, Director of the UK Institute of Management, delivered the 1999, Sheffield Management lecture entitled ‘Managing in the Knowledge Society’. She pursued the theme that in the global market place where physical resources and finance are widely available and products easily replicable, competitive advantage now springs primarily from the effective management of an organisation’s human and intellectual rather than physical assets. There was an early view that such management of knowledge would simply involve it being straightforwardly transferred from employees’ minds and onto databases. Quickly, however, this is has come to be seen as rather naive, and there has been no formal framework for managing knowledge in many organisations.

Gesturing toward the rationale for such a framework Halliday tells us "Ovum defines Knowledge Management as 'the task of developing and exploiting an organisation's tangible and intangible knowledge resources. The former includes patent licences and information held on databases. The latter include skills, experience and knowledge". More specifically, one of the keys to effective Knowledge Management, according to Woods and Sheina, is the inter-relationship of the different types of knowledge resource (as noted by Ovum), and he considers this as ‘best exploited by encouraging the development of virtual communities’. Indeed, Halliday considers that technology will enable those introducing Knowledge Management to their organisation to meet their greatest challenges which relate to people, process, content, change management and culture.

But what factors undermine the effectiveness of Knowledge Management? Birkinshaw argues that four key failures are due to:

- Firms ‘not sufficiently recognising that they are already doing it’
- Information Technology often being regarded as a substitute for social interaction
- Knowledge Management typically focusing too much on recycling existing knowledge, rather than generating new knowledge
- Most Knowledge Management techniques looking like traditional techniques.

To answer these and similar problems, De Geus has introduced the concept of the learning organisation, which requires a workforce that is trained to meet the challenges facing organisations in a culture of openness and trust, with an ability to challenge assumptions. De Geus considers that it ‘is up to business leaders to create the conditions to make the best use of the brain capacity and experience available’. This is what the future success of companies will depend upon.

So, while the business case for Knowledge Management may be understood, the practical considerations of adopting it as a strategy are challenging for both individuals and the
organisations that employ them. Therefore, future engineers need to be able to develop appropriate structures, systems, or organisational cultures that will support a successful exploitation of both knowledge and new technologies. Indeed, as Winch 19 argues, ‘the three facets of knowledge innovation and technological advancement are closely linked as drivers of competitive advantage, particularly in engineering and manufacturing’. Knowledge Management has come of age; rather than being merely a fad, it is now a well-established school of thought. Nevertheless, one of its clearest drawbacks is the difficulty in implementation, and this represents one of the new challenges facing engineers in this changing business-context. As we argued earlier, in many respects, Knowledge Management is one element of the Strategic Management process, the bigger picture, which is the final theme for discussion.

**Strategic Management**

Strategic Management can be defined as understanding where are you now, where you want to be and how you are going to get there (described in Fig 2). This process should be seen as continual for engineering in which the strategy formulators or ‘thinkers’ work together with the strategy implementers or ‘doers’: a relationship which can be seen to benefit from an understanding of de Geus’s concept of the learning organisation (discussed earlier). Organisations are made up of people: the learning organisation concept encourages the thinkers to do and the doers to think thereby emphasising continual improvement.

The Learning Organisation

![Figure 2 The Strategic Management Process](image)

(Adapted from Johnson and Scholes: Exploring Corporate Strategy 20)

To give an example of strategic management in action: several years ago a colleague of ours, working for the Business Planning Centre, visited a small engineering company in the centre
of Sheffield – ‘one man and a dog’. Our colleague was researching whether such small businesses had clearly developed strategies to help move them forward, or whether everything was driven by luck. The businessman did not really tune in to what our colleague was asking, and whilst in conversation the phone rang. It was a customer who wanted some of the man’s products by the end of the week. Our colleague observed the very customer-focussed approach of the business from the nature of this telephone call and after the conversation the man turned to my colleague and said: ‘If you look down the road all my competitors’ businesses have had to close, but I am still here. So don’t you come talking to me about strategy.’

This story begs the question: has the man actually got a strategy? Do you think he could predict the future? One might consider that the businessman was purely operational in his approach. However, on closer examination it is clear he understands his business and he has a strategy: one of survival. But does he know this? And, clearly, understanding and developing strategy is too important to leave to chance. However, he does know that continual improvement can only be achieved through quality and customer-focussed management skills.

Strategic Management is critical to all organisations. Kuprenas and Chinowsky\textsuperscript{21} argue that ‘in today’s engineering and construction industries the concepts of company loyalty, traditional competitors and employee development are changing at a pace that has not been previously been encountered in post industrial times’. Indeed, as mentioned earlier, changes within engineering business require changes in the skills of engineers. Mackenzie\textsuperscript{22} summarises that these changes ‘are leading to a more dynamic and agile manufacturing sector in the UK which in turn is placing increasing demands on the educational system for the skilled people it needs to compete in the global markets in the 21st Century’. The response to this, we believe, is an emphasis on both the management of knowledge and on more strategic thinking.

**What we have done at our institution**

We run a residential leadership course for our final year undergraduates within an assessed module of ‘Leadership and Teamwork’. This course, although an option has proved very popular and is always oversubscribed. Additionally, the six key themes have been incorporated and embedded within our postgraduate programme in engineering, particularly within our MBA in Industrial management. The UK Institution of Mechanical Engineers has accredited the whole programme of MSc courses, including this MBA as ‘advanced further learning’, which is an essential requirement for those graduates wishing to become chartered engineers.

**Summary**

Recent developments in the institutional and industrial contexts of engineering have required a sea-change in the way engineers are educated. Advances in Higher Education quality management and changes in the requirements of industrial bodies have forced engineering educators to become increasingly attentive to the business-based requirements of modern engineering graduates. Offering the analogy of a sub-divided cake, or ‘success on a plate’, we suggested that such requirements can be categorised in terms of six key themes, with the plate referring to the business context and the slices referring to each of six themes: marketing;
quality and project management; human resources; leadership; strategic management and knowledge management. The ‘success on a plate’ portions of cake can be covered in an engineering undergraduate and postgraduate curriculum.

References


