P044

Engineering Management – The Lost Discipline?

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Abstract: *The management content of engineering degree programmes today is variable. It is not uncommon for students to struggle to see the relevance of the subject to their engineering studies and consequently not realise the full benefit of this part of their education.*

With increasing interest in the relevance of higher education to a graduate's career after study, the argument can be made for a more thoughtful exploration of how we introduce the management discipline to developing engineers. The value of a sound grounding in management is often realised by engineers after graduation. Of all the specialist divisions and groups offered by the Institution of Mechanical Engineers for instance, it is the Management Group that is identified by most members as being of interest. Engineering Management is clearly relevant, so how do we make it more engaging for our students?

This paper will explore what we mean by engineering management and describe the approach taken at Aston University when introducing a Masters programme in engineering management. The motivation for students to enrol will be discussed along with the creative approaches to teaching and learning that have seen the programme become well established within the School of Engineering and Applied Science. Importantly, the future development of the programme and the opportunities to transfer experience to undergraduate engineering programmes will be considered.

Introduction

Engineering education has seen much attention in recent years (Royal Academy of Engineering, 2007; Spinks et al, 2007). For the future prosperity of the UK, the need to train and educate more engineers is well documented (CBI, 2007). Additionally, the Leitch Review of Skills (2006) has suggested that skills development and employer focused programmes need to form a more substantial part of the university sector. These act as drivers towards the development of more relevant and engaging offerings from higher education institutions.

Universities, employers and professional bodies all acknowledge the need for effective engineers to have skills in management and business. Often though, management teaching comes in the form of modules 'bolted on' to an established programme and taught by staff unfamiliar with engineering.

As a graduate engineer working in industry, my personal experience was one where I felt 'poorly armed' for the management aspects of my job. The gap between my knowledge and what was expected of me was noticeable and a key focus of my early development. With promotion the gap became wider until I responded and studied for

a management degree. It was then as though someone had 'switched on the light', my new skills and knowledge were in everyday use allowing my contribution to the company to become more effective. My engineering viewpoint was supplemented by an awareness of business that enabled balanced critical decision making.

The personal element to this paper is important. Having spent 14 years working in industry prior to entering academia, my story is consistent with many I have heard over the years. It is this 'need' that drives the desire to see engineering management recognised as a discipline in its own right.

What is Engineering Management?

Engineering Management effectively straddles the engineering and business subject areas. As such, its cross-disciplinary credentials are welcome but the subject itself can suffer from a lack of definition.

In today's engineering business environment, many engineers find that their path towards career advancement means a move into management. This step may seem natural, but to engineers it can often present a significant challenge. To properly understand this we should ask ourselves, why do people study engineering in the first place? Most often the choice is made due to an interest in the sciences and mathematics, areas that can, to a great extent, be well defined using numbers. This same logic holds as these people progress into the engineering profession. All the time that technical challenges are the focus, the engineer tends to feel comfortable with their work. Then there is the move into management! Working with people and the requirement for soft skills is often not the easiest of steps for an engineer to take. This is where engineering management comes in.

There are two ways to look at the Engineering Manager. They may be perceived as the person responsible for specifically managing the engineering processes within an organisation (O'Connor, 2005). Alternatively they could be playing the role of a more global manager within an engineering company (Chang, 2005). The difference is subtle. The first would still expect to be very much involved in the technical aspects of the business, as their focus would be only in those areas of work. The second considers a more rounded person involved in all aspects of the engineering business and likely not to be so involved in the technical detail.

Different organisations will require different characteristics to dominate in their engineering managers. Today, the 'well rounded' engineer is much sought after. This person is someone with an ability to understand a range of technical disciplines, be able to assimilate the information they generate and then direct, motivate and guide themselves and others to a successful technical and business outcome. They may have a technical specialisation, but they are expected to be knowledgeable about a broader range of subjects, sufficient to make informed business decisions. Goldberg (1995) talks about life skills for engineers as being a first step towards a career in engineering management. The development of these skills can ultimately lead to a leadership position, but for many the truth of the relation 'Technical Skills + Life Skills = Engineer' is the most important realisation.

The life skills are the key to unlocking the power of the people an engineer works with. They can help make things happen, encourage creativity and foster an atmosphere of enjoyment amongst colleagues. Looking back over my career, I can remember those times when a 'team spirit' was evident at work and the prevalent feeling was that 'no mountain was too tough to climb'. Engineering by its nature, is a

discipline that often throws up surprises, so the better equipped the engineer, the more likely the challenges are to be successfully overcome.

A good indication of the importance of engineering management is borne out by figures from the Institution of Mechanical Engineers (IMechE). From a total membership of close to 80,000 people, the Management Group is identified by 23,000 people as being of interest to them (IMechE, 2008). This makes the Management Group the largest special interest group within the Institution.

Looking at higher education, the engineering management course offerings are limited. The common feature is that they all tend to be at MSc level. This is understandable as the management knowledge should be built on a sound engineering foundation. Table 1 identifies the courses available in the UK under the title Engineering Management and two of the most common 'engineering related' management titles – Project Management and Supply Chain Management.

Subject	Number of courses	Sample institutions
Engineering Management	16	Aston, Exeter, Greenwich, Cranfield, Loughboro, Bristol, Northumbria
Project Management	34	Lancaster, Newcastle, Portsmouth, Warwick, Manchester, Bradford, Dundee
Supply Chain Management	24	City, Hull, Liverpool, Plymouth, Lincoln, Strathclyde, Glamorgan

Table 1 **Engineering Management MSc Courses offered in the UK (a survey conducted in October 2007)**

Specialist courses such as project management, supply chain management, and increasingly environmental management, are found in greater numbers than those in engineering management. The geographical spread is broad, so access to an 'engineering related' management MSc is not likely to be a problem for most students.

The reasons students give for enrolling on the engineering management programme at Aston reinforce the earlier argument made concerning the development of effective engineers for industry. The entry questionnaire for the 2007 cohort asked why the students selected the programme. The responses are given in Table 2.

What attracted you to the Engineering Management programme?	
The need to supplement my engineering knowledge with management / business knowledge	9 (45%)
The content of the course (structure and modules)	7 (35%)
To enhance my future job possibilities	4 (20%)

Table 2 **'Attraction of the programme' responses for 2007**

Of the 20 responses received, despite the three different classifications identified, the basic message is the same. The students see the programme and its content as important to developing their careers as effective engineers and gaining 'good' jobs on graduation. Talking to individual students, their passion for the course of study they are on is significant with comments such as "the course is the most relevant for

my future development as an engineer" being commonplace. To some students they see the programme as a way to "complete my engineering degree" acknowledging the demands of the ever-changing business environment.

Against this background, the approach adopted at Aston University to the development of the programme now and in the future will be discussed.

Developing the Programme

Engineering programmes are often taught using the traditional lecture and laboratory approach. Authors such as Race (2007) offer suggestions for innovative teaching practice to encourage student engagement. Similarly the Project Based Learning in Engineering (PBLE) initiative is an example of thinking and practice that has taken steps towards a more creative and relevant approach to teaching and learning for engineers (PBLE, 2003). Proponents of Problem Based Learning (PBL) consider engineering an appropriate application (Savin-Baden and Howell Major, 2004), but it does not come without its difficulties (Benjamin and Keenan, 2006). The features of an immersive learning environment – relevant, multi-modal and self-created – are attractive to the current generation of engineering students (Blashki et al, 2007). Work in the UK Centre's of Excellence in Teaching and Learning (CETL's) has explored creative practice in the engineering discipline. In particular the Centre for Excellence in Enquiry-Based Learning (CEEBL) at Manchester University has developed several case studies documenting change and the issues encountered (Moore et al, 2007). At Sheffield Hallam University, the Centre for Promoting Learner Autonomy (CPLA) has focussed on first year engineering students, exploring the introduction of PBL and the student's critical review of their experiences (Bramhall et al, 2006).

The context of this paper is an MSc in Engineering Management. The programme recruits graduates with a first degree in engineering who aspire to become senior managers in technically focussed companies. The programme is the first engineering management programme in the UK to be accredited by the Chartered Management Institute (CMI) and there is a desire amongst the teaching team to ensure that the programme becomes an example of best practice. To do this PBL has been identified as one of the key components of the teaching strategy, along with the need for variety in the range of approaches to teaching employed across the programme.

The programme has a conventional structure for an MSc programme with 10 taught modules each worth 10 credits and an 80 credit project. Of the 10 taught modules, 8 are core and 2 are electives. The cornerstone modules are strategic management, strategic finance, project management and management of change. These modules promote strategic thought, develop an awareness of the importance of finance to any enterprise and provide a framework for getting things done, all within the dynamic environment that is business today. The teaching team use a wide range of creative teaching strategies to promote engagement with the students and to ensure the relevance of the programme such that it meets the aspirations of the students. Constructive alignment (Biggs, 1999) is ensured through regular programme reviews, now reinforced by the requirements of accreditation. The goal has been to work towards developing a robust blended learning environment.

The teaching strategies employ lectures, in class exercises, on line tests, movies, role play, case studies, group work, presentations, guided reading, small group tutorials and PBL. One of the strengths of the programme has been the relationships that develop between staff and students. Recent work has identified the importance of the relationships between staff and students in effective learning environments

(Barnett, 2007; Clark, 2006), also the need for role models and teacher support in team activities (Aman et al, 2007). Good communication between students and the teaching team means that all are fully briefed and prepared for the learning and assessment strategy being deployed on the programme. The small cohort size of around 30 students has also been an advantage.

Although the university has a strong examination culture, the approaches to assessment are varied consistent with the teaching strategies. Having said this, the robustness of the assessment is a subject for review in the future.

In order to demonstrate the approach of the programme, two case studies are presented that describe the creative teaching and learning employed on two different modules.

Case Study 1 – Project Management

Project Management is a subject that can appear very mechanistic in nature when it is first encountered. The relevant professional bodies and text books (Gray and Larson, 2008) describe a framework that can be used in any project situation. Unfortunately for the developing engineer, the framework is only the starting point. Hidden are the many 'soft skills' that are often the key difference between project success and failure. It is within this context that PBL has been employed.

The key attribute of PBL is that it enables learning to take place in a practice-based environment, exactly what a developing engineer wants to experience. Groups work on problem scenarios to provide solutions. There are usually no 'right answers', so the groups will often develop a range of possible solutions. This range of solutions provides a valuable basis for the groups to then collectively discuss the merits of the various options. The groups represent the teams that we invariably have to work in when faced with real life. The problem is often complex and the path to a solution unclear, so the group is challenged to develop their approach and use their skills such that a successful and feasible outcome is attained.

Quite often the PBL exercise is targeted towards a particular area of the curriculum, in this case project management, so the students have an idea as to what may be the key points to explore in developing a solution. This does not preclude the students bringing in other areas of their studies and knowledge that they have gained from experience. The motivating factor for the students is often the almost tangible link between the exercise and what they may experience in their employment after graduation. For the lecturer though, they must learn to take on the role of facilitator rather than expert, something that they may not be comfortable with.

One of the main challenges of PBL is ensuring that the assessment reflects the approach to learning. This has been discussed in detail by Macdonald and Savin-Baden (2004). Key amongst the requirements is the need to ensure that the assessment supports learning. In order to achieve this it is often better to consider a multi-dimensional assessment strategy rather than relying on one single approach. By creating a professional environment and encouraging the students to develop and make use of a range of abilities, it would follow that the assessment should comprise different components. This has been the approach adopted within the project management module.

Within the project management module, the students are identified in groups and play the part of a project team over the course of the module. The project is defined, the company they are part of introduced and the tasks they need to consider identified. Although the tasks follow the material covered in lectures, the groups have

the freedom to explore the subject and the solutions in their own way. They are required to meet milestones as in a real project situation, so the work is continuous throughout the 10 weeks of the module.

Example projects have been a contract to inspect rail in China, the development of technology for the International Space Station, implementing a new roller coaster at a theme park and the construction of a 50m swimming pool in Birmingham for the Olympics. In each case, the group members take on roles that they can grow as they wish. The milestones are met through presentations, meetings, briefing documents and the production of a project portfolio, as would be the requirements in a real project situation.

Although to make the project work, there has to be some detail in terms of specification, time and finances, a lot of the emphasis is on the way in which the group works together, makes decisions, presents its work and feeds back to senior management (the lecturer). These are the areas most commented on by students as being of value to them.

Formative and summative exercises are employed to help the students build a knowledge base outside the project, so the project focus is on application and the common issues encountered in practice. Student feedback has been positive towards the approach (Clark, 2005).

Case Study 2 – Management of Change

Unlike Project Management, Management of Change is less defined as a subject, so it presents the lecturer with more scope for creativity. The lecture material presents the students with ideas to consider and this is then reinforced through three approaches to teaching:

- case studies
- role play
- reflection.

Case studies are not as common a feature of engineering education as they are business education. As such, students need to be introduced to the method of study before the use of cases can become effective. To achieve this, the students are provided with some guidance notes and a case study is explored over two weeks in class, firstly in small groups and then as a whole class. This allows for plenty of discussion about technique as well as the material being studied. The students are then invited to study additional cases both as formative and summative exercises. The cases offer value in that they present real engineering / technology situations for students to analyse and discuss in an environment where alternative courses of action can be explored without risk.

The study is then taken a step further using role play. The case of a fictitious company is introduced and the students take on roles in the organisation and act out what may happen in the situations presented. The company is a small manufacturing company grappling with its growth strategy and the need for efficiency. As such, the class is presented with scenarios that consider a re-organisation, changes to production, a merger / acquisition opportunity and a company relocation.

The class is split into participants and observers. The participants are further split into the roles of workers, managers and shareholders. The role play takes the form of a company meeting or presentation and the focus is on the interactions that take place between the different stakeholders. The sessions are recorded using a video camera and used as the basis for later discussion. The discussion that takes place

immediately following the role play explores what happened and why, any 'flash points', what would have been a more productive course of action and how the experience relates to the ideas presented in the lecture part of class.

Initially some students are very nervous about the whole idea of participating in this way. Each student has two opportunities to participate and two to observe. Generally, the second participation is more confident and only rarely are there students who don't speak up. The exercise often starts out with a conflict situation developing, as can often happen in a real business. By the second round of role play situations, a more constructive air develops and the observers note the increased awareness of change interventions adopted by the participants.

The students comment on the transition from chaos in the beginning to a constructive solution in the later scenarios, as well as the increased confidence they feel they have developed in recognising and responding to change situations.

The final approach is a reflective exercise and personal to each student. Although it has been around for a few years now, 'Who Moved My Cheese?' (Johnson, 2002) is a good book to stimulate students thinking about their approach to change. The exercise requires the students to identify with one of the four characters in the book and to then explore why they think this and how they would like to develop themselves, all within the context of change. A characteristic of the responses to this exercise has been the openness expressed by the students.

These three approaches represent an evolution from developing knowledge, to putting it into practice, to the students looking carefully at themselves and their actions. These exercises, based around 'soft skills', do not always come easily to engineering students, so the challenges they represent can often be considerable. Despite this, verbal feedback at the end of the programme often identifies the role play and reflection as two of the most useful exercises experienced by the students.

Other considerations

The focus of the programme development to this point has been around two key areas – a passion for engineering management as a subject and the belief that an effective learning environment is critical. As a team we still have much to do, particularly in formalising aspects of the programme, developing our assessment and measuring the effectiveness of our approach. Unhindered by past practice, the programme has benefited from a creative energy that regards the student's time with us as part of a much bigger picture.

There are several issues that have arisen and will be reported briefly, as they have and will continue to initiate change. One aspect of modern teaching and learning that has not been discussed in any great depth is e-learning. Although it has many forms, the value adding component of technology must be demonstrated for its implementation to be worthwhile. Overwhelmingly to this point, the team's investment in e-learning has been small as the value of any investment has been unclear. As both staff and students often point out, "management is about people, so face to face interactions are more relevant than working behind a keyboard all the time". This will surely change as opportunities arise.

A useful recent introduction to the programme, driven by the accreditation requirements, has been that each student is now encouraged to develop a reflective electronic portfolio. The system that has been chosen for this is Pebblepad (Pebble Learning, 2008). This is an example of where the introduction of technology has value, as the students are now able to easily record the development of their career

in a way that allows them to make plans for the future and share their thoughts with others. Simply having Pebblepad available also promotes the importance of reflection within the academic environment and future life.

The School of Engineering and Applied Science Teaching and Learning Support Group reported in EE2006 continues to flourish (Clark et al, 2006). Now joined by colleagues from the School of Life and Health Sciences, this group continues to act as a forum in which colleagues are able to explore teaching and learning issues, problems and ideas such that module and programme offerings remain innovative and relevant. For the team members, this has become an important place to share and learn.

The diversity of the students on the programme is not without its problems. Quite often these can become learning experiences for all concerned. Disagreements between group members may create the feeling that 'the teaching strategies aren't working' but as you explore why they may have happened, you quite often discover that this is simply mirroring a situation that may occur in a culturally diverse project team anywhere.

With a culturally mixed student cohort, the opportunities to explore a global perspective on learning are present. In Australia, Stewart (2007) has explored student readiness for self-directed learning in a similar MSc programme with a diverse group of students and has highlighted areas of difficulty. This study will be used as a benchmark against which the Aston Engineering Management programme can be compared.

Students graduating from the programme have entered a range of different jobs – project managers, management trainees, entrepreneurs and consultants being the most popular. The success of the programme is ultimately measurable in the successful careers of the graduating students. By promoting communication with graduating students, we receive updates on the developing careers of graduates. A longitudinal study is planned in the future.

In November 2007 the following was received from a graduate of the programme and provides a testimony to the value of the Engineering Management programme.

"I am now employed by East African Breweries Limited, a subsidiary of Diageo. The company is the second largest in Kenya, but has high hopes of being the biggest drinks company in Eastern Africa by 2010. My new job title is Demand Planning Manager. The Supply Chain Management Department is just 2 years old in the company and I can see my opportunities for growth are enormous.

I have been told by different sources that I emerged first in a rigorous search for 12 management trainees from 8500 applicants. I was therefore removed from that programme and given direct employment. This, I largely believe, is due to the education and exposure I got on the Engineering Management programme".

Looking to the future

As was alluded to earlier, there are aspects of the programme that will benefit from review in the coming months. For the long term, the broader strategy of Enquiry-Based Learning (EBL) has been identified as appropriate for the development of the programme. The idea being explored is that the student experience will be focused around the operation of an engineering company or project rather than studying discrete modules. The MSc programme is a good candidate as it is self-contained,

has a student cohort of around 30 students and takes one year to complete. The overall objective is to develop a model that can be transferred to other programmes at both undergraduate and postgraduate level within the School.

Much of the current work on the implementation of self-directed learning in engineering has been about discrete examples. The strategy for the Engineering Management programme will be the implementation of EBL across an entire engineering MSc programme and the gathering of student and staff perspectives on the changes implemented, thus providing a rich evidence base. An essential step will be the development of full and open induction sessions for students and staff such that any training needs are identified at the outset (Baillie, 2007).

The overarching aim will be to embed and evaluate an approach to learning and assessment that will develop engineering graduates as reflective professionals.

Beyond this, in common with many MSc programmes, the part time programme structure needs to be fully developed. A programme such as Engineering Management has potential appeal to working professionals, so time invested in this development is important, particularly when considering the Leitch Review.

Conclusions

Engineering Management is a subject that needs to receive more attention. It has tended to become lost amongst the wealth of business and management focused MSc offerings from universities across the UK.

The needs of engineers require attention if the graduating students are to become effective professionals. A key aspect of their education should be a coherent grounding in management knowledge. Engineering Management programmes can offer the appropriate learning opportunity.

With so many engineers expressing interest in the management discipline it is pleasing to see professional bodies such as the IMechE developing links with the CMI. The professional engineering bodies must continue to develop a more robust approach towards management education for their members as stories of difficulty and failure are still too prevalent.

In describing the development of an Engineering Management MSc at Aston University, the paper has emphasised the need for variety in the teaching and learning strategies adopted in order to maintain the relevance to the profession and the creation of an effective learning environment.

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