Proposals for Strategic Development of Engineering Management Education aimed at Improving Business Outcomes

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Abstract: This paper points to perceived deficiencies in teaching management knowledge and skills to engineers. There has been a largely ad-hoc approach to the inclusion of management in engineering degrees that was not based on objective research. There is anecdotal evidence that employers and professional institutions are dissatisfied with the management abilities of new graduates and that this may be adversely affecting the strategic competitiveness of engineering organisations. A literature review of teaching management to engineers is presented and research is proposed that will objectively evaluate the effectiveness of current engineering management education teaching strategies with a view to recommending more effective methods for the future.

1 Introduction

The art and skill of management has become a prime imperative for future graduate engineers. Many researchers have commented on the need for engineers to attain managerial skills, either at university during their initial degree or later by undertaking a Masters degree (either a specialist degree or an MBA). However engineers undertaking a post graduate degree, particularly in management, would appear to be in the minority. The Henley Management College report (The Royal Academy of Engineering, 2006) commented that business skills are rated as relatively unimportant (averaging about 2.65, as compared to practical application at 29.01). One comment made was that the students tend to learn these skills as they go along whilst another comment made was that engineers are usually the last people in any business to realise that business skills are important. The survey contacted, by questionnaire some 8,000 companies with a useable return of some 444 completed questionnaires. This is a return rate of approximately 5.5% and appears to cover engineering firms only. As a percentage of engineers will manage manufacturing and other types of industries this appears to limit the value of this survey. Engineers Australia accreditation criteria for Professional Engineers (EA, 2007, document P05) list under PE3 Professional Attributes various managerial type skills that must be attained and in Document S02 Accreditation Criteria Summary (ERA, 2007) again various managerial skills are listed under Section 4.2.4 Personal and Professional Skills Development. However there are no precise details as to time and resource commitment required to teach these in an undergraduate program. Previously Holfield and Thomas (1999, p229) had made the comment, with regard to the British scene, that

> '*British management and managers have …… been castigated for an apparent lack of professionalism. This has been equated with the lack of relevant professional qualifications. By this we mean that people who end up in managing a team, department, or even a division, usually have (in industry, for example) a first degree in Mechanical Engineering, but by implication, know nothing about, say, motivation or the mystique of managing other people.'*

The Association of Professional Engineers, Scientists and Managers conducts yearly surveys of remuneration for Australian based engineers (and others).They use a five part Responsibility Level classification with the highest three (3) levels containing management responsibilities. This indicates the overall need for engineers to attain management skills as the higher the level the higher the salary (APESMA, 2007)

2. Literature Review

A large body of scholarly literature has identified that engineering management should be considered an integral part of the skills and attributes that a graduate engineer should possess (Brisk (1997), Carmichael & Gibson (2001), Kocaoglu (2003), McCahon and Lavelle (1998), Nambisan and Wilemon (2003),Wilkinson & Thomas (2002) and others).

A short review of the development of engineering management education (EME) and in particular engineering management has shown that this field is a serious area of concern to engineering educators. One of the those areas of concern questions whether, it is possible to blend a hard fact driven education, such as engineering, with a discipline that seeks *optimal* solutions as opposed to an *optimum* solution. With optimum solutions the solutions usually meet only one criterion and are definitive whereas an optimal solution aims to satisfy a range of criteria and often is the 'best fit' solution. In an optimal solution what was a good decision today may not be tomorrow as criteria change within the decision making area.

Whilst EME is widely agreed to be important, there appears to be little literature on the needs and perceptions of employers in relation to the skills and attributes that they perceive as being either essential or desirable for graduate engineers and the resulting influence this has on business performance. Universities generally list the graduate attributes for engineers as including management skills and imply that they are identified as important and key attributes. However these attributes lack clarity and have diverse explanations of what is required and vary in their emphasis.

Research on the general attributes and skills required by an engineer is mostly discipline based and is covered by a small range of authors. A generalised list of authors is as follows - Gibson and Carmichael (2001), Chisholm & Burns (1999), Editorial (2004) Holfield and Thomas (1999), Rifkin et al (1999) Plonka et al (1994), Edum and Fotwe (2000). Of these some authors have attempted to define these general engineering skills without a particular reference to managerial skills.

Robinson et al (2005), working with an aerospace company identified 42 competencies for design engineers. They were then divided into six competency groups. These were:

Personal attributes
Project management
Cognitive strategies
Cognitive abilities
Technical abilities and
Communication.

Of the 42 attributes identified approximately 50% could be generally classified as managerial attributes. These include such attributes as motivation, problem solving, process management, ethics and integrity. Surprisingly there is no mention of financial skills. This is surprising as financial skills would be assumed to rank highly on any list of management attributes for engineers

Other authors who discuss the problems and benefits of EME are Pulko and Parikh (2003), Fink et al, (2002), Adams, Turns and Atman, (2003) and Chinowsky and Diekmann, (2004). All are viewing EME from an academic viewpoint and as such the view can be biased in regard to what 'academia' wishes to teach engineers. Adams, Turns & Atman (2003) look at research-based education, Fink et al

(2002) look at problem based leaning and its effectiveness in an international context and whilst Pulko & Parikh (2003) examine EME from a pedagogical basis.

The need for engineers will likely continue to grow as the economy and globalisation continue to expand. Engineers over the next decade will require different attributes and skills. The attributes that will be needed of future engineers, apart from their discipline based skills could be summarised as follows (Liyange, 2001, Gibson and Charmichael, 2001 and Thilmany, 2004):

Liberal arts
Business and law
Social sciences
Technology and engineering and,
Physical sciences

Midwinter (2000) developed these principles into a layered model which was adapted by Gibson and Carmichael (2001) (Figure 1) featured below which incorporates the above with the cross purposes of understanding and applications.

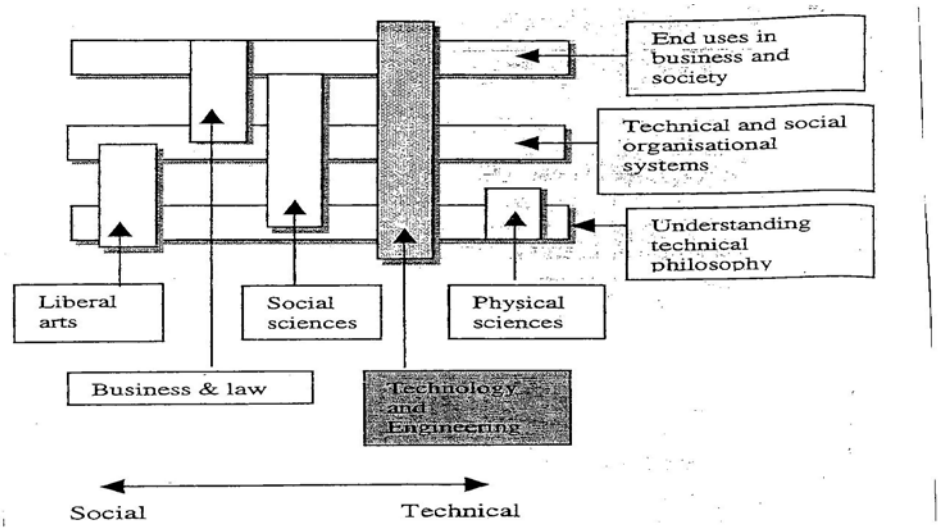

Figure 1 Adapted Layered model showing unique range of discipline in engineering and technology. (Gibson & Carmichael, 2001)

This model encapsulates the way in which management can be considered and applied. The authors continue;

> *"Financial restraints and exploding technological complexities are affecting universities' ability to offer universal solutions that will allow engineers and technologists to fully cover (the) breadth and depth in their undergraduate programs. ….*
>
> *(Gibson & Carmichael 2001, p 13)*

The type of education engineers will require will be both discipline based as well as social science (management) based. It is recognised that it is difficult to include extensive coverage of both within a four (4) year degree course. Taking into account that the engineering accreditation process has accepted that between one-eighth and one-quarter of an engineering curriculum should be devoted to managerial skills. (Wei, 2005) a solution needs to be found. However there is a lack of clarity and agreement on what constitutes the essential managerial skills for undergraduate engineers

3. Strategic Imperatives: Engineering Managers' Skills and Abilities

All authors reviewed thus far have identified problems with EME. The varied topics taught in or recommended for management education across the papers reviewed and what constitutes this discipline requires clarification, where this discipline will be taught, who will teach it and at what level will the courses be offered. Underlying this dilemma are the questions:

> What special skills (both technical and managerial) will future engineers need?
>
> And how and by whom will these various skills best be taught?

In the context of this review engineering management is considered those skills as typically taught in a Commerce faculty or a Graduate Business School. That is, the 'softer skills' for example the skills of management of financial and human resources.

These considerations are not new. In the 1955 R.L. Katz in the Harvard Business Review (HBR) listed out the skills of an effective administrator (manager). These were listed as

> *Technical – [he/she] need[s] sufficient technical skill to accomplish the mechanics of a particular job for which he is responsible*
>
> *Human – [have] sufficient human skill in working with others to be an effective group member and to be able to build cooperative effort within the team he leads.*
>
> *Conceptual – [have] sufficient conceptual skills to recognize the interrelationships of the various factors involved in his situation which will lead him to take that action which achieves the maximum good for the total organization.*
>
> *(Katz, 1955 p42)*

This seminal paper was reprinted as a HBR Classic in 1974 with the additional comment that all managers, whatever their level will need some skills in all these three areas. In 1986 HBR again reprinted sections of the paper and in 2004 it was again revisited by Peterson & Fleet (2004) who expanded and modified some elements but still stayed essentially true to Katz's, original statements.

From this series of papers we can postulate a summarised series of management skills that it is felt that graduate engineers should possess;

Human skills	- Communication
	- Motivation
	- Leadership
	- Decision making
	- Innovation
	- Group dynamics
Conceptual skills	- Financial
	- Cost analysis
	- Customer relationships

Whilst this is a shortened list it does outline the areas that should be considered when evaluating what management skills a graduate engineer should possess.

4. The Future

The type of engineer needed in the future will depend on the changes in both the developed and developing world in which the former is moving rapidly to become a service economy and then onto a knowledge economy with its changing requirement of engineering skills, whilst the developing countries will likely still need traditional engineers for some time. However it is believed that this time frame is shortening rapidly (Wei, 2005).

Brisk (1997) attempted to forecast the type of engineer that will be graduating in 2010 and has made some very interesting comments, particularly regarding the gender split that he believes will occur. He believes that culture of engineering education must change from being male dominated to a more gender balanced state. Also engineers must become more socially and community aware. He also comments on the differing directions that engineering education will take regarding sustainability and environmental issues.

He also comments (p 4) that engineers must obtain vastly improved communication skills and he also highlights the need for engineers to be capable of working in teams and also of becoming *'multi-discipline generalists'*.

As can be seen from the above authors EME is of concern to many researchers and many are questioning the methods, content and outcomes.

Engineers are being asked to perform more and more tasks and, both in Australia and overseas, they are being asked to manage engineering and company assets. In addition the decisions that they make daily can impact severely on the finances and the well being of an organisation. Engineers are also being asked to demonstrate competency and transparency in their decision making.

Based on the above literature review very little has been discovered regarding the effect that engineers can have on the outcomes, financially or otherwise, of all types of organisation and also, how the current education of engineers and their attributes can affect the business performance of an organisation.

There appears to be consensus between engineering employees and the engineers' professional institutes on the need for 'management' to be included in engineering degrees. It appears that whilst 'management' has been included since the early nineties, many, from both employers groups and institutions, are continuing to suggest that business performance has not improved and that engineers remain somewhat naïve about the business side of their engineering endeavours. It seems that there is a distinct possibility, which is to be investigated in this research, that current efforts towards management education in engineering degrees are ineffective.

Similarly, there is anecdotal evidence that a substantial portion of undergraduate engineering students are poorly motivated by management subjects – 'not seeing their relevance' and not really understanding the future needs of their profession.

Thus it can be postulated that there is a gap in the knowledge between what managerial skills a graduating engineer should possess, what those skills should be and how these skills may be defined as attributes of a graduating engineer.

5. Research Proposal

The aim of the research currently being developed is to evaluate the knowledge and attitudes of engineering students to the concepts of management skills. The research will involve surveying first year students (those commencing an engineering degree in 2008) on their attitudes to learning about engineering management. This initial 'pre-test' survey will be followed up with 'post test' surveys at the completion of first year. There will be a pre-test survey carried out with second year students in early 2008 and also a follow up post-test survey at the end of the year. The survey research will also

look at the attitudes of students to participation in the current voluntary SAE racing car project (an innovative problem-based learning initiative with an emphasis on learning management process rather than content) and their view as to how they perceive this project in relation to developing management appreciation and skills.

Action research (Carson et al, 2001, Blaxter, Huges & Tight, 2001) will also be used to research student attitudes to and learning of engineering management, with the annual race car design and build project that is organised by the Society for Automotive Engineers (SAE project) being researched as a case study. The aim is to evaluate the impacts of problem based learning as a method for instilling managerial concepts within the SAE group. The researcher embedded within the SAE group and will be actively involved in the various aspects of the project. The research methodology will involve questionnaires (longitudinal), face to face discussions, group activities and observer involvement in the project.

6. Conclusion

It appears that the call for management to be included in engineering degrees is not new. There is anecdotal evidence that both employees and professional institutions have held a view for some time that engineers are not given sufficient skills and insights to enable them to function effectively in modern organisations. Further there is a view that the resulting performance and efficiency of engineering organisations is adversely affected. However, there appears to be very little objective research to support these views. In the past there appears to have been an attempt to incorporate management content into engineering degrees. However, the effectiveness of this has not been demonstrated. There is further anecdotal evidence that employees and institutions remain dissatisfied with the lack of mastery of these skills in new engineering graduates. There is also a view that graduates are insufficiently conscious of the role of management in engineering and perceive little need for it. Research proposed here is designed to test hypotheses that

> (i) there is lack of appreciation and understanding of the role and importance of engineering management in current engineering students,
>
> (ii) engineering students' attitudes to engineering management education change during the academic year,
>
> (iii) some teaching and learning activities are effective for influencing or developing students' attitudes towards and understanding of engineering management.

Investigative methods will include surveys of student groups and a study of an innovative management teaching approach (SAE Project) with a view to proposing more effective strategy for teaching engineering management.

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