Management Education for Engineers

Peter Childs
University of Wollongong, Wollongong, Australia
pchilds@uow.edu.au

Peter Gibson
University of Wollongong, Wollongong, Australia
peterg@uow.edu.au

***Abstract**: This paper considers the notion that for the majority of engineers, the development of managerial skills will be essential and cannot be 'picked up on the job'. Engineers will, increasingly need to understand the interaction of design with quality, sustainability, commercial and product planning, organisation, management of people, team work and finance. This paper considers the need to develop managerial skills The two disciplines, Engineering and Management have enjoyed a rather difficult relationship for some time. Each needs the other because complex engineering tasks cannot be carried out in an increasingly challenging business environment without an integrated management focus. Engineers are finding they need to take on more complex tasks that include very significant managerial issues. Most engineering faculties have attempted to teach managerial skills in their engineering curricula. However, management has often been viewed as secondary to technical skills and hence does not encompass the integrated range of skills needed. This has not motivated students to become interested in and committed to the management aspects of their future profession with the result that management education for engineers remains a problematical issue. This paper considers some of the contemporary literature on teaching management to engineers. Some ideas are discussed, for future research to be carried out by the authors, aimed at documenting current shortcomings with a view to developing a more effective future strategy for engineering management education.*

Introduction

"For the majority of engineers, the development of managerial skills will be essential and cannot be picked up on the job. The engineer will, in general, increasingly need to understand the interaction of design with quality control, commercial and product planning, organisation and finances, and will need to develop the managerial skills of financial control, industrial relations and marketing."

This statement was made by Lord Flowers, FRS, Rector, Imperial college of Science and Technology, London at the Second World Conference on Continuing engineering Education, Paris, France in 1983 (cited by Martinec (1984)). Engineers are finding they need to take on complex tasks that include very significant managerial issues. These tasks include a strategic focus, financial management and control, quality management, human resource and stakeholder management and industrial relations. In more recent times, due to the nature of their technical knowledge and education, engineers are also finding themselves leading the crucial thrust towards sustainable engineering business. However, university education has tended to rely on the knowledge of engineering technology experts who have little inclination towards engineering business and resulting commercial challenges of the 21st Century. University engineering education can no longer be described as 'basically scientific and technical in nature' and must be integrated with a knowledge base associated with Commerce and Business. Most engineering faculties have attempted to teach managerial skills in their engineering curricula. However, this has often been approached as secondary and 'bolt-on' to the technical skills and hence

does not fully encompass learning the integrated range of management issues and skills needed. This has not motivated students to become interested in and committed to the management aspects of their future profession. Consequently, problematical teaching of management areas is an issue for many Faculties of Engineering. Employer dissatisfaction has also appeared because new graduates are not orientated to meet engineering management challenges and consequently they cannot immediately contribute to business outcomes in many engineering organisations. Engineers tend to be uncomfortable with management aspects of their profession because engineering is considered a rigorous, scientific discipline whereas management is a social science discipline, taught by case studies, anecdote and other non quantifiable methods. Many students chose engineering because they did not wish to study in that way, leading to further compounding of the problems. This paper attempts to describe and review the managerial skills that will be needed by graduate engineers to allow them to perform to satisfactory levels within the current multiskilled work environment and better meet the needs of employers. The history of management skill identification is reviewed from the work of Katz (1955) through to the present and a list of the identified managerial skills needed of a manager is presented. This list is then modified to highlight those that the authors suggest as being relevant to the training of a fully rounded and competent graduate engineer.

Engineering Management – What does it mean?

In general, when the term 'engineering management' is raised two views are taken. These are:

> 1) that this is the skill of the management of engineers, engineering skills and engineering equipment.
>
> 2) that this is the skill of managing both engineers and other non-engineering employees in a practical commercial, non-commercial environment. The additional skills that will be needed for engineers to successfully manage in these environments will include human resources, strategic, leadership, financial, operational, marketing and others.

In order to differentiate between these two definitions in this paper the term 'Professional Management Skills (PMS)' will be used to describe the skills believed to be necessary for undergraduates or post graduates to allow them to participate fully in the running of an organisation and be fully conversant with the skills and attributes required for successful management of disparate groups of both professional and non-professional employees, in a timely and efficient manner. Whilst it is clear that employers are not reticent in expressing dissatisfaction in the management skills of newly graduated engineers, little has been discovered to date on the needs and perceptions of employers in relation to the skills and attributes that they perceive as being either essential or desirable in graduate engineers, and resulting influence on business performance. As such, the authors of this paper discuss their work to determine what employers really desire from their newly appointed graduates in terms of their management skills. The scant literature covering this aspect and the limited scholarly research on the attributes and skills required of an engineer generally, is mostly discipline based and is covered by a small range of authors. Some authors have attempted to define these general skills without a particular reference to managerial skills. The generalised list of authors is as follows - Gibson and Carmichael (2001), Chisholm (1999), Editorial (2004) Holifield and Thomas (1999), Rifkin et al (1999) Plonka et al (1994), Edum and Fotwe (2000) and others.

.

Muster & Weekes (1983) questioned the failure of the major Western nations to maintain productivity gains when compared to Japan in particular and Western Europe in general. Their analysis of the situation indicates that they believe there has been a systematic failure in the education of engineers initially and then a failure of engineering management education, although this has been addresses to some extent in recent times. Liyanage (2001), Gibson & Carmichael (2001) and Thilmany (2004) have all reviewed the needs and dimensions of engineering courses. They have all highlighted the need for engineers to study and absorb 'management concepts'.

The areas that these authors have highlighted are;

Liberal arts

Business and law

Social sciences

Technology and Engineering and

Physical sciences

Wei (2005) has also posed the question 'what type of engineering management education will be needed in a post-industrial world?' In reviewing current education he comments:

' It has always been a point of tension to achieve both breadth and depth in 4 years, and the engineering accreditation process has accepted the notion that between one-eighth and one-quarter of the engineering curriculum should be devoted to humanities and the social sciences'.

Wei continues to review 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, whilst the developing countries will continue to need traditional engineers for some time. However, it is believed that this time frame is shortening rapidly. This short review of the development of engineering management education has shown that this field is an area of concern to engineering educators. This area 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.

Professional Management Skills (PMS)

In the 1955 paper by R.L. Katz in the Harvard Business Review (HBR), listed his understanding of the skills of an effective administrator (manager). These skills were listed as follows with the authors' comments in parenthesis:

> *Technical – need sufficient technical skill to accomplish the mechanics of a particular job for which he is responsible (*these skills would presumably be part of an undergraduate degree curriculum)
>
> *Human – (have) 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.* (generally not taught as an integral part of an undergraduate degree)
>
> *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.* (generally not taught as an integral part of an undergraduate degree) *(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 of these three areas. In 1986 HBR again reprinted sections of the paper and it was revisited by Peterson & Fleet (2004) who expanded and modified some elements but still stayed essentially true to Katz' original statements.

Peterson & Fleet (2004) considered the history of management skills thinking traced through the examination of textbooks over the period from the mid-1980 till the present. They found that text space dedicated to Katz's theory has remained relatively unchanged. This has been assessed allowing for the fact that some authors whilst not acknowledging Katz have used his concepts. Others have fully acknowledged Katz's contribution. In their review, Peterson & Fleet also identified an additional seven skills listed in the texts alongside Katz's three skills. Thus, from this series of papers we can

postulate a summarised series of ten management skills that it is felt graduate engineers may need to possess. The ten attribute skills are as listed here and encapsulate current thoughts on the skills that a manager needs to be fully effective. These are Technical, Analytic, Decision making Human, Communication, Interpersonal Conceptual, Diagnostic, Flexible, and Administrative. These ally relatively well with those 'softer skills' identified by Robison et al (2005).

These attributes skills are being used by the authors of this paper in their research in the development of a questionnaire to assess the current status and success of engineering management education that will be sent to industrial and commercial engineering organisations to determine what they really want from their newly graduated engineers. This list outlines the areas that should be considered when evaluating what management skills a graduate engineer could possess. However it does not mention financial concept skills, quality management skills, marketing skills as well as other skills as discussed.

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 also comments on the differing directions that engineering education will take regarding sustainability and environmental issues. He also comments that engineers must obtain vastly improved communication skills and he highlights the need for engineers to be capable of working in teams and becoming *'multi-discipline generalists'*.

Holifield and Thomas (1999) also 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.*

Whilst engineers have a binding set of knowledge that allows them to call themselves engineers there is no similar system to claim the title of manager. The research of the authors of this paper attempts to highlight the managerial skills that will be needed by graduate engineers to allow them to perform at a satisfactory level within the current multiskilled work environment. The history of management skill identification has been reviewed from the work of Katz (1955) through to the present and a list of the identified managerial skills needed of a manager is developed and then this list will be modified to highlight those that the author suggests as being relevant to the training of a fully rounded and competent graduate engineer. Work by the authors that has attempted to characterise the nature of integrated engineering management and initiatives will also be reported and discussed at a later stage. The basis of the research of the authors of this paper is to ascertain what employers want their engineers to be capable of. For those that follow the first definition above then the engineering curriculum should suffice. However for those who expect their engineering employees to become professional managers (at some stage in their career) then the skill set required will be different. It will also be different for different applications as well as for different phases of the economic cycle.

The following is a discussion on the skills that a professional manager should possess (again based on the work of Katz and others). In this discussion the various traits are identified and a potential list of skills is developed. All authors reviewed thus far have identified problems with the concept of PMS outlined above and the methods of incorporating the relevant subject matter into the curriculum. One of the major problems is that there appears to be no firm agreement on what subject matter should be taught and what attributes a newly graduated engineer should possess. A review of the literature did not identify any areas of agreement of what management attributes a graduate engineer should

possess. A major paper reviewed by Robinson, Sparrow & Clegg (2005) surveyed design engineers in the UK on what skills they should possess to competently carry out their tasks. The tabulation of these outcomes is included in this paper and indicates the six groupings into which the authors categorised the skill sets identified. This survey was biased towards an engineering perspective but surprisingly identified many of the softer skills of management as put forward by Katz (1955).

The groupings identified are as follows;

Personal attributes

Project management

Cognitive Strategies

Cognitive abilities

Technical Abilities and

Communication

These groupings include up to 11 subgroups defining the various aspects of the group skills. When these are reviewed, a range of the softer management skills can be identified. These include such areas as;

Problem solving (possibly technical or managerial or both)

Decision making (possibly technical or managerial or both)

Task analysis (possibly technical or managerial or both)

Communication – (human relations?)

Thinks outside the box - (the big picture?)

Time management

Seeks support from others (group activities and working in a organisation)

Good interpersonal skills.

The surprising omission was financial skills, but this could be due the focus of the study being on design engineers and the group chosen for the study. More recently, it has also become necessary to add the need for new engineers to appreciate the need to manage engineering as an environmentally sustainable activity. This adds further complexity to engineering management teaching task. It is proposed that in the research of the authors of this paper that the work of Robinson et al be blended with the work of Katz (1955 etc) with later authors, Peterson & Fleet (2004). The work of Katz (1955 etc) and others is included as it reviews management skills from the 'commerce' side of an organisation. However, managing sustainability must also be included as an essential future dimension for engineers to manage.

Conclusion

The authors reviewed thus far point to problems with professional engineering management education. The varied topics to be taught in professional management education across the papers reviewed and what constitutes this discipline require clarification as follows:

- which subjects constitute this discipline.
- where this discipline will be taught, (e.g. in the engineering faculty or in the commerce or business school faculties?).
- who will teach it and at what level will the courses be offered.

Underlying this dilemma is the question of how engineers can be trained to satisfy tomorrow's requirements. Sustainability is clearly becoming a further management challenge for engineers. What skills will these engineers need, what skills will academics need? And how and by whom these various

skills will be taught? The aim of the authors of this paper is to answer that question and propose a list of skills be developed that can be put forward as those skills required by engineers and employers to allow the graduate engineer to seamlessly integrate into the organisation and be ready to assist in the attainment of the goals and objectives of the parent organisation.

From the research discussed it is the opinion of the authors that management skills are necessary for a graduate engineer to possess to enable to carry out their activities to add value to their employer organisations. To reinforce this view, face to face interviews will be conducted with a range of organisations that employ engineers to ascertain the necessary professional management skills that they would wish their employed engineers to possess. As described above, these two sets of data will be combined to develop a questionnaire that will be submitted to a suitable range of organisations to evaluate the needs of employers and close the perceived gap in the relevant literature.

References

Chisholm, C. U. & Burns, G. R., 1999, The Role of Work-Based and Workplace Learning in the Development of Life Long Learning for Engineers, *Global Journal of Engineering Education, 3,3*

Edum-Fotwe, F. T., McCaffer, R., 2000, Developing project management competency: perspectives from the construction industry. *International Journal of Project Management,* 18

Gibson, P. R., Carmichael, D. G., 2001, Future Challenges in Management Education for Graduate Engineers and Technologists, *8th Australasian Conference of Engineering Management Educators*

Holifield, D., Thomas, N., 1999, Continuous Professional Development: Why Improving Managers and Management is Difficult, *Global Journal of Engineering Education,* 3, 3

Katz, R. L., Skills of an Effective Administrator, Harvard Business Review, Jan- Feb 1955

Katz, R. L., Skills of an Effective Administrator, HBR Classic, Harvard Business Review, Sept-Oct 1974

Liyanage, S., 2001, Technology and Innovation Management Education in the Knowledge Economy – What Managers Need to Know, *8th Australasian Conference of Engineering Management Educators*

Munster, D., Weekes, W. H., (1983) The relevance of analysis and synthesis in management and engineering education, Engineering Management International !:287 – 298

Peterson, T.O. & Van Fleet, D.D., 2004, The ongoing legacy of R. L. Katz, an updated typology of management skills, *Management Decision*, 42,10

Plonka, F., Hillman, J Clarke Jnr. M., Taraman, K., 1994, Competency requirements in the Greenfield Paradigm: The manufacturing Engineer of the 21st Century, *Frontiers in Education Conference*

Robinson, M A., Sparrow, P. R., Clegg, C., Birdi, K., 2005, Design engineering competencies: future requirements and predicted changes in the forthcoming decade, *Design Studies,* 26, 2

Rifkin, K. I., Fineman, M., Ruhnke, C. H., 1999, Developing Technical Managers – First you need a competency model, *Research Technology Management,* 42, 2

Thilmany, J., 2004, New Skill Sets: a Growing Area of Graduate Education Mixes the Art of Management with the Technology of Engineering, *Mechanical, Engineering – CIME,* 126, 3

Wei, J., 2005, Engineering Education for a Post- Industrial World, *Technology in Science,* 27.