*Int. J. Engng Ed.* Vol. 10, No. 6, pp. 539–545, 1994
Printed in Great Britain.

0742-0269/91 $3.00+0.00


# Industrial Engineering in Australia*

JOHN W. H. PRICE
*Mechanical Engineering Department, Monash University, Caulfield, Australia*

*The paper describes something of the background of industrial engineering in Australia, and the work that is now being undertaken at Monash to develop the Bachelor of Engineering in Industrial Engineering and generate interest among potential students and employers. Some issues are the development of definitions of industrial engineering, identifying the core subjects and differentiating the degree clearly from management degrees and other engineering degrees. In the employment market we find employers throughout Australia very interested in the concepts, though they rarely advertise positions with the title 'Industrial Engineering'.*

## INTRODUCTION

THE CRUCIAL subjects of industrial engineering deal with the means of detailed study of work and how things get done. The real advantage of industrial engineering for a graduate is that it can be applied to any business where work is done and thus has particular relevance to service type industries as well as manufacturing; the subject is therefore very relevant to all the key growth areas in the economy.

Industrial engineering is not a large branch of engineering in Australia in terms of numbers of graduates. It is now only actively pursued as a degree at Monash University in Melbourne where there are about 25–30 graduates a year. While several universities have been involved in industrial engineering, they have tended to reduce their involvement. At present the only other course is in Newcastle NSW, but this took its last intake of a few students in 1994. Ten years ago there were more universities offering an industrial engineering course. Other universities teach some subjects which might be described as IE subjects, but usually in the context of a manufacturing or production engineering degree.

At Monash we see that it is very important to develop a course which is seen very much as an independent branch of engineering. As it has been developed, it deviates from our Mechanical Engineering course by two subjects as early as the beginning of second year. In the final year it has only some electives and one management subject in common with Mechanical Engineering [1].

## SOME DEFINITIONS OF INDUSTRIAL ENGINEERING

Two definitions of industrial engineering are 'the technical and human aspects of quality and productivity',and 'the design of complete productive processes'. The definitions do not perhaps clarify the situation entirely since nowadays everyone in business thinks these things are important. In many ways the definition of industrial engineering is clarified by differentiating it from other professions.

The key focus in industrial engineering is on technical description of what the workers are actually doing, and describing how the product or information on which they are acting is being transformed. This is very different to other branches of engineering. When dealing with production or manufacturing, the other branches of engineering will concentrate on the machines or the processes (such as the presses, the chemical reactions or the welding). An industrial engineer may be interested in these matters but the attitude and the techniques are completely different. Industrial engineering starts with mathematical descriptions of the work the humans do, and grows to a means of studying the entire productive activity.

When comparing industrial engineering to management there are many differences. Management courses contain many things such as leadership, accounting and finance, and marketing, but rarely do they concentrate on what is actually happening in the productive process. Although there has been a growth in interest in issues such as total quality management (TQM), even these techniques tend to be studied in generalized descriptions of how to enact change in the workplace rather than focus on the detail of the work itself or on the productive system. Industrial engineering not only concentrates on the productive work but also provides the means of quantifying it and scientifically improving it.

Table 1 gives an Australian official definition which is quite informative.

Industrial engineering as a profession sees itself moving into areas of wider scope than just studying the details of work. Industrial engineers are moving on from the detail of the study of efficiency to 'effectiveness and quality, [they are moving] from

*Accepted 28 July 1994

Table 1. Definition of industrial engineering and specific expertise areas

Industrial engineering is the engineering discipline concerned with the planning, organizing and operation of industrial facilities and processes for the economic, safe and effective use of physical and human resources. Industrial engineering is applied design for the integration of material, human and financial resources, and of production sequences and methods, optimum flows and layouts, and of work methods and procedures, labour organisation, and in economic evaluation of facilities, processes or techniques. Specific expertise areas include:

Industrial engineering practices
Materials handling engineering
Operations research
Safety and environmental engineering
Manufacturing process engineering
Methods engineering
Quality assurance and control

From National Competency Standards for Professional Engineers
Institution of Engineers, Australia, ACT, March 1993.

relatively small systems to large or macrosystems, from analysis and modelling only to integration of the whole system' [2].

At the undergraduate level it is necessary to be cautious as to how much these grand concepts can be introduced. In a degree it is most important to emphasize the basic skills. While the concept of moving to integration of whole systems may be vital to business, the young graduate has to be able to work with very definite analytical skills and tools. Just as a mechanical engineer must start with understanding the basics of applied mechanics before moving to design whole the aircraft, so industrial engineers must start with studying the individual work activity of individuals before moving to the total productive system. Systems integration is a concept that tends to be left until the last year of the course.

The lack of community understanding of the basic sciences on which industrial engineering rests has created the problem with understanding what appears an absolutely fundamental discipline. In many ways the sciences on which industrial engineering is based are simply poorly developed and offer a massive opportunity for research. The sciences might be identified as 'science of management' and 'science of operations', which exist independently of the type of business that is being studied: health care, airlines, banking, retailing or manufacturing. All businesses require analysis of quality, productivity, inventory and scheduling [3].

## THE NEED FOR INDUSTRIAL ENGINEERING

All businesses need high-calibre people who can analyse the productive system comprehensively, and who can design systems that can increase productivity and make products of higher quality. Businesses, however, are slow to grasp that there is actually a scientific way of doing these things.

The subjects of the industrial engineering degree are thus vital. The traditional approach to management skills in engineering was to pick up the techniques in an *ad hoc* fashion after they graduate. This occurs by on-the-job training, wider reading or by participation in short courses. In a graduate diploma in management or an MBA there can be found subjects which are included in an undergraduate industrial engineering degree (and probably in more detail). MBAs and graduate diplomas have achieved a high level of participation in Australia because engineers and other professionals find that in the workplace they are soon concerned with subjects such as quantitative decision making, facilities and work design, and quality management.

In 1991 in Victoria 1690 students graduated in engineering; thus our course accounts for only about 1.5% of local Victorian graduates or 0.6% of all Australian graduates. Victoria has the second largest population of Australian states and is the centre of manufacturing in Australia and home to nearly half the major industrial companies. It must be noted that many people who practise as industrial engineers have not graduated as industrial engineers in Australia. Many are immigrants, have transferred from other disciplines, or have upgraded from diploma type qualifications. The number of members of the Australian IIE is about 800 out of a total engineering population in Australia of about 60,000 (see Table 2). This gives a percentage of 1.3% of employed engineers.

This proportion of industrial engineering graduates would appear to be out of line with the needs of industry if measures such as the US situation are taken as a guide (see Table 3). In the USA industrial engineering is the fourth largest branch of engineers and accounts for 8.9% of all engineers (135,000 people). The best estimate of growth of the branch is 19% growth during the decade to 2000.

Job advertising for industrial engineers by name is not high in Australia. There are only a few such advertisements each month. However, there are a significant proportion of employment advertisements which fall into the category of engineering management. In the second half of 1992 this proportion was over 21% (IEAust survey of metropolitan newspapers). Such jobs may not, of course, be easy for fresh graduates to apply for. However,

Table 2. Australian Bureau of Statistics 1986 Census: number of engineers employed in Australia (data on graduations in Australia)

| Branch | | % branch | Male | Female | % female |
|---|---|---|---|---|---|
| Chemical | 1,935 | 3.3 | 1,831 | 104 | 5.7 |
| Civil | 18,637 | 32.9 | 18,332 | 305 | 1.7 |
| Electrical | 19,611 | 34.6 | 19,305 | 306 | 1.6 |
| Mechanical | 11,754 | 20.9 | 11,669 | 85 | 0.7 |
| Mining | 1,890 | 3.3 | 1,861 | 29 | 1.6 |
| Other | 2,736 | 4.8 | 2,653 | 83 | 3.1 |
| Total | 56,563 | 100 | 55,651 | 912 | 1.6 |

Department of Education and Training statistics for total number of engineering graduates in 1991: Australia, 5156; Victoria, 1690.

Table 3. US Bureau of Labor Statistics engineering branches: 1990 employment and 'moderate' projection to the year 2000

| | People (000s) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Electrical | Mechanical | Civil | Industrial | Aeronautical | Chemical | Mining, nuclear petroleum | Materials | Other |
| 1990 | 426 | 233 | 198 | 135 | 73 | 48 | 39 | 18 | 347 |
| 2000 | 571 | 289 | 257 | 160 | 88 | 54 | 40 | 22 | 436 |
| Increase (%) | 34 | 24 | 30 | 19 | 20 | 12 | 1 | 21 | 26 |

we have identified numerous advertisements each week which could be applicable. These fall into categories such as

- Production, manufacturing or process engineering
- Quality management/control
- CAD/CAM, automation
- Manufacturing design
- Health and safety
- Scheduling and planning
- Shift engineer or plant supervision
- Bank analyst, business systems analyst
- Re-engineering
- Marketing
- Project management
- Logistics management
- Industrial engineering

Many of these categories were identified as important future employment areas in a recent survey of a wide range of Australian organizations [4].

## COMMUNITY RECOGNITION AND ATTITUDES

Industrial engineering is an important branch of engineering worldwide. The US situation is shown in Table 3 and the branch has a strong tradition in Germany, Japan and most industrialized nations. In Hong Kong the new University of Science and Technology is hiring 16 staff in industrial engineering.

Australia, however, follows the British tradition in education more than the US tradition, and industrial engineering is not as well recognized. Australia has also followed the UK in the area of workplace organization and unionism. In the UK the early industrial engineering movement was strongly opposed by the union movement and as a result the whole study of industrial engineering was suppressed.

However, the situation in Australia is changing. In Australia in the 1990s the focus in the industrial environment is on restructuring and pay increases through productivity gains. At Monash we are finding that the unions are often very supportive of scientific investigations of work practices. Consultative arrangements between unions and management have led to much of our external teaching. These programs have tended to be aimed at empowering the work force with industrial engineering methods so that they can think about their own jobs and how they can improve their own workplace productivity.

However, to focus on work study as the essence of industrial engineering is to ignore what vigorous growth this branch of engineering has undergone in the hundred years since Taylor first conceived of it [1]. If you take a modern industrial engineering handbook such as Salvendy [1], then the subjects of work standards, time and motion study, and related activities contribute only about five chapters out of 108 (the main chapter headings of ref. 1 are given on Table 4). In the Monash course these topics occupy one 4-point subject out of 196 points required for the degree.

Table 4. Main subject areas in Salvendy, *Handbook of Industrial Engineering* [1]

| |
|---|
| *Industrial engineering function* |
| *Technology* |
| Information technology |
| Computer-integrated business |
| Manufacturing engineering |
| Service technology |
| *Human dimensions* |
| Organizational design |
| Work design |
| Ergonomics/human factors |
| *Planning, design and control* |
| Product planning |
| Engineering economy |
| Methods engineering |
| Performance measurement and control of operation |
| Facilities design |
| Planning and control |
| Quality assurance |
| *Quantitative methods for decision making* |
| Probability theory and models |
| Statistics for industrial engineers |
| Computer simulation |
| Optimization |

## STUDENT DEMAND

Student demand for industrial engineering as such is not high because only very few 17 year olds in Australia have studied the engineering profession adequately to know that the branch exists and what an industrial engineering career involves. Indeed industrial engineering is significantly different in concept to the other branches of engineering, in its focus on processes rather than things, so it is not easy to stereotype with objects such as bridges, aeroplanes, computers, etc. Industrial engineering is not a choice that emerges naturally in high school students unless they know people who work in the discipline.

Since it is a branch that deals with large numbers of management concepts it is probably most attractive to students who do not think of doing engineering at all, even though their entry scores are adequate. These are students who may choose management or business degrees, computing or accounting. These students would have interests such as how organizations work, the relationships between people, multidisciplinary problem solving and having a management career path. This sort of interest profile suits industrial engineers as well. There are indications that a proportion of female students is one group that has interests aligned to those relevant to industrial engineering but may not presently be considering engineering careers.

Industrial engineers have significant advantages over graduates of purely business type degrees. They have a thorough base in engineering. A B.Bus. (Manufacturing Management) course, for example, has low levels of technical content. My personal experience of working in a manufacturing environment suggests that the most effective way for a graduate to lead tradespeople and other operatives is to try to know more about the techniques of what they are doing than they do. People of no technical background will receive little respect from shop-floor people when they are faced with practical problems. Indeed businesses are often faced with the complex multidisciplinary technical and human problems for which we train the graduates of industrial engineering.

Thus the problem is that some of the best potential students for industrial engineering do not even know that it exists. Moreover they do not understand the reasons why they should undergo the much more rigorous and lengthy training required of an engineer. To engage in a marketing exercise to overcome these problems requires an extensive long-term commitment addressed to a group of potential students not necessarily shared by the other branches of engineering.

## THE WORDS 'INDUSTRIAL ENGINEERING'

One of the biggest problems faced by industrial engineering is the fact that even in its homeland, the USA, there is not wide understanding of the meaning of the words. Industrial engineering includes nowadays such a broad range of subjects that it is suffering a name crisis [4].

While the term was originally always associated with manufacturing there is nowadays major employment of the graduates in the service sectors such as financial institutions, transport and distribution, marketing and retail. The Monash experience is that we see at least half our graduates going into these areas, and support from external organizations, e.g. Australia Post and supermarket chains, has been very enthusiastic. The word 'industrial' of course conjures up the vision of smokestack factories and is a major impediment to recognition of the range of tasks performed by industrial engineers.

One reflection of the name crisis is the wide range of terms used to describe activities related to industrial engineering such as manufacturing systems, production engineering, productivity and quality management, industrial effectiveness, systems engineering, bank analysis and others. The problems with the term industrial engineering certainly contribute to the problems associated with employer and student recognition. Within the university the name has such a practical ring to it that there are those who suppose it is not a field for fundamental research; though, of course, industrial engineering's claim to be an area of fundamental research is as good as any other engineering discipline.

The resistance to changing the term industrial engineering to something else resides primarily with the fact that these words have major assets associated with them. There are numerous working professionals who have these words on their testamurs and there are institutions, such as the Institute of Industrial Engineers, and journals that use the

term in their title. These facts mean that the term does have a reasonable level of recognition among those who need to know. The other resistance to change is that no one has proposed a wholly suitable replacement since all other terms seem to cut out a segment of activities in which industrial engineers have been successful. The concept of systems engineers seems to be a proposal favoured by some members of the IIE in the USA, but in Australia the term systems engineering often relates to physical systems such as the whole aeroplane or the whole pumping system and these ideas have little to do with industrial engineering.

The debate on this issue will undoubtedly continue for some time and it is entirely possible that Monash may be forced to reconsider the name of its degree as other universities have, e.g. Melbourne and NSW. One of the options that will have to be considered is retaining the basic industrial engineering course content but changing the name to a Bachelor of Engineering Management or some other similar title.

## INDUSTRIAL ENGINEERING AT MONASH

The industrial engineering course was established in 1980 and has a common first year with the civil, electrical and mechanical engineering courses at the Caulfield campus. The course falls administratively into the Mechanical Engineering Department. It is currently the smallest stream of engineering at Caulfield, attracting about 25–30 entrants a year out of about 180 students completing the first year.

While all engineering courses are under continuous revision because of technology change, industrial engineering is probably more sensitive to changes in other areas such as economics, industrial relations, social sciences and business management. As a result the course content of industrial engineering is in many ways changing more rapidly than other branches of engineering. Table 4 shows the chapter headings from Salvendy and these can give some guide as to a modern concept of the skills or tools with which an industrial engineer might need to be acquainted. Another listing of skills is shown in Table 5. Table 6 gives a list of desirable attitudes of an industrial engineer. This type of listing is much more general in style and in many ways these attributes would be desirable in any professional employee.

The Monash degree is being defined by reference to degrees in other countries, by reference to recent books and conferences about industrial engineering, and our own knowledge and that of our industry advisers and estimations of the needs of Australian businesses. The tables give an idea of some of the inputs that can be used to construct the concept of the degree. The subjects of industrial engineering are given in Table 7.

The industrial engineering degree has a number of very important management aspects to it. As one graduate said to me 'industrial engineering is at the leading edge of management sciences'. She also added that 'doing industrial engineering is like doing an MBA early in life'.

These comments are very encouraging and are a useful indication of the mission of industrial engineering. However, they also convey some of the difficulties in teaching this subject. Many people believe that undergraduates are insufficiently broad in their understanding of the world and not adequately focused on business-type problems to be really involved in management subjects. Some engineers have an additional characteristic that they regard subjects without a mathematics bias as being 'soft', though in surveying we also find high

Table 5. Some important subjects for industrial engineering and the approximate date of their development (modified from [3])

| | |
|---|---|
| Accounting | 1494 |
| Interchangeable parts | 1750 |
| Mass production | 1830 |
| Time studies | 1890 |
| Division and specialization of labour | 1890 |
| Organizational concepts | 1915 |
| Wage incentive plans | 1916 |
| Scheduling and planning | 1920 |
| Statistical quality control | 1929 |
| Tool design | 1930s |
| Plant layout | 1941 |
| Operation analysis | 1955 |
| Automation | 1955 |
| Reliability analysis | 1955 |
| Computer information systems | 1958 |
| Material resource planning (MRP) | 1965 |
| Total quality management (TQM) | 1975 |
| Just in time (JIT) | 1980 |
| Flexible manufacturing systems | 1980 |
| Quality systems | 1985 |
| Computer integrated manufacturing (CIM) | 1988 |

Table 6. Knowledge and attributes for industrial engineers (condensed from [4])

| |
|---|
| Industrial engineers must |
| have a sound foundation in science, mathematics and engineering |
| be skilled in technical problem solving and decision making |
| be able to lead conception and implementation of new techniques |
| understand the process of improvement and know how to manage it |
| be able to integrate problems with technical, human, information and financial aspects |
| have project management skills and good business understanding |
| be able to act in an entrepreneurial manner to sell their solutions |
| have a commitment to lifelong learning |
| focus on the client/customer needs and understand the fundamentals of a complete enterprise |
| have good communication skills and beresponsive |
| be able to use an international awareness to develop innovative solutions |
| have the highest professional standards, making valuable contributions to the community |

Table 7. Monash University, Bachelor of Engineering (industrial and computing)

**Level 1 (common to all branches)**
- Engineering communications[b]
- Computer applications[b]
- Electrical technology[b]
- Applied mechanics[b]
- Computer science[b]
- Mathematics[b]
- Physics[b]

**Level 2**
- Engineering management A[c]
- Engineering material science[b]
- Computer applications 3[b]
- Mathematics[b]
- Methods engineering[a]
- Computer applications 4I (computer control)[d]
- Mechanics of solids 1[d]
- Manufacturing processes[d]
- Fluids and energy[d]

**Level 3**
- Engineering management[c]
- Computer applications 5 (programming)[b]
- Computer applications 6I (industrial engineering applications)[a]
- Industrial project[a]
- Facilities planning and design[a]
- Quality systems and control[a]
- Design for production[a]
- Engineering accounting A[a]
- Process control[d]
- Engineering materials[d]

**Level 4**
- Computer applications 7I (industrial engineering applications)[a]
- Engineering management D[a]
- Industrial project[a]
- Production planning and control[a]
- Design of productive systems[a]
- Operations research[a]
- Health, safety and environment[a]
- Engineering accounting B[a]

Electives: select any two (normally one per semester) from
- Computer applications 8[a]
- Systems reliability[a]
- Automation and manufacturing[a]
- Systems[a]
- Fluid systems and management[d]
- Any other approved 4–credit point subject

[a]Industrial engineering subjects.
[b]Engineering common core.
[c]Subjects relevant to industrial engineering.
[d]Cross-discipline mechanical or electrical.

proportion of students indicating strong interest in management subjects.

The structure of the course means that the first two years are dominated by straight engineering and the most managerially oriented subjects are in the third and fourth year when the students are already more mature. It is necessary to create a cultural change in the students so they become accustomed to a world of complex and multi-disciplined problems with no set answers.

## CONCLUSIONS

The paper outlines some of the issues surrounding the industrial engineering degree provided by Monash University and the ways this course may be developed.

*Acknowledgements*—The data collected in this paper has been found in many places and I acknowledge the assistance of my colleagues, in particular, Peter Gregory and Damian Kennedy, and staff of the IEAust.

## REFERENCES

1. 1. G. Salvendy (ed.), *Handbook of Industrial Engineering*. Institute of Industrial Engineers and John Wiley, New York, p.5 (1992).
2. J. G. Bitcon, *The Future Employment of Professional Engineers: A Survey to Assess Niche Areas for Future Professional Engineer Employment*. Department of Employment, Education and Training/ Institution of Engineers, Australia (Victoria Division) (1993).
3. W. C. Turner, J. H. Mize and K. E. Case, *Introduction to Industrial and Systems Engineering*. Prentice Hall, Englewood Cliffs, NJ (1987).
4. G. K. Bennet and L. Voller, *Industry and Academic White Paper*, International Industrial Engineering Conference, Detroit 1991. Institute of Industrial Engineers, Georgia (1991).

Associate Professor **John W. H. Price** is the head of the Caulfield Division of the Mechanical Engineering Department at Monash University, which is Australia's largest university. The Mechanical Engineering Department operates on two campuses in Melbourne, and at Caulfield the specialities are manufacturing and industrial engineering. John Price was

**appointed to the university in 1992 after a career in industry in Australia and the UK. He has a BE and M.Eng.Sci. from Melbourne University and a Ph.D. from Imperial College, London. Apart from his interest in management areas he is one of Australia's leading consultants in the area of the design, operation, life assessment and failure of pressure vessels and pipework.**