RESHAPING ENGINEERING EDUCATION TOWARDS THE PRACTICING PROFESSIONAL

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Consider the turtle. It makes progress when it sticks its neck out.

The evolution of knowledge based economies coupled with the accompanying social changes is placing new demands on engineering education in meeting societal needs. The poor image of the profession reflects the lack of strong links between engineering and communal development. Restructuring of engineering curricula is needed to strengthen the professional practice and to make the profession attractive to higher calibre entrants, including women. An argument is presented for increasing the liberal arts and materials science components in engineering curricula, the first to broaden the professional practice, the latter to enhance engineering literacy.

INTRODUCTION

Engineering practice cannot be anything but a cultural artifact, the way of doing things, setting up the societal infrastructures reflect the cultural traditions that encompass engineering enterprise. It is therefore no surprise that engineering education flows from such cultural nexus; the structure and curricular of engineering education are anchored to societal beliefs and traditions. In continental Europe, new separate structures were constructed early in the 19th century to accommodate post-baccalaureate engineering education. In Britain the empirical tradition of Universities facilitated the entry of engineering as an extension of the existing schools and faculties of science.

Australia had inherited the British educational traditions. Though not all formal engineering education was delivered through the University system. In the state of Victoria in particular, a second string of engineering education was provided at the turn of the century. The technical colleges, admitted students at the mid-secondary school level and provided practical based education.

The diplomats of these colleges had lower status than university graduates in engineering. However this secondary system had considerable support from the employer groups and state governments, though there was a class dimension here. It reflected the prevailing British attitudes that engineering was an occupation for the labouring classes. An attitude that has not quite disappeared till this very day.

The introduction of four year engineering courses at post year 12 level by the successors of the technical colleges in the 1970's changed the landscape of engineering education in Australia. Research allocation by government bodies increasingly placed greater emphasis on fundamental science based research. In response, these institutions re-aligned themselves towards science based goals. All government based assessment criteria, accountability and yearning for parity of esteem transformed these engineering education providers to mirror the engineering faculties in the older universities. The transformation was reflected in the recruitment of new academic staff. Priorities were given to applicants with Ph.D's in scientific research. The diversity of engineering education in Australia thus disappeared.

Yet there are inherent problems plaguing engineering profession:

- Low status of engineers in society
- Gender imbalance within the engineering body
- Lack of trust of engineers within society
- Low attractiveness of engineering courses to secondary school students.This translates into poor calibre entrants into engineering courses.

The employer groups also expressed concerns in the area of practical rationality: the deficit between practice and training or education. Many survey's among employer groups indicated a general satisfaction with the scientific literacy but expressed concerns in the shortcomings of social, managerial, legal, environmental and even engineering literacies among engineering graduates.

Thus Frenkel's model (Figure 1) of engineering linked to the scientific domain must be replaced by a more realistic model (Figure 2) where engineering is at the 'coal face' of creativity.

One way of altering the current way of educating engineers in Australia must involve a cultural turn around. New or different models would perhaps ameliorate current concerns. However, the adoption of what may be more appropriate engineering education models from U.S. or Japan which accommodate diversity or the European continental model need a change of perception in Australia. This ought to be a long term objective.

In a short term objective the change can be simply effected through the disciplines of humanities and material science. There is no need for cultural change to occur in the faculties of engineering in Australia. Simply expanding the teaching of humanities and material science, the new curricula would enhance social, environmental and engineering literacy amongst the new engineering graduates. Obviously there is zero sum effect, and these courses would need to expand at the expense of the existing science based courses which are crowding the current engineering curricula.

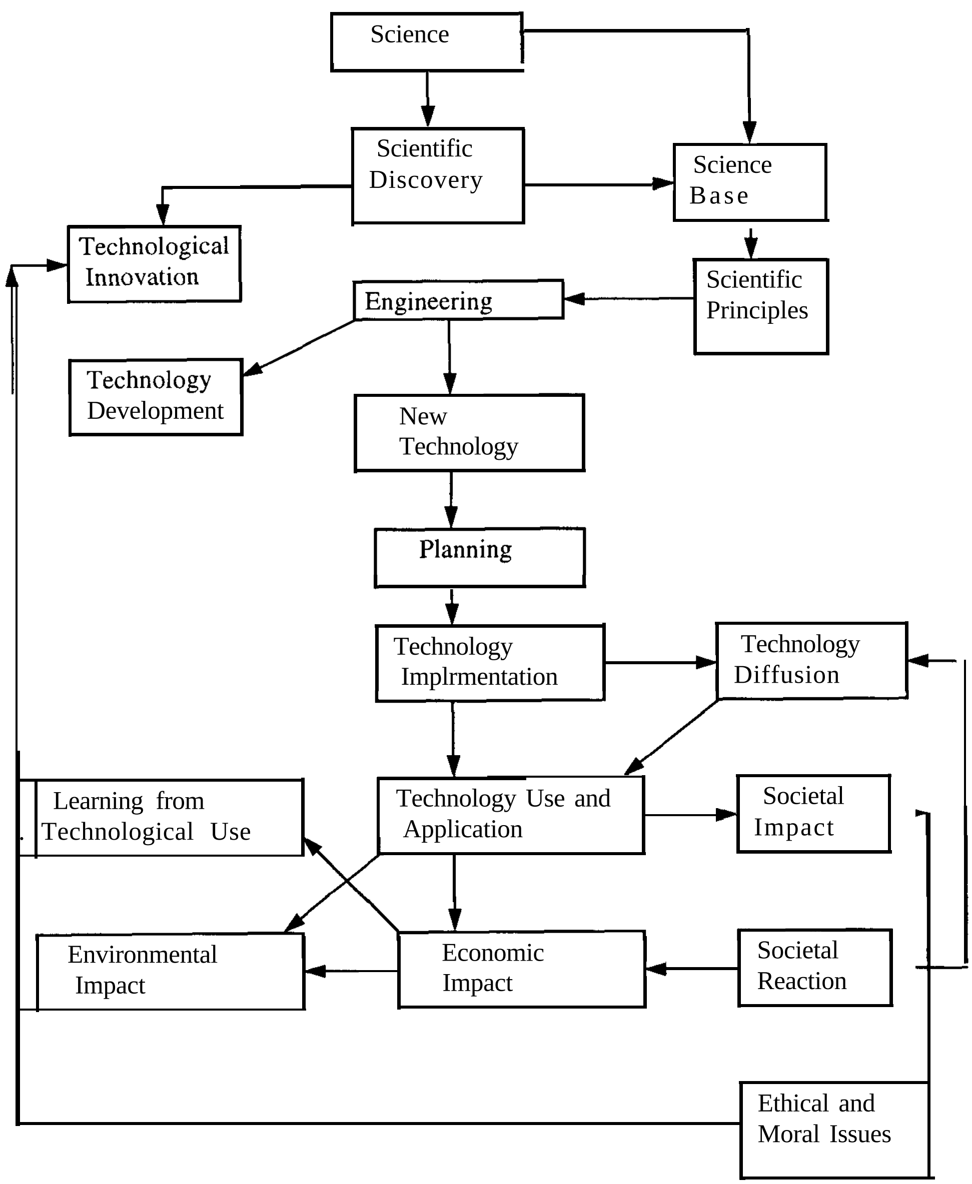

Figure 1. Frenkel's model of linkages between society and technology

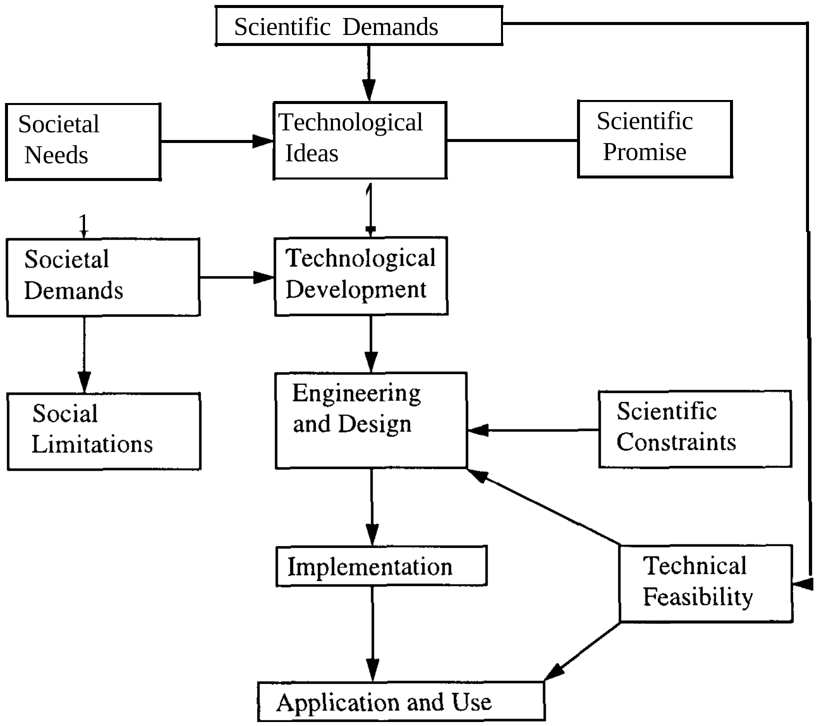

Figure 2. An alternative model which identifies the linkages between science, technol ogy, engineering and society.

HUMANITIES AND SOCIAL SCIENCE

Towards the end of the 19^{th} century it was realised that greater productivity gains could be achieved through the emphasis of organisation of work and division of labour. Engineers became increasingly concerned with the human dimension of management. The paradigm shift to less mechanistic role of the engineer is reflected by the changing engineering curricula in the leading American universities.

The change of the engineering curricula in Australia over the past forty years can be observed by the increased content of sciences(especially computer science)and engineering science with the accompanying dilution of the practical aspects of the course. The highly focused curricula has produced a crisis in practical rationality leading to the increasing isolation and poor standing of the engineering profession in the community. The perceived view of the engineer as a practitioner with a tunnel vision has diminished the profession's trustworthiness.We are increasingly seeing the society invoking defence mechanisms through regulation and legislation to engineering decisions.
Obviously some change is required.We can start with the entry point of the profession ie education.To begin with, the undergraduate curriculum needs some restructuring.It must be linked to a stage of communal development to produce a professional who is socially conscious of his or her role.The argument for increased humanities studies in producing an all rounded professional is not new,disparate people such as Eric Ashby and Finniston in his report into Engineering education saw

in the increase content of humanities as enhancing the engineering curriculum In 1968 the UNESCO secretariat in its international perspective on engineering education argued, ...*In view of the engineers dual role as a professional worker and as a person actively engaged in the transformation of the society, the social sciences and the humanities,* ***can*** *take their place as an integral part of his education.... They contribute to professional competence...in a broad sense of enabling the engineer to see his own activities in their human and social contexts...*

The incorporation of humanities and social sciences subjects into the engineering curriculum must be more than tokenism.These disciplines must permeate all the levels of the 4 year course starting with the first year,where the subject is presented in the form of dualistic knowledge and is allowed to evolve in the final year into a critical form of contextual multiplicity of knowledge.The restructured course would expand social awareness breadth of contextual knowledge and sharpen critical faculties of the graduate engineer to meet the challenges required of the decision maker operating in the technical domain.It would add to the transformation towards nomo-pragmatic knowledge.

In Victoria, Monash and Melbourne universities incorporated humanities into engineering by the introduction of 5 year double arts/engineering degree.The introduction of these courses exceeded all expectations

- The graduates from the double arts/engineering course had a higher employment rate than graduates from an equivalent length Master of Engineering courses,.
- The arts-engineering graduates had consistently higher average salaries than other engineering graduates employed in he engineering industry or in some technical/decision making capacity.
- .The double degree course attracted higher calibre entrants.The entry cut-off scores were comparable to the cut-off scores of the faculties concerned with “ivy 1eague” professions such as law and medicine.
- The double arts/engineering course attracted women to engineering. In some engineering disciplines the proportion of women students exceeded 50% of the total This compares to average 15% proportion in straight engineering courses.
- The desirability of expanding the content of humanities, social sciences and management in the engineering curriculum has been recognised at Victoria University of Technology (VUT).

In restructuring the existing courses the underlying philosophy of the faculty of engineering was driven by considerations of pragmatism and communal needs;

1. to produce a graduate with enhanced social consciousness,
2. to attract women to engineering,
3. to stimulate greater interest in engineering among senior secondary students,
4. to improve the retention rates in engineering at VUT

With the introduction of a common first year the faculty of engineering at VUT has included a new major subject *Engineer and* Society..It is hoped that this subject will promote an awareness of the engineering profession and the environment in which it operates.It is also hoped that the inclusion of this subject will enhance the attractiveness of the course.

MATERIALS CURRICULUM IN ENGINEERING

Materials is the “staff’ engineers work with,and the spectrum of materials based knowledge imposes the limits of competitiveness and responsible environmental behaviour.Allan Bromley,the science advisor to President Bush stated in 1990; Material Science is by far *the most important subject in* USA..The American
Academy of Science through its COSMAT report called for coherent materials policy The congruency between materials knowledge,design and manufacturing affect decision making processes. that spill over into the domains of markets and their associated economies and societal well-being.The almost spiritual properties conferred on materials knowledge is not far fetched when the realms of industrial and post-industrial social structures are considered.The competitiveness of nations are linked to the market forces that are intertwined with productive processes. Materials constitute one of the cornerstones of the productive process (see fig. 1).

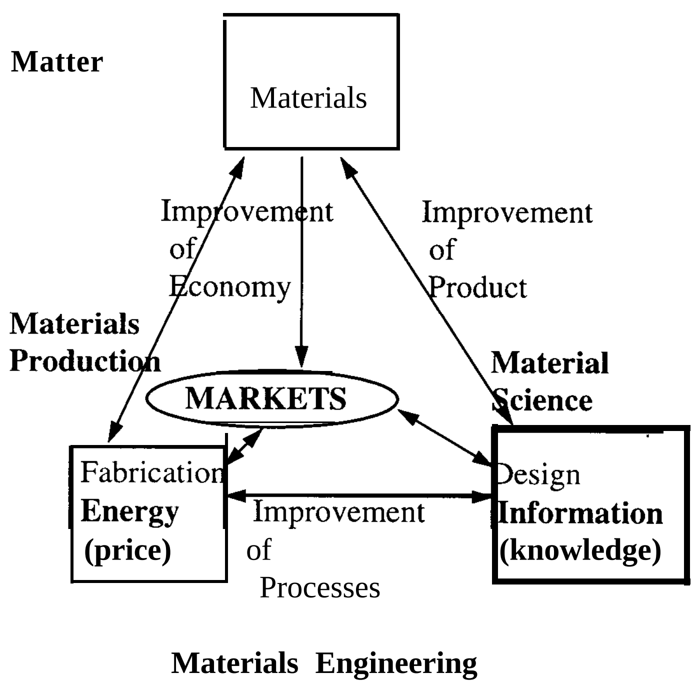

Figure 3. Interrelations between product factors:
Materials linking to fabrication affects the economy. The nexus between materials and design confers quality and performance on the product.Materials Engineering links design with the fabrication processes.

The environmental concerns are the by-products of the product factors.Materials and energy factors are interconnected,and in fact many environmental questions can be distilled in terms of these two factors.Clean manufacturing,minimizationofenergy,reduction of green house gas emission, increased product longevity and performance through life-cycle analysisand recycling are issues increasingly raised in the community. These issues must therefore must therefore occupy the centre stage in engineering decision making.It is not necessary to cast the net wide to realise that materials education strengthens engineer’s appreciation of environmental problems.

It may be desirable to incorporate materials and environment in engineering curriculum as shown by figs 2and 3.

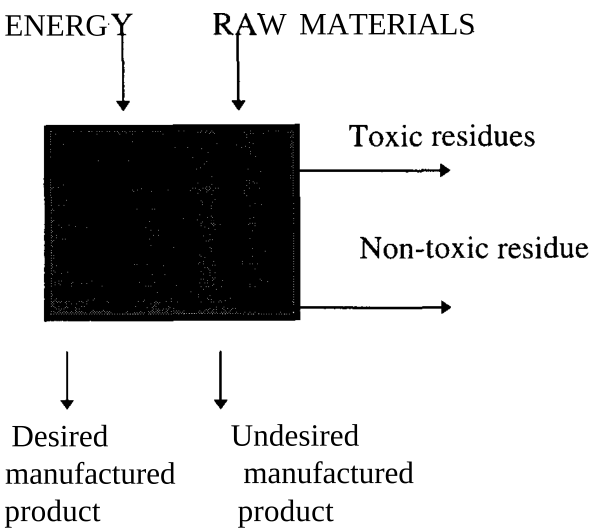

Figure 4. A simple picture

The uninformed are unaware of possibilities and limitations.The 1985 study performed by Bishop showed design engineers in Britain grossly deficient in literacy of new materials and manufacturing processes.Ten years on, there is sufficient anecdotal evidence to suggest that the gap between materials based knowledge and practice has widened.

As a service subject,materials science is given low priority by most academic engineering departments in Australia.This is despite the fact that high priority is conferred on materials by the government policy making bodies and industry.The restructuring of engineering courses at VIJT did not increase the materials science component in the new courses,instead was observed in some cases.This is not unique to VUT.What is unique is the failure is the failure by many education planners to perceive the changing diversification of engineering practice.

CONCLUSION

The design and implementation of a professional course such as engineering must be based on certain beliefs:

- Beliefs about engineering.
- Beliefs about becoming a professional practitioner
- Beliefs about student learning
- Beliefs about knowledge in engineering

The argument taken in this paper is that contemporary engineering practice is increasingly concerned with social production and integrative knowledge.The expansion of humanities and social science subjects in engineering curriculum will address many problems facing the profession; the more attractive courses will generate greater interest translating into more gender balanced and higher calibre body entering the profession.Humanities and social science subjects tend to produce a more divergent thinker who is able to reformulate cn engineering problem.

The argument for increased materials content in the engineering curricula has to do with increasing engineering literacy among engineering graduates Materials Science subjects carry the knowledge domain of engineering and technology such as strength of materials,electrical and electronic behaviour of materials,process technology.design and environment.

The author is aware that such inclusions are incorporated at a cost.It is here that rethinking of engineering must be done.Engineering must be separated from Science which must be considered as one of many hardwares available to the practicing engineer. Engineering after all is reflected and assesed by practical outcomes,rather than research papers.The argument is thus anchored in a general engineering course with much reduced emphasis on heavy science.

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BIOGRAPHICAL INFORMATION

Josef Rojter has undergraduate qualifications in chemistry and chemical engineering and postgraduate research degrees in chemistry and materials engineering.In addition to extensive industrial and consultancy experience,Josef Rojter has lectured and developed courses in polymer,materials and chemical engineering.He is currently participating in a project at Monash University concerning professional education directions.