2006-1881: THE NATURE OF ENGINEERING WORK IN SOUTH ASIA: IDENTIFYING ENGINEERING ROLES

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The Nature of Engineering Work in South Asia: Identifying Engineering Roles

Abstract

This study started with the observation that the real end-user costs of engineered services such as water supplies and energy in developing countries can be considerably higher than in industrialized countries. We hypothesize differences in engineering practice, the nature of engineering work, contribute significantly to this problem. The relatively scant literature on engineering work provides a weak basis for comparison because most contributors have been social scientists with limited ability to understand the technical dimensions of the work. No comprehensive description of engineering work practices seems to be available in the published literature. We have therefore analysed interviews with engineers and field observations to build a framework of engineering work roles and we propose to use this to test differences in work practice between South Asia and Australia.

Introduction

Engineering innovations fuel economic growth, competition and human progress. Industrialized countries enjoy a high standard of living because of technology and engineering advances. But in most developing countries the scenario is different. These countries are facing serious productivity problems and poverty. The end user costs of basic necessities such as water, energy, construction, transportation and communication are high compared to industrialized countries, even though hourly labour costs are much lower (Trevelyan and Tilli 2003). It is time to ask what engineers do in developing countries and under what conditions they do it. More specifically, we must understand how this differs from what they do in industrialized countries. Are these differences affecting the way they think and act? With thousands of excess graduates in engineering disciplines unemployed in South Asia, we need to explain why there are skill shortages and a lack of competition in engineering sector of the economy.

The authors' personal experience, early interviews and field observations in South Asia have suggested many ways in which engineering work is different, despite the close similarities in technical education curricula. Organizations tend to have more hierarchy levels, larger numbers of people for the same work output, and engineers seem to have less financial awareness and authority. Engineering work relies on a narrower choice of materials and component supplies, and technical skills available in the workforce are relatively low in comparison to industrialised countries. Employers seem less willing to follow technical advice from engineers and seem to place little trust and confidence in their engineers. Engineers are paid at rates that are typically between 30% and 50% of levels in Australia but work shorter hours with considerably less work intensity and responsibility. At the top end of skills and abilities, however, engineering remuneration seems comparable with international norms.

Given these initial observations, we can look for ways to attempt a systematic comparison between engineering practices in South Asia and Australia. Here we encounter a surprising difficulty. There seems to be no readily available description of engineering practice that would allow such a comparison to be made systematically. The engineering practices developed in different countries and companies are very poorly understood, at least in the open research literature. Since these practices are now at the centre of almost all social projects such as water, energy, transportation, etc, we might as well say that we know very little about what people really do in the course of engineering work. Our strategy for answering these questions is to study engineers in two regions of the world, one in South Asia and other in Australia. We realize that a broader comparison of South Asian and Australian engineers would reveal diversity and complexity in engineering practices. Consequently we also decided to explore more systematically the nature of engineering work itself.

Literature Review

Of the few contributions in the literature about engineers and engineering practices, most has been written by philosophers, social scientists, and ethnographers (see Table 1). They were primarily motivated to study the social and political aspects of engineering work. They were also interested to see how advances in technology and increasing use of capital equipment shaped the work of engineers and non-engineers. They proposed debates and various theories about the significance of engineers in society and the organization of technical labour (Schön 1983; Zussman 1985; Whalley 1986; Barley and Bechkey 1994; Orr 1996; Darr 2000).

Philosopher	1
Sociologist	5
Anthropologist	2
Engineers	3
Technician	1

Table. 1: Scholars and their background

Schön (1983) gives us a language for understanding professional practice, and how designers (engineers, architects, consultants etc) really work when they solve real problems. A ‘professional’ might create a ‘frame experiment’, a new frame for the problem situation from a ‘stock of knowledge’ and an experiment devised to test out the new frame by applying a ‘repertoire of practices’. When a professional successfully handles a failure or a new case, a new ‘recipe’ is created every time.

The author also argues that professional education should be centred on enhancing the practitioner’s ability for ‘reflection-in-action’ to create new knowledge (Schön 1983). It is that process that allows us to reshape what we are working on, while we are working on it. Engineers are described as technology workers. The engineers that Schön describes are seen only as inventors dealing with technology issues, and he may have overlooked most elements of professional engineering work such as organization of people to produce useful products and services.

Zussman (1985) combines detailed observations of organizations both in advanced and old industrial settings with intensive interviews of American engineers within those organizations. He observed that engineers believe that the theoretical content of engineering education does not seem to bear any direct relationship to engineering practices even in research and development (Zussman 1985). In contrast, he recognised that non-technical skills such as ability to work with others could be more important to performance than technical skills and certainly more important than competency in high level mathematics and science.

Whalley (1986) described how technical work 'is socially produced' in advanced capitalist societies with in-depth interviews of engineers in two British factories. He argued that engineers belong to the category of 'trusted workers' (Whalley 1986). These workers carry out strategic jobs within the corporation where mistakes are potentially costly and consequently they are granted a significant degree of autonomy to take decisions. "What is missing in management's eyes is the responsibility to use to it [the knowledge] appropriately in a world where technical knowledge is only a small part of the skills necessary to be successful in getting things done" (Whalley 1986).

Most of the practising engineers interviewed in these comparative case studies had no history of formal degree qualification and were promoted from the shop floor due to the lack of university trained engineers (Zussman 1985; Whalley 1986). There is little evidence in these studies of systematic differences in skill levels of engineers between old and advanced industry.

Orr (1996) presents ethnography describing relations among three elements - customers, machines and technicians - arguing that the understanding of work is not the result of any single factor but emerges from combination of all these features. Technicians' reputations predominantly reflect their ability to solve difficult technical problems and social skills are neither valued nor acknowledged. (Barley and Bechkey 1994) conducted an ethnographic study of science technicians. Despite low status and low pay relative to professionals, the demands of the job lead technicians to "value independent thinking, flexibility, and the other attributes of scientists". Orr and Barley also viewed technicians as being highly organised in carrying out everyday procedures, carefully writing up their work on logbooks, parts and order forms, keeping their tools and parts neat and tidy and so on.

Darr (2000) complements the above studies on organization of engineering labour with for a study of sales and R&D engineers within a work organization.

The predominant focus on organization of technical occupations has diverted many researchers away from the actual engineering practices by which engineering work is accomplished. We simply know very little about the details of what engineers do and where they acquired the skills they practice.

Bucciarelli (1988; 1994) researched the inner working of design teams of two small high technology engineering firms as an insider and team member. One company was involved in making photovoltaic modules for the conversion of solar radiation into electricity. The other company was engaged in the production of X-ray equipment for a variety of purposes including medical diagnostics, the quality control of materials production, and baggage inspection.

Bucciarelli's ethnography of design identified three different themes of a commercial design process. First, the concept of 'object worlds' is invoked to describe the different design spaces (mechanical, electromagnetic, managerial etc.) and the movement of design participants within the worlds of technical specialisation. Second, the concept of 'specifications and constraints' is used to discuss the types of facts and laws that rule over the designer's practices that limit their development of design solutions. Third, the notion 'design discourse' is developed taking into an account of the importance of negotiation from different viewpoints during the design and production of artefacts. It is evident Bucciarelli has a clear mind-set 'that design is a social process' and informal social structures determine the effectiveness of work activity.

Based on a pre-conceived model of technical work in terms of problem solving, craft skills, networking and integrating, (Solomon and Holt 1993) interviewed engineers at different stages in their career to gain a picture of mechanical engineering work practices. This article concludes with suggestions that most engineering careers lead to a substantial involvement with people in accomplishment of engineering tasks. We can ask whether this report provides reliable information on the nature of engineering work. Most of the informants were fresh graduates who were in a stage of transition, without significant engineering experience.

Florman (1976; 1987) contributed widely cited accounts of the role that engineers have played in history, and, how their work is connected to the overall progress of civilization and the human race. Florman (1976) extols at length the sensual absorption, spiritual connection, emotional comfort, and aesthetic pleasures to be found in engineer's intimacy with technical artifacts. However, there is little to help working engineers identify the roles they play in successful completion of projects.

Some recent comparative research studies examine the relative status of engineering in different countries, the way engineers are produced and institutionalised, the quality of engineering education, the utilization of engineers and possible implications of cultural differences (Meiksins and Smith 1996; Lynn 2002). This literature seems to have some political agendas and was primarily motivated to find reasons for national competitive advantage in engineering of one state compared to others. American and European researchers have expressed some concern about Japanese success especially in automobile and electronics manufacture. There is little examination of day-to-day engineering practices, however.

The technical content of engineering work as a 'mental and thoughtful process' (Zussman 1985, p29), makes it difficult for sociologists and anthropologist to make observations about engineers. Also, their empirical perspectives are social and class differences in organising the engineering labour including engineers, technicians, planners, and draughtsman (Zussman 1985; Whalley 1986; Barley and Bechkey 1994; Orr 1996; Darr 2000). Nonetheless, we still have nothing resembling a systematic model dealing with both technical knowledge and skill required for engineering work and social relations connected with its performance. Although some engineers adopted ethnographic approaches for studies of engineers in action to investigate the essentials of engineering practice, we still know little about how engineers combine technical and social aspects of their work.

Is engineering work different?

Theoretical aspects of engineering curricula are similar in most countries. Training in mathematics, chemistry, physics, thermodynamics, electrical circuits, engineering design and costing are recommended in engineering technology programs despite specialization in different fields (Beder 1989, p179). There is also evidence that engineers do not use most of this theoretical knowledge in the course of their industrial practice (Zussman 1985, p62). Rather, it is their ability to apply technical knowledge; to communicate their ideas and work with others on a team that includes non-engineers, and other related technical and social skills that define engineering work. Detailed comparisons of production establishments in the US, Germany and Britain suggest potential linkages between skills and knowledge of supervisors and the degree of efficiency with which production operations are carried out (Mason 1998). Thus we would expect that skill translates to efficiency: the more skilled a person is the more productive they are and the higher quality of results. Therefore, we propose to test the following hypotheses in this research.

> *Hypothesis 1:* Engineering work in Australia is different from engineering work in South Asia despite similarities in engineering education.
>
> *Hypothesis 2:* Differences in engineering skills can be related to differences in efficiency of design, manufacturing and operations.

In industrialized countries the perception of high labour costs drives capital investment in labour saving tools, training and techniques (e.g. Jones 1982). As workers have more, and higher quality equipment to use, they can produce more per hour of their time. For example, an auto mechanic can perform repairs faster if he has a full set of hand tools available than if he has to share tools with other mechanics. He can work faster still if he has some power tools available (and faster yet if he has a diagnostic computer, a lift, etc). This in turn raises wages, labour standards and improves productivity. It is commonly believed that labour is cheap and abundant in developing countries (Trevelyan and Tilli 2003), and we could ask whether this perception reduces the incentive to make use of it efficiently by providing education and skill development. To evaluate these claims, we set forth:

> *Hypothesis 3:* Perception of labour costs is different in different countries.

Research Methodology

The empirical evidence needed to test the above hypothesis relies on field observations and interviews with engineers and their co-workers. It is essential to recognise that most engineering work involves people with different roles interacting and communicating in successful creation of products and services. This study has a specific focus on the roles and technical knowledge involved in engineering work.

Qualitative methods are preferred when the aim of the study is to better understand any phenomenon about which little is yet known. They can also be used to gain new perspectives on things about which much is already known (Patton 1990; Strauss and Corbin 1990). This thesis will be based upon qualitative research studies involving inductive reasoning since the nature of engineering work is still rather unexplored and a broader picture has to be archived. The study will begin with formulation of hypotheses and go on to take specific observations and interviews, detect patterns and regularities, test hypotheses with data, and finally end up developing general conclusions or theories. In addition, the validity of research findings is important to enhance the accuracy of interpretations made (Miles and Huberman 1994).

From a methodological stance, (Zussman 1985; Bucciarelli 1994; Orr 1996) present useful qualitative procedures. Their overall framework is very clear about how many informants participated in study, how careful observations were done, how they recorded the interviews during fieldwork, where and how long the discussions lasted, and finally how data collected was interpreted. Their writings were lucid, convincing and it is easy to see where interpretations originated. Since transcription and coding are expensive processes Zussman and Bucciarelli reconstructed field notes and checked against the tapes themselves to resolve ambiguities.

The different working methods and techniques adopted in these countries are contingent on a better understanding of roles engineers perform. (Trevelyan 2005) has closely identified and defined 80 engineering roles so far based on the preliminary analysis of interviews in Australia. This concept of roles will be extended further in research and will be used as standard codes in computer assisted qualitative data analysis. This approach is used in order to analyse emerging patterns rather than make random comparisons of differences between engineers in South Asia and Australia.

Three examples of the engineering roles we have identified so far are:

> Role: C05 internal transfer
> Apply for internal transfers to provide opportunities for skill improvement and work experience on particular projects or assignments.
> Role: E01 design
> Create technical solutions to meet client needs from available resources and commercial off-the-shelf (COTS) components using specific technology expertise, design of new systems or components to meet client needs constrained by need to use available materials, production technologies and expertise.
> Role: E28 manage project
> Manage project: review budget and plans, time and resource estimates, progress data, resource allocation, re-plan where dependencies can be 'relaxed' (eg combining manufacture with testing, concurrent engineering etc).

Initial Results

At the time of writing this paper we have completed about 40 two-hour interviews and a large number of field observations, about half in Australia and half in Pakistan. The need for a comprehensive description of engineering work has forced us to focus first on the Australian data. Trevelyan (2005) presents the results of this first phase. The current focus is on technical knowledge, which seems to be more elusive than the vast number of published engineering technical papers might suggest. The most significant results from this first stage are:

a) Engineers spend much of their time coordinating the work of other people over whom they have little formal authority. This includes insiders – people in the same organization – and outsiders in client organizations, suppliers, contractors and community organizations.
b) The significance of this coordination has much to do with the need to bring people together with the diverse range of technical knowledge and skills needed to complete engineering project successfully. Much of the working knowledge is unwritten. Written knowledge, where available, is often accessed verbally through individuals familiar with the specific details.
c) Advocacy, persuasion and compromise (on many occasions engineers need to advocate alternative solutions or compromise the situation or sometimes persuade other engineers, clients, suppliers)

d) Formal procedures seem to be highly significant in successful engineering work, perhaps to ensure that information is distributed to people who need it.
e) Many apparently non-technical roles in engineering work such as project management, staff supervision, negotiation, delegation, contract management and performance evaluation seem to involve tacit technical knowledge. Engineers who claim that they "don't do real engineering work anymore" seem to rely on this knowledge more than they at first admit.
f) Nearly all the technical knowledge required and nearly all the roles performed in engineering work are not covered in university courses. Engineers have much more to learn than any have explicitly been able to tell us in interviews. However, at the same time we are a long way from being able to say that any significant portion of university engineering is wasted effort. Most still seems to be useful training.

Future Research

We plan to conduct a larger number of research interviews in Australia, India and Pakistan over the next two years to provide the data we need to support or refute the hypotheses we have presented. We expect to have definitive research findings by 2008.

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