ENGINEERING AS CAPTIVE DISCOURSE

Stephen Johnston, Alison Lee, and Helen McGregor, University of Technology, Sydney, Australia

In this paper we examine contemporary engineering in terms of the discourses within which its practices are framed. The term discourse is used in the sense developed within recent social theory, from the work of Michel Foucault, to refer to the ways social institutions name, define, and regulate the practices which occur in the name of those institutions. We describe our concern that the discourse of engineering education has been dominated by the discourse of engineering science, to the virtual exclusion of other discourses which contribute importantly to the practice of engineering. We argue further that engineers have accepted inappropriate constraints placed upon their profession by the discourses of commerce and science, which have been permitted to define and delimit what engineering is and can be. The result has been a serious limitation in engineers' capacity to examine the social meanings and effects of their work and to self-consciously reflect upon their practice and professional identity. We suggest directions in which the discourses of engineering education and practice need to change so that the engineering profession can achieve the goals stated explicitly in its professional codes of ethics. Our analysis seeks to open the way for change in how engineering is structured, practiced, and taught. By exposing the workings of the constitutive discourses, it is argued, the way is opened for unshackling engineering from its present constraints—freeing the discourse and making critical reflection possible.

1. THE CAPTIVITY OF ENGINEERING EDUCATION

As university educators, we begin this analysis with our own most immediate concerns. Engineering as an academic discipline is founded upon and validated by engineering science. Glover and Kelly (1987, p. 112) note that in the United Kingdom, “Engineering tends to be viewed as a branch—the applied branch—of natural science.” One consequence is that, while engineering teaching and scholarship have remained closely connected with the academic disciplines of science, to a large extent they have remained isolated from the pragmatics of engineering as a professional practice. This is not a surprising situation when viewed from the perspective of the discursive history of modernist science. Where areas of engineering science, in particular mathematics and physics, draw heavily on the empirical approaches similar to Logical Positivism, issues of meaning and social impact are rejected or ignored. The more radical of the Logical Positivists, such as A. J. Ayer, argue that all assertions about moral, aesthetic and religious values are scientifically unverifiable and therefore neither true nor false, but simply meaningless. Scientific method, the structure of hypothesis, proof, validation, publication, and critique, is clearly embedded in the scientific culture and serves it well. However, much of this academic endeavor has been essentially de-contextualized for engineering students. The culture and discourse of science impose their own rigor on the academic discipline of engineering and when adopted by engineering, their authority becomes almost absolute. Practitioners commonly believe themselves immune from the influence of theory or philosophy, but the discipline of engineering remains to a great extent captive to the sorts of ideas developed within positivism, due to the overwhelming dominance exercised by positivism in the development of scientific thought during this century. The irony of this situation is that most engineers have probably never heard of Logical Positivism or any of its philosophical spokespersons. As Keynes (1936) noted in a parallel context: “Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually the slaves of some defunct economist.” Such influences, often exercised almost subliminally, can add up to real cultural bondage.

A major review of engineering education in Australia in the last decade found it necessary to point out that engineering had a human as well as a technical side, and that this should be taken into account in the education and training of engineers (Williams, 1988). Perhaps it is unsurprising that undergraduate engineers have been seen as boringly rational and literal, given the dominant discourses and practices which are modeled for them. It has been noted that many students have been uncomfortable with the discursive limitations of their educational experience without understanding why (Taylor and Johnston, 1991). Those who did not fit in tended to be marginalized from the mainstream engineering culture. There can be little doubt that engineering education had become captive to the dominance of a discourse of engineering science, losing touch with the social context of engineering. Engineering science had been allowed to define the types of problems and the acceptable solutions, and to become the major source of scholarly authority in engineering education.

2. THE CAPTIVITY OF ENGINEERING PRACTICE

The loss of context by engineering education was carried through to and compounded by another level of constraint, which Goldman (1990) has described as the "social captivity" of engineering. He argues that this captivity operates in two ways, intellectually and practically. Intellectually, engineering is seen merely as the application of science, with all the principles of scientific practice assumed to cover those of engineering as well. Practically, Goldman sees the context of engineering as being framed and governed by corporate managerial hierarchies, rather than by the engineering profession itself:

> [Engineering practice] is captive to social determinants of technological action that selectively exploit engineering expertise, define the problems engineers are to address as well as the terms of acceptable solutions (Goldman, 1990, p. 121).

Goldman also supports earlier commentators in asserting that their education has prepared engineers to identify with the interests of their employers, and that they "simply do not feel an urge to be freed [from corporate goals] to protect the public interest" (Florman, 1986). All these influences have constrained and confined the discourses of engineering—the ways in which engineers define their own profession and their practice (in so far as they attempt to do so at all). As a result, engineering practice is not available for critical scrutiny from within.

We are using the term discourse in this paper to draw on an approach developed within recent social theory. Briefly; social institutions produce specific ways of writing or talking about certain areas of social life which are related to the place and nature of that institution. That is to say, in relation to certain areas of social life which are of particular significance to an institution, the institution will produce a set of statements which largely define, describe, delimit, and circumscribe what it is possible and impossible to say with respect to that area, and therefore how it is to be talked and written about (Kress, 1985, p. 139).

A discourse has the power to create reality by naming that reality and giving it meaning. According to Foucault (1984), this power to create is always a "distributive" politics, that is, what is "real" and "true" determines what is included and what is excluded, so that what cannot be named may not even be noticed. Put most simply, our fundamental concern is that, without a broader discursive framework, engineering cannot carry out the self-evaluation needed for renewal and regeneration of the profession. It simply does not have the linguistic tools to accomplish the task.

3. ENGINEERING AS A DISCURSIVE COMPLEX

In the previous sections, engineering has been discussed as if it were essentially a single discourse which, once constituted from the discourse of engineering science, has developed relatively impermeable boundaries. The engineering profession was shaped and defined by men whose attitudes reflected the positivist values described earlier. However, engineering as an institution consists of what engineers actually do; and in order to examine the possibilities for changing engineering, it is useful to start by looking more closely at the current institutional context of engineering. What soon becomes evident is a discursive "complex," a term which refers to the co-existence in any one institution of a multiplicity of discourses defining the nature and practice of that institution. There are many different discourses of engineering that exist in some tension with each other, if not in actual conflict. In terms of distribution of status and resources, their ranking varies enormously. Engineering science provides an essential rigor for the production of reliable outcomes in physical terms, but it is only one of these discourses.

Other important discourses from which engineering borrows include:

—management, including the management of engineering activity. In so far as this requires understanding of technical as well as personnel and financial issues, it is recognizable as essentially engineering activity;

—business, including supporting innovation in systems, processes, and products as well as economics and wealth creation;

—industrial design, including aesthetic and ergonomic issues. The needs of the users will to a large extent determine the appropriateness of the design of the system or product;

—sociology, including locating engineering in its social and cultural contexts;

—politics and development, including equity issues at national and international levels;

—philosophy and ethics (and etiquette);

—environmental studies (itself a discursive complex). This last is still marginal within engineering generally and often regarded as merely an add-on to civil engineering (e.g., Beder, 1993).

The argument here is not that one discourse should supplant another, for example, that engineering science should be replaced by business in defining what is appropriate or necessary for engineering activity. Engineering is a large-scale, highly-disciplined activity, which needs to be directed into well-defined channels. The building blocks, from nuts and bolts to solid state circuitry, need to be available in reliable, standardized forms. For engineering products to be widely adopted, the importance of national and (increasingly) international standards, protocols, and procedures can hardly be overstated. The fax machine and the personal computer vividly illustrate this issue.

However, the limitations of a reliance solely on engineering science to define engineering activity can readily be demonstrated. The central focus in engineering research is on innovation, aimed at increasing productivity and developing new products, processes, and systems. This focus can readily be construed within the existing discourse of engineering science. As production falls inside the discourse it is real and true. However, the focus on production elides the question of distribution of the benefits of engineering, an issue not seen as the terrain of engineering itself, but of other discourses altogether—those of business or of politics.

Distribution falls outside the discourse of engineering science, so engineers do not even see themselves as having a role (let alone a responsibility) in setting the terms on which it takes place, and what is more, do not see distribution as the concern of engineering.

The argument we are developing here is that these competing discourses need to be named and articulated, and the relationships between them openly explored and debated. This is part of the essential role of the discipline within the profession and needs to be carried out from within the institutional boundaries. It requires a considerable expansion of currently available ways for engineers to define themselves and their work.

4. ENGINEERING AND ETHICS

Engineering cannot be separated from its context. However, in practice the context within which engineering activity is carried out is too often narrowly defined and framed by the interests of business, commerce, and politics (Goldman, 1990). Such limitations are implicitly accepted in the proposition that, “Professional engineers are men and women who use technology as a means to the market-competitiveness or cost-effectiveness of the client” (Samson, 1989, p. 9). Because business, commerce, and politics have to a large extent remained outside what engineering counts as its own validating or explanatory discourse, the engineering profession lacks an adequate definition of human or community needs on which to base ethical judgments on its activity. The subordination by engineering science of all other discourses means that engineering has defined its practice as lying outside the context in which it occurs. Paradoxically, this is precisely what renders engineering captive to other discourses and practices. Engineers may not even be conscious of what is actually occurring within the context in which they are doing their work, because the dominant discourse does not name it. If they cannot discuss their work in context, then they cannot develop an ethical approach to it. There has been some progress towards a more contextualized approach. The Institution of Professional Engineers of New Zealand (IPENZ) acknowledged the problem in 1993 when they characterized their old code of ethics as essentially a “code of etiquette.” For all practical purposes, its focus was on ensuring polite relations within the profession, rather than on ensuring practice which was responsive to community needs and aspirations.

In our experience, most engineers have a strong individual commitment to socially responsible behavior, and are well able to deal with personal ethical issues which arise in the course of their work. However, the community (and some members of the profession) have come to see the professional codes of ethics as superficial and even trivial. Ethical issues are marginalized in engineering education and practice. The fundamental ethical problems in engineering arise in identifying the problems to be addressed and choosing between possible technical approaches to be considered. Because the dominant discourse locates these decisions as outside the responsibility of engineers, the profession's codes of ethics are not seen as applying to them.

5. ENGINEERING AND COMMUNITY RESPONSIBILITY: THE SHAPING OF CITY AND SUBURB

In this section we consider the development of the city and the suburb as an example of the ways in which the limitations of the currently dominant engineering discourse manifest themselves in practice. The products, processes, and systems developed by engineers have made both the modern city and suburb possible. How have engineers understood their relationship to this process?

In Australia, because of particular historical circumstances, government engineers took a major role in infrastructure development. A noteworthy example was the group of engineers in the New South Wales Public Works Department in the 1920s who shaped the development of Sydney. The group included J. J. C. Bradfield, whose combination of visionary planning and design and tireless public and private lobbying played a large role in building the city and suburban rail system and the Sydney Harbour Bridge (Raxworthy 1989).

However, in recent years, engineers in government and private employment in Australia have taken a much narrower view of their roles and responsibilities, looking to solve only problems framed and formulated by others—generally their own corporate or political masters.

Engineers must recognize the relevance of community needs in every aspect of their work if they are to sustain their claim to be professionals. Indeed, the first tenet of the Code of Ethics of the Australian professional body, the Institution of Engineers, Australia (IEAust), is that their prime responsibility is to the wider community. How can this responsibility be met, when most engineers are employed by large organizations which dictate the specific focus of their engineering work? How can engineers be involved in the establishment of design briefs which are an authentic expression of community needs? Effective moves towards ecological sustainability will require the framing of problems and the formulation of solutions by multi-disciplinary teams which will include engineers together with other professionals and other stakeholders. Engineers need to be able to communicate effectively with other team members and with their community clients. In this process (if only to contain professional liabilities, Miller, 1990), engineers will need to see their role in the community as offering options which meet social as well as technical needs, rather than as arriving at definitive solutions to problems.

To improve the processes of public consultation, engineers need to develop an analysis of their own responsibilities and be able to position themselves explicitly in relation to other stakeholders. The modes of consultation and the checks and balances of the discourse of science are certainly not adequate for community oriented engineering practice. For consultation to be effective, there needs to be shared understanding and acceptance of the validity of the issues. A discourse of engineering is needed which provides access to a wide audience to determine what issues are to be addressed and to develop socially acceptable ways of tackling them.

6. THE CHANGING FACE OF ENGINEERING: THE GLOBAL CONTEXT

Contemporary engineering activities transcend national barriers. Engineering has become a global enterprise, of which the latest form is probably akin to what Steven Goldman of Lehigh University describes as “agile manufacturing.” In this approach, conception, design, and production are carried out by “virtual enterprises,” which may include elements of otherwise competing organizations, joined only electronically, and distributed nationally and even internationally. The need for a truly international language has become pressing, and the NATO agreement on standardized technical language is a move towards a global communication system which is already emerging. Economically, such global engineering activity is very important. Intellectual property is now a major tradeable commodity, with significant implications for national balances of payments.

The social status and public influence of professional engineers vary widely around the world, as do the discourses defining engineering itself. The British view of engineering owes more to “engines” than to the French sense of “ingenuity.” Colonization dispersed these differing meanings and practices around the globe, with indigenous variations subsequently superimposed. Colonialism impacted very differently on different countries and cultures. Japan, which escaped colonization, drew on and adapted ideas which suited its own cultural traditions, and retains a distinctive engineering aesthetic. It is interesting to speculate on the effects which global diversity is having on providing starting points for change. One impact of modern information technology is that a dominant culture that controls the communication links can completely overpower a domestic culture. For example, rather than an international discursive complex which celebrates diversity, CNN (Cable Network News) is a modern colonizing influence.

As other cultures come to articulate their relationship to the development and transfer of technology, the globalization of engineering is changing the profession. There are other social shifts, changing engineering from its former identity as a Western, white, male domain. In Australia, for example, a national target of 15% for female representation in engineering undergraduate courses has already been exceeded in many areas, and seems likely to be met overall. Increased participation by non-traditional entrants will not of itself change the profession, but it can generate pressure for change, particularly if the dynamics of change processes are widely appreciated. In particular, the very meaning and value of its practices are being questioned and contested, in line with broader social changes with respect to increased access and participation of women in traditionally masculine institutions.

7. "RE-ENGINEERING"

We argue, then, that engineering needs to broaden its discursive parameters and free itself from its "captive" state. The consequences of failing to appreciate the actual contexts of engineering practice are well documented. The profession is under pressure from two directions: on the one hand as a result of social and political expectations for it to be more inclusive, and on the other as a result of exclusion from traditional roles and power bases. Engineers in Australia now talk of major public instrumentalities becoming "de-engineered"—their engineering capability being all but eliminated. One serious implication of de-engineering is that the quality of decision making on technical matters is likely to decline.

If engineering is to be successful in regaining a position where its professional expertise can be best employed, it must, we argue, develop a discursive competence adequate to the increasingly complex social environment in which it operates. Here, it is useful to compare engineering with another, related discipline, geography, in terms of its history of recontextualization of its discursive parameters.

Geography has been, along with engineering, one of the professional disciplines most intimately involved in shaping our physical environments. It is interesting to recognize similarities, particularly in the United Kingdom and Australia, between the two disciplines. Both can be characterized as more or less specific (but somewhat arbitrary) assemblies of material, drawing on aspects of other disciplinary areas, but generally lacking a tight, clear disciplinary focus in their own right. In the modern period both have been imperialist projects, closely associated with the building of nation states, with imperialist expansion and with what Baran (1973) and Frank (1978) described as the "development of underdevelopment." Both have been centrally concerned with questions of urbanization, decentralization, urban decay and renewal, and regional development, with their associated demands on housing and transport and problems of resource use and constraint and pollution.

Unlike engineering, however, geography has developed some degree of self-reflexivity, mostly via feminist and post-colonial critiques of the dominant positivist geographies. The discipline is in the process of re-conceptualizing itself from inside, as evidenced in mainstream journals like Australian Geographical Studies and monographs like Soja (1989). We believe that some of the references cited here (and the very existence of this paper) show that the same process is starting to happen in engineering.

If "re-engineering" is to take place, it will require the incorporation of broader truths, bringing engineers to a reflexive consciousness of the contexts and consequences of their practice. As areas of the profession respond to these forces, a new constituency can be expected to emerge, giving rise to pressure from within the profession for reconstitution of the discourse.

8. ENGINEERING AS A "SCENE OF DISCOURSE"

Contemporary engineering practice is changing in ways not reflected within the terms of the dominant discourse. The radical shift away from hands-on practice and towards managing the development and application of technology supports our argument for the development of a discourse oriented towards the analysis of engineering practice.

Engineering practice has always been based centrally in the activity of design. The design process begins with selection of the problem to be addressed, a step which we have indicated above is typically controlled by corporate or political managers. The next stage is to define the characteristics of an acceptable solution. It is then necessary to generate alternative approaches to solving the problem, to review these alternatives against the specification, to decide on a preferred solution, to document, communicate, and implement the solution, and finally to review the design outcomes. Design is an iterative process, involving continuing refinement of problem definition, product, and production process. Because engineers have not adequately articulated the nature of their work in their own terms, they and engineering educators have been unable to locate design adequately within the discourse and to see the need for development of design skills. The importance of these skills has been increased by the character and impact of modern information technologies. In line with a more general change in the contemporary workplace, the scene of work has become a scene of discourse (McCormack, 1991). There are several important features of this shift, which we note here briefly.

The first is a burgeoning feature of engineering practice: that of documentation. There is increasing emphasis in engineering practice on both the documentation to support engineering systems and processes and the document products which form part of the total package, such as maintenance manuals. Information technologies are essential for developing effective documentation. Global markets have accelerated demand for a wide range of engineering support which is functional and user-friendly in an international context.

The second is the increasing need for high level communication skills, imposed, among other things, by flatter management structures and the greater complexity of engineering work. Engineers are expected to work effectively in teams, not only with other professional engineers but across disciplines and hierarchies. Employers of engineers commonly interpret the gap between the outcomes of engineering education and the demands of engineering practice in terms of a lack of communication and management skills. One reason for much of the current criticism of the communication skills of engineers is that engineering educators, operating within the discourse of science, have seen such interpersonal skills as irrelevant and failed to support their development. To its credit, the IEAust (1990) has now established a requirement for substantial attention to be paid to this area in the education of engineers in Australia.

In the contexts of communication and documentation, engineers are increasingly being called on to explain, justify, argue, and persuade. Engineers have been accustomed to working only within their own discourse, where they have assumed that the engineering facts spoke for themselves. To work effectively across disciplines they need to recognize that facts are discursive constructs, whose validity and significance must be presented, explained, and argued for.

9. RECONTEXTUALIZING ENGINEERING EDUCATION

A central issue for the engineering profession today is that re-engineering, while technically desirable, is unlikely to take place unless the discourse of engineering changes fundamentally to include political, social, economic, and environmental considerations.

One approach to improving engineering education has been to assert the importance of social responsibility in engineering. Obviously beneficial and unambiguous design projects, such as aids for disabled people, have been used in this way. Their main limitation is that the analysis of the problem usually starts after the basic parameters have been defined by others. This approach encourages students to apply engineering science material to realistic (but usually relatively well-defined) problems. However, it generally does not open up political issues such as equity or the sustainability of continuing economic growth—issues which have often been seen by academics as outside the area of real engineering, and thus perhaps personally risky.

Another important approach to integrating engineering practice into engineering education has been the deliberate introduction of periods of industrial experience, along with thorough briefing and debriefing. The value of this approach is indicated by the persistence of cooperative courses in engineering, despite the often unrecognized and generally underfunded effort involved in running them.

Structured planning to re-contextualize engineering education at the University of Technology, Sydney, goes back to 1980, when we introduced the course, Engineering and Society, in the middle of the undergraduate mechanical engineering program. This has since been extended to a stream of professional orientation subjects which runs through the whole course (McGregor and Johnston, 1992). The effort required was greatly increased by the absence of a suitable text; eventually we wrote our own (Johnston *et al*., 1995). To the authors, this offered the exciting prospect of opening up the professional discourse, as well as an opportunity to introduce non-engineers to engineering discourse. An important sidelight on this process has been that because of synergies between technical and contextual material, student learning of the engineering science content of our engineering courses has generally been enhanced by the professional orientation stream. Putting technical material into context makes it more comprehensible and motivates students to put more effort into understanding it.

As the above example demonstrates, the situation is slowly starting to change. There is some communication between those upholding the dominant discourse and its challengers. The concepts of consultation, diversity, and globalization have emerged as key elements. They are generating a new discourse which transcends the captivities imposed by both science and business. To meet the demands of the future we need a discourse of engineering which is environmentally aware and socially sensitive and inclusive, while also acknowledging the global nature of engineering.

REFERENCES

Baran, Paul. *The Political Economy of Growth*. Harmondsworth: Penguin, 1973.

Beder, Sharon. *The Nature of Sustainable Development*. Newham, Vic.: Scribe, 1993.

Florman, Samuel C. "An Engineer's Comment. " *Technology and Culture* 27, no. 4 (October, 1986): 681.

Foucault, M. "The Discourse on Language." In his *The Order of Things*. London: Tavistock, 1970.

Foucault, M. "The Order of Discourse." In Shapiro, M., ed., *Language and Politics.* New York: New York University Press, 1984.

Frank, A. G. *Dependent Accumulation and Underdevelopment*. London: Macmillan, 1978.

Goldman, Steven L. "Philosophy, Engineering and Western Culture." In Durbin, Paul T., ed., *Broad and Narrow Interpretations of Philosophy of Technology*. Dordrecht: Kluwer, 1990. Pp.125-52.

Goldman, Steven L. "The Social Captivity of Engineering." In Durbin, Paul T., ed., *Critical Perspectives on Nonacademic Science and Engineering*. Bethlehem: Lehigh University Press, 1991. Pp. 121-45.

Institution of Engineers Australia (IEAust). "Policy on Management Studies in Engineering Undergraduate Courses." Canberra, 1990.

Institution of Professional Engineers New Zealand (IPENZ). *The Pathway to the Future*. Wellington, 1993.

Johnston, S. F., Gostelow, J. P., Jones, E., and Fourikis, R. *Engineering and Society: An Australian Perspective*. Sydney: Harper Educational, 1995. See esp. chap. 11.

Keynes, J. M. *The General Theory of Employment, Interest, and Money*. London: Macmillan, 1936.

Kress, G. "Socio-Linguistic Development and the Mature Language User: Different Voices for Different Occasions." In Wells, G. and Nicholls, J., eds., *Language and Learning: An International Perspective.* London: Palmer, 1985.

McCormack, R. "Framing the Field: Adult Literacies and the Future." In Christie, Frances, ed., *Teaching Critical Social Literacy*. Canberra: Department of Employment, Education and Training, 1991. Pp. 224-56.

McGregor, H. T., and Johnston, S. F. "Professional Development in the Mechanical and Manufacturing Engineering Cooperative Degrees." In Duggan, T. V., ed., *3rd World*

Conference on Engineering Education, vol. 3. Southhampton: Computational Mechanics Publications, pp. 274-8.

Miller, Peter, ed. "Are You at Risk: Managing Expectations." Canberra: IEAust Standing Committee on Liability, 1990.

Raxworthy, Richard. *The Unreasonable Man: The Life and Works of J. J. C. Bradfield*. Sydney: Hale and Iremonger, 1989.

Samson, D. *Management for Engineers*. Melbourne: Longman, 1989.

Soja, E. P*ost Modern Geographies: The Reassertion of Space in Critical Social Theory*. New York: Verso, 1989.

Taylor, E., and Johnston, S. F. "Why Transforming Engineering Courses Will Attract a Diversity of Students—Including Women." *Proceedings, Third Annual Conference*. Australasian Association for Engineering Education, 15-18 December, Adelaide, 1991. Pp. 239-44.

Williams, Bruce. *Review of the Discipline of Engineering*. Canberra: Australian Government Publishing Service, 1988.