

# **Contingent Immersion: A Naturalistic Methodology for Discovering the Socio-technical Realities of Engineering Practice**

David F. Radcliffe  
School of Engineering Education  
Purdue University, West Lafayette, USA  
dradcliffe@purdue.edu

## **Context**

Over the past decade engineering programs have moved to an outcomes-based paradigm relying on lists of desirable graduate attributes (e.g. ABET 2000; IE Aust, 1999). These lists of attributes were arrived at through conversations between accrediting bodies, industry and professional associations. However there is no real empirical basis for the selected attributes. Rather they are based on what various representatives perceive to be necessary now or into the future. Indeed there have been very few published studies of engineering practice as it happens, let alone studies that might inform the lifelong education of engineers based on the experience of practice. The literature contains many normative descriptions about what engineering practice is or should be like in different industry sectors. Most of these have not been tested empirically; yet they influence perceptions of engineering practice in the minds of students and educators.

There have been a limited number of studies of engineering knowledge use in practice, although the best known of these by Vincenti (1990) was a retrospective. Over the past two decades researchers have studied engineering design and design management practice using forms of ethnography (e.g. Bucciarelli, 1996) and practitioner-observation (e.g. Hales, 1987). These and other studies have contributed to the understanding of engineering design as a very complex social process as much as it is a technical or process based-activity. Different studies have explored a variety of ways to getting access to authentic engineering practice especially in the area of design (Lloyd and Busby, 2001; Demian and Fruchter, 2006; Henrick and Dorst, 2001). A few empirical studies have led to theory development as a way to characterize the nature of engineering work (e.g. Koskela et al., 2001).

This paper describes a new approach – contingent immersion – for exploring empirically some of the complexities of engineering practice as a socio-technical endeavor.

## **Research Question**

The motivating question was how is engineering actually practiced and how does this vary across different industry sectors, different engineering disciplines and different stages of the life-cycle of engineered products, systems and processes? This led to the precursor question addressed in this paper: How can we effectively study authentic engineering practice “in the wild” in a naturalistic way?

This research is vital if we are to make meaningful decisions about the future shape of engineering education. One of the five areas of engineering education research articulated by the Engineering Education Research Colloquies (EERC) was “engineering epistemologies” (Anon, 2006). This area includes, “describing and defining the nature of engineering work as a professional enterprise and articulating the roles of engineers in that work are critical components of creating this synergy”. Although the research depicted in this paper commenced before the EERC research agenda was developed, it responds nevertheless to the challenge put forth by the EERC, namely “The ever increasing pace of change in the engineering enterprise makes characterizing engineering a particularly challenging yet essential step to developing a meaningful understanding of the nature and long term needs of engineering education.”

### **Theoretical Framework**

This paper reports on experiences over the past eight years developing and testing a new framework for studying engineering in situ over extended periods; viz. contingent immersion. This framework draws on concepts from contingency theory and applies these both to the nature of the practice being studied and to the way its study is approached. Contingency Theory argues that there is no one best way to organize and manage firms and thus organizations should be designed to match their particular environmental / operating circumstances. Accordingly studies of practice using contingent immersion are not seeking to discover the laws of good engineering practice but rather to provide rich descriptions of practice and to characterize it in terms of its contingent nature.

Furthermore the way of going about this is contingent on the particular circumstances and the types of work being studied and the particular circumstances of the work environment. Contingent immersion is not a ground theory approach but utilizes existing theories from the social and learning sciences, design and management to help interpret observed phenomena. It can also contribute to theory extensions or the development of new theories where existing one prove inadequate.

Contingent immersion draws upon the concept of participant-observation from classical cultural anthropology. It incorporates the idea that an “insider” has unique access to things that happen in the moment in a way that other methodologies cannot discover. In the context of complex engineering work it is assumed that this insider perspective differs according to the background of the researcher; so an engineer will ‘see’ different things to that which an anthropologist will ‘see’ and each will interpret what they see differently – the sorts of theoretical constructs they use will differ considerably. The emphasis is on engineers as practitioner-observers in study of practice. Thus it complements traditional ethnography conducted by an anthropologist. Naturally the engineering practitioner-researcher must have sufficiently developed skills of observation, reflection and interpretation if they are to be effective in detaching from the work environment in order to ask the deeper questions about the underlying patterns in practice. This is not about making second rate ethnographers or management researchers from engineers but rather creating a distinct engineering research methodology that brings additional insights to an interdisciplinary appreciation of engineering practice.

## Methodology

In 1999, a series of naturalistic studies of engineering practice in situ was initiated by a research team at the University of Queensland in collaboration with leading international engineering design, aerospace and construction firms based in Australia. The work was made possible by establishing strategic partnerships between the individual firms and the university focused on combined education and research programs that would bring mutual benefits to both parties. Critically the coordinator of these partnerships was immersed in the firms and spent at least 50% of his time on a weekly basis located in a live practice setting as an engineering practitioner-observer linked to major projects and initiatives in these organizations. Because the partnerships were instigated and sanctioned at the highest level in the engineering organizations and the university, the coordinator had direct access to projects and personnel at all levels of the organizations. This approach affords unique and privileged access to what happens day-to-day and moment-to-moment in engineering practice. In contrast much research in business schools on business practices relies on occasional direct access with the firms under study complemented by once removed data gathering using tools like surveys.

Through direct involvement in education and capacity building programs in the firms, the partnership coordinator in the role of chief investigator could gather data directly in the form of notes and reflections upon participation in engineering project meetings and other project-based activities (workshops, design sessions, site visits, training programs), every type of work document and product (meeting minutes, reports, emails, artifacts, design reviews), informal discussions and senior management planning sessions. Further a series of co-CIs on funded research projects linked to the engineering firms also had access to much of this material, although they did not spend nearly as much time immersed in the firms.

Between 2003 and 2008, six graduate students also spent extended periods of time immersed in the partner firms conducting research on a variety of issues around practice. They were immersed in live projects for between 1 and 4 days per week for a total period of up to 3 years each as engineering practitioner-observers. For some this meant periods of full-time immersion and periods away while for others it amounted to a few days per week almost continuously. In all cases they contributed materially in some way to the project team they were immersed in. They also had time to step back and use the data they gathered to ask deeper questions about the nature of the practice.

The research was not a case of doing day-to-day consulting or offering process improvements to the team. Rather it was about one of having intimate daily access to fully appreciate what is involved in a real project; earning trust and respect from the other team members who were understandably skeptical about having PhD students in their midst. Engaging as a practitioner and contributing to the effort earned them social credit with the team. This “insider access” enabled them to not only gain unprecedented data through observations-in-practice but also to have privileged access to team members for gaining additional quality data via informal discussions, interviews and surveys. The coordinator was the principal advisor for each of the graduate students immersed in the firms and they held regular discussions on the premises as part of the research methodology.

## **Findings and Conclusions**

The focus of the multi-year research projects conducted by the graduate students included; the culture of design management across project stages and disciplines, knowledge conversion in risk and opportunity assessment in major projects, innovation diffusion of virtual construction technology at a project level, the impact of computer-aided design technology on creativity and thinking consequences in the uptake sustainable development concepts and methods in a firm. In addition the coordinator conducted two studies on the adoption of new approaches for in-house learning programs.

Each study using the contingent immersion approach required a tailored set of data gathering and analytical methods based on a relevant theory; one best able to interpret and give meaning to the phenomena that arise in the study. Most projects used mixed methods, a combination of qualitative and quantitative in order to both richly describe the observed phenomenon while also trying to gain an estimate of the frequency of occurrence and the patterns across different practice settings. Over an extended period of time (months to years) there was no way to control the unpredictable history of even the best planned of engineering projects being studied so the researchers had to be agile in responding to unexpected shifts and turns. Specific data gathering and analysis methods were also contingent on the emergent circumstances and could not be fixed in advance. This is not to say that the approach was unplanned or undisciplined; rather it was adaptive and sometimes opportunistic.

One unifying element for each study using the contingent immersion methodology was the selection or development of the most revealing theoretical framework for interpreting the observations and data. Selecting this framing was shaped not only by starting question(s) being asked in the study but also on phenomena that were only revealed during the study. It often took several attempts to find the most evocative framework.

All the studies identified phenomena and/or made theoretical contributions to new knowledge as measured through academic publication and acceptance by peers. Equally the findings provided hardened and often cynical practitioners with new insights as measured by the level of discussion and responses to numerous formative and summative presentations to management and members of project teams. This ability of the results of contingent immersion studies to speak to issues of concern for practitioners as well as meet academic acceptance is very promising. It offers a bridge between theory and practice for engineering education to build upon.

The methodology is very time intensive and it requires a sustained effort. In spite of having support from the senior management there is considerable effort required in developing and maintaining relationships with managers and all levels in the organization and with key personnel in projects or activities that are studied. Researchers from an engineering background require training and experience in observation methods and qualitative data analysis, and this cannot be rushed.

## **Recommendations**

Studies of practice are an underdeveloped area of research in engineering education. The opportunity exists to establish consortia of academics and students engaged in naturalistic

studies of engineering practice in order to build national and international capability for this type of work and to share methodologies and methods.

Contingent immersion offers a proven way to engage graduate students in research-on-practice and research-in-practice. While it is relatively time intensive and requires preparation and stamina the benefits are considerable. For graduate students it provides both time in industry while simultaneously developing new research skills and completing their dissertation. For faculty who participate or advise such projects it provides a methodological basis for engaging with industry on mutually beneficial terms plus insights into practice that could inform and enrich teaching methods, curricula and course content. For industry it provides some additional resources that might contribute (if only indirectly) to improved practices and processes, but more importantly it establishes a practical bridge with the academy at a critical time in the history of the profession.

Future research around the methodology of contingent immersion will focus on (a) the development a more complete theoretical underpinning for this approach and (b) the issues associated with the adoption and diffusion of the methodology.

### **Acknowledgements**

The author wishes to thank the firms involved for their financial and other support and the team members who contributed so freely to the research and the ARC for funding two linkage grants; LP 0347391 and LP 0455721. The author also wishes to acknowledge the pioneering efforts of the graduate students involved in this work.

### **References Cited**

- ABET, (2000) *Criteria for accrediting engineering programs*. New York: Accreditation Board for Engineering and Technology.
- Anon (2006) The Research Agenda for the New Discipline, *Journal of Engineering Education*, 259-261.
- Bucciarelli L. L., (1994) *Designing Engineers*, Cambridge, MA:MIT Press.
- Demian, P. and Fruchter, R. (2006) An ethnographic study of design knowledge reuse in the architecture, engineering, and construction industry, *Research in Engineering Design*, **16** (4), 184-195
- Hendriks, D. and Dorst, C. H. (2001), Design Project Management in Practice - The E-Mail Diary Study, 13th *International Conference on Engineering Design*, ICED '01, Glasgow, UK,
- IE Aust (2005) *Accreditation Management System Educational Programs at the Level of Professional Engineer*. Canberra: The Institution of Engineers, Australia.
- Hales, C. (1987), *Analysis of the Engineering Design Process in an Industrial Context*, Cambridge, UK: Gants Hill Publications.
- Koskela, L., Huovila, P. and Leinonen, J. (2002), Design Management in Building Construction:From Theory to Practice, *Journal of Construction Research*, Mar, 3(1), 1-16.
- Lloyd, P. and Busby, J (2001), Softening Up the Facts: Engineers in Design Meetings, *Design Issues*, 17(3), 67-82.
- Radcliffe, D.F. and Jolly, L. (2003) Dilemmas in Framing Research Studies in Engineering Education, *Proceedings ASEE Annual Conference*, Paper 1630.
- Vincenti, W.G. (1990) *What Engineers Know and How They Know It: Analytical Studies from Aeronautical History*, Pub Johns Hopkins Studies in the History of Technology.