Exploring the culture of engineering education: The journey *

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SUMMARY: *This paper charts some of the challenges faced in attempting to develop a framework for studying the culture of engineering education. The in-depth analysis of the culture at one institution, using an interpretive case-study methodology, highlighted issues of integrity and rigor, encountered when engineering educators cross disciplinary boundaries in education research. The framework of cultural dimensions developed in this study for engineering education has the potential to enable other institutions to similarly examine their own manifestations of the discipline culture.*

1 INTRODUCTION

My aim in this presentation is to chart some of the challenges I faced in attempting to define the culture of engineering education, in the hope that my experiences might highlight issues encountered when engineering educators cross disciplinary boundaries to educational research. At this time I am making the assumption that my audience is predominantly engineering educators with an enthusiasm for (but relative lack of experience in) educational research methodologies, while acknowledging that as my own experience continues to build, I am positioning myself as a fellow learner rather than an expert.

My research began in the mid 1990s, when the women in engineering community in Australia was spotlighting the masculinity of the culture of engineering as an inhibitor for increasing women's participation. This focus was illustrated by the first Women in Engineering forum in 1994, aptly named "Transforming cultures: Nurturing diversity in organizations" and in the position paper prepared for the 1996 Australian review of engineering education (Roberts & Lewis, 1996). Literature from this community (McLean et al, 1997) and internationally (Carter & Kirkup, 1990; Hacker, 1981; McIlwee & Robinson, 1992; Tonso, 1996a) not only highlighted the masculinity of the culture of engineering, but exposed the lack of cultural studies from within the mainstream of engineering education. Although the concept of culture is common within the wider educational community, it has only been in the last 10 years that the terms "culture" and "cultural change" have increasingly entered the engineering education discourse and literature, with definitions, perspectives and understandings abounding. I saw this focus as emanating from calls for reform in engineering education that cited change in the culture as "key to systemic reform" (Bucciarelli et al, 2000; Cordes et al, 1999) and the need for engineering educators to "question their implicit assumptions and radically reorder their priorities and practices" (IEAust, 1996). These calls for change in the culture of engineering education appeared to rely on the premise that engineering educators understood the concept of "culture" and its relationship to observable behaviours and practices. The literature of the time and the plethora of papers at international engineering education conferences since the 1996 review, have confirmed for me that a very high proportion of engineering educators do not share the familiarity and understanding of social scientists around the concept of culture. The focus appears to have continued to be on the characteristics of the behaviours and practices, "what is and what they should be" rather than the values, beliefs and assumptions that underpin "how they came to be". Amid the wealth of literature and reports detailing curriculum and program changes as products of those reforms, the engineering education culture has, however, rarely been defined nor has it been made clear exactly how those changes have impacted

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on culture (Baba and Pawlowski, 2001; Godfrey, 2001; Merton et al, 2004). Baba & Pawlowski (2001) went so far as to suggest that "limited or deficient understandings of culture hampered earlier efforts to modify or influence academic or organizational culture".

By the end of 1997, I had identified a lack of theorising around engineering education as a disciplinary culture, which led me to the realisation that building substantive theory around the concept of culture with respect to engineering education had the potential to contribute to a better understanding of the role of that culture in the participation of women. Although imperfectly formed at that early stage, my main research question was: "What are the dimensions/ elements of the culture of engineering education in the case study institution and how do they interact with gender?"

My first challenge was an excess of enthusiasm, coupled with a personal lack of academic background in the social sciences and more particularly in cultural theory. An intensive, but wide-ranging reading and discussion program followed. I was immediately struck by the complexity inherent in Geertz's description of culture:

> *Man is an animal suspended in webs of significance he himself has spun. I take culture to be those webs, and the analysis of it to be therefore not an experimental science in search of law but an interpretive one in search of meaning* (Geertz, 1973, pp. 5).

This complexity was exemplified in the many and varied approaches to culture to be found in the literature. Geertz (1973, pp. 4) cited some of the definitions of culture as: (i) total way of life of a people: (ii) the social legacy the individual acquires from his group: (iii) a way of thinking, feeling and believing; (iv) an abstraction from behaviour; (v) a theory on the part of anthropologists about the way in which a group of people in fact behave; (vi) a storehouse of pooled learning; (vii) a set of standardised orientations to recurrent problems; (viii) learned behaviour; (ix) a mechanism for the normative regulation of behaviour; (x) a set of techniques for adjusting to the external environment and other men; and (xi) a precipitate of history and as similes a map, a sieve and a matrix.

The concept of culture has been central to anthropology and folklore studies for over a century, and ongoing anthropologic debates continue as to whether culture is "subjective" or "objective". Sociologists, with their concern for contemporary societies, developed more fully the notion of group cultures and this opened the door to the study of organisations and institutions. From this tradition a wide-ranging literature considering disciplinary cultures (Becher, 1989; Gaff & Wilson, 1971; Neumann, 2001), higher education cultures (Bergquist, 1992; Tierney, 1988; Trowler, 1998) and organisational cultures (Hatch, 1993; Schein, 1985; Smircich, 1983) has developed.

The next challenge I encountered was realising that there was a need to identify a theoretical framework and research paradigm on which I would base my study. As Waller (2001) pointed out, engineering faculty are not accustomed to explicitly articulating the theoretical frameworks or assumptions underlying their disciplinary research. Scientific and engineering laws and theories, such as Boyles Law, are implicitly agreed upon by the discipline and not explicitly stated as assumptions, whereas in education research such certainty and agreement are not uniformly agreed upon. Frameworks, assumptions, perspectives and paradigms must be stated and their relevance for the study discussed. Without this sort of explicitness, informed peer review is deemed impossible.

Initially, because my early academic background and the likely audience for this study were both anchored in the positivist disciplines of science and engineering, I was drawn towards quantitative methodologies such as that used by Hofstede et al (1990). However, I quickly recognised that Likert-style questionnaires and their associated statistics were unlikely to contribute to a better understanding of the cultural dynamics and processes of enculturation, given that the latter, as suggested by McLean et al (1997) and Tonso (1996a), appear to be inextricably linked in the interaction of gender with the culture of engineering education.

Research in engineering education has been said to "almost exclusively depend on positivist methods of research using experimental evidence, usually quantitative, to support a defined hypothesis" (Tonso, 1996b, pp. 143). Positivist and interpretivist research paradigms were suggested by Bassey (1999) to indicate differing beliefs about the nature of reality and in consequence differing underpinnings for research actions. He suggested that positivists expect a single, tangible reality where knower and known are independent, and time and context free generalisations are possible. Things and events in such a reality are measurable and can be counted, and therefore the methodologies used by positivists are quantitative. In contrast, the interpretive researcher, Bassey suggested, saw reality as a construct of the human mind resulting in similar, but not necessarily the same, understandings. As a consequence, interpretive enquiry tries to uncover structures of meaning in use in a setting and "synthesise an image of that group's reality and make it available for consideration and reflection" (Smircich, 1983, pp. 164).

As engineers stepping outside their perceived discipline boundaries, McLean et al (1997), Radcliffe et al (2002), Tonso (1996b) and Waller (2001) all recognised that, contrary to the positivist research paradigm where the researcher is assumed to be objective, unbiased and distinct from the participants,

qualitative research methodologies were the methods of choice in situations where local knowledge and interpretation were needed to assign meaning to words and actions consistent with the meanings assigned by members of the group under study.

Among the various cultural theories and perspectives, I chose to use Schein's theoretical framework and definition of culture (Schein, 1985) as the foundation for my study. An influential conceptual framework for analysing and intervening in the culture of organisations, it has served as a departure point for many organisational theorists. Although engineering education was not itself an "organisation", the discipline was manifested inside educational departments and institutions and each of these was likely to form an identifiable group. Schein defined culture as:

> *... a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid, and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems* (Schein, 1992, pp. 12).

Although Schein's approach has been critiqued as a "functionalist" rather than "interpretive" approach (Hatch, 1993), in common with other culture theorists he has emphasised the need to go below the surface level of observable artefacts and behaviours to more tacitly known cultural knowledge and norms. In Schein's framework, the essence of culture exists in the deepest, unconscious level of basic beliefs and assumptions, which underpins the more visible cultural manifestations. In particular Schein suggested that extensive ethnographic research was required to understand this deepest level of culture, although the process could be shortened with the assistance of motivated "insiders".

In my research design I therefore chose to study engineering education at one institution in depth, over a specified period of time. Although definitions of the exact nature of a case study abounded in the literature, there appeared to be agreement that case study research always involves "the study of an instance in action" (Bassey, 1999, pp. 24), which allowed the researcher to "reveal the multiplicity of factors which have interacted to produce the unique character of the entity that is the subject of study" (Yin, 1988, pp. 82).

My intention with the case study was to generate theory, namely a framework or model for defining the culture of engineering education. Using a case study for the purpose of building theory has been recognised by several authors (Bassey, 1999; Merriam, 1988; Stake, 1994) as a common and valid research design, particularly in education. In such cases, the case itself is said to be of secondary interest, "playing a supportive role as it facilitates our understanding of something else" (Stake, 1994, pp. 237); in this instance, defining the dimensions of the culture of engineering education.

One criticism that has been levelled against the use of case studies is that working with one system, in this case one institution, makes the findings too specific and theory therefore not suitable for generalisation. Yin (1994, pp. 10) countered this criticism with the reminder that the goal of a singular case study was to generate or test theory ("analytic generalisation") rather than enumerate frequencies ("statistical generalisation"), and that the conclusions found were generalisable to theoretical propositions rather than populations and universes.

Although not linked specifically to a particular discipline, my research design followed the lead of a large number of earlier culture researchers from anthropology, sociology and organisational studies (Schein, 1985; Spradley, 1979; Tonso, 1997) in using ethnographic methods such as participant observation within an overarching interpretivist research paradigm. Denzin (1989) suggested that a central feature of an ethnographic approach was that data are collected by a participant observer who is committed to adopting the perspectives of those studied by sharing in their day-to-day experiences. Although my study was not designed entirely as an ethnography, my role as participant observer was "doing ethnography", which was the description, classification and interpretation of a particular group's way of life. I saw this approach as appropriate for answering my research questions, directed as they were at accessing cultural beliefs and assumptions. In particular I suggest that these methods were well suited within a cultural study, which needed to answer questions like "what is going on here?", and to decipher "how things are" and "how they got to be that way".

In summary, therefore, I designed my study as an interpretive (theory building) case study including, although not exclusively, ethnographic methods within an overarching interpretivist research paradigm. My analysis of previous research convinced me that this research design would allow me to analyse in depth the culture of the case institution, and using Schein's theoretical framework as a starting point, provide answers to my research question.

2 ROAD MAP

Eisenhardt (2002) proposed a "road map" for theory building case studies. Although I primarily used the work of earlier authors such as Merriam (1988) and Yin (1994) to guide my research design and data collection, combined with the work of Miles & Huberman (1994) and Bogdan & Biklen (1982) to guide data analysis, the "road map" suggested by Eisenhardt provides a useful framework within which to discuss my study procedure. This road map

is summarised and adapted with reference to this study in the table 1.

2.1 Getting started

The first step was the initial definition of research questions and tentative theoretical constructs. These have been described above. In essence, getting started was moving from questions such as "What problem is my research addressing?", "Why is this a problem?", "What is already known that will inform my exploration of this problem" and "Why is the resolution of this problem important?". From those beginnings, research questions were framed and a theoretical framework identified with which to approach the research.

My in-depth knowledge of the women in engineering research and engineering education literature enabled me to identify the lack of clarification and definition of the dimensions of the culture of engineering education, and the need to make visible the interaction of all aspects of that culture with gender.

As explained earlier, my decision to start with the theoretical construct provided by Scheins framework was based on its clear identification of "layers" of the culture, with the essence of the culture lying in the unconscious shared beliefs and assumptions that guided behaviours, actions and reactions. Although viewing these beliefs and assumptions as "shared", giving the members of the group cohesion and a sense of belonging, they were like dominant images or prevailing winds in that not every member of the group would believe or understand in exactly the same way. I was choosing an interpretivist research paradigm searching for meaning, and therefore needing to work with qualitative methodologies, specifically an interpretivist case study.

2.2 Choice of site for case study

The choice of a site for a case study has been seen as lying in "what it is you want to be able to say something about at the end of the study" (Patton, 1980, pp. 100, cited by Merriam, 1988, pp. 44). My research goal of establishing whether there was a causal link between the dimensions of the culture and the underrepresentation of women led me to suggest that the School of Engineering at the University of Auckland, New Zealand, would be a desirable institution to use as my case for the study for the following three reasons: (i) the availability of access and the opportunity for my prolonged engagement; (ii) a relatively high female participation rate of over 18% (implying some aspects of the culture encouraged or at least tolerated women's participation); and (iii) the introduction of a new degree structure and curriculum in 1996, the year immediately prior to my study, which appeared to contain elements that had been identified as leading to a gender inclusive culture (IEAust, 1996).

2.3 Methodology

Case studies using ethnographic methods are typically built up from multiple sources of evidence, known as triangulation, "the development of converging lines of inquiry" (Yin, 1994, pp. 92). Methodological triangulation, common in qualitative research, combines dissimilar methods (such as interviews, observations and physical evidence) to study the same unit. Within the interpretivist research paradigm, the majority of data will be qualitative (ie. words), but quantitative data are also appropriate within the same study (Eisenhardt, 2002), particularly in support of a generalisation made from a single or limited observation. It has been suggested (Denzin, 1970, cited in Merriam,

Table 1: "Road map" of research design (adapted from Eisenhardt, 2002).

Step	Activity
1. Getting started	• Initial definition of research questions • Some initial albeit tentative theoretical constructs
2. Selecting a case	• Selection of an appropriate site – chosen for theoretical not statistical reasons
3. Crafting instruments	• Multiple data collection methods – potential triangulation of evidence, including qualitative and quantitative
4. Entering the field	• Frequent overlap of data collection and analysis, including field notes • Flexible and opportunistic data collection methods
5. Analysing data	• Within-case analysis, gaining familiarity with data • Emergent themes and categories
6. Shaping theory/ categories	• Tentative themes, concepts and relationships emerge • Highly iterative – aim for theory to closely fit data
7. Enfolding literature	• Comparison of emergent theory with existing literature
8. Reaching closure	• Incremental improvement to theory is minimal • Theory proposed and implications for further study

1988, pp. 69) that "the rationale for this strategy (methodological triangulation) is that the flaws of one method are often the strengths of another and by combining methods observers can achieve the best of each". Data triangulation uses purposive sampling within one method, such as interviews, to ensure different perspectives by choosing participants of different gender, status, ethnicity and, where deemed useful, participants known to hold opposing or alternate viewpoints. A comparison of data from different years, students and staff, made possible by long-term and repeated observation, is another way of validating the interpretation of data, and this has been named as "time triangulation" (Cohen & Manion, 1994). My study used methodological, data and time triangulation to enhance reliability and validity of data interpretation.

In summary, data were collected from:

- Questionnaires with responses anonymous, but coded by engineering discipline, were mailed to:
  - o Final year students – 50 female (56% responded) and 100 male students, matched by ethnic and academic background (28% responded)
  - o Academic staff – 28 out of100 responded.
- Semi-structured interviews were conducted with:
  - o 27 final year or newly graduated female students
  - o 7 final year or newly graduated male students
  - o 18 first year students (9 female and 9 male)
  - o 25 academic staff across all levels of seniority, including a current and former Dean.
- Seminar/workshops/targeted discussions with academic and general staff.
- Personal field notes from 4 years of observation of classes, tutorials, meetings, daily interactions, etc.
- Documentary evidence, including strategic plans, statistics, meeting minutes, publications.

2.3.1 Questionnaires

The goals of using questionnaires were to:

- get "broad brush" information on individual students' experiences, both academic and social of their engineering education
- provide a basic set of themes and issues to be explored in greater depth by further interviews
- look for commonalities and shared understandings, but also contradictions and differences, that might be linked to gender, ethnicity or engineering disciplines
- give voice to those who might otherwise be "silent" when interviews were conducted with a much smaller group. I particularly wished to solicit responses across the full range of ethnicity and gender.
- seek impartial, anonymous responses that would not be affected by bias that might otherwise occur in an interview situation where I was likely to be known to many of the informants.

The low response rates from male students (~28%) was disappointing but in the range quoted as normal (Alreck & Settle, 1995) for a postal questionnaire without follow up reminders, and provided an acceptable cross-section of responses. An ongoing challenge in postal surveys is how to increase the response rate without compromising anonymity.

2.3.2 Interviews

Informants were chosen for interview using purposive or purposeful sampling (Merriam, 1988), rather than by random sampling. When the questions to be answered are not "how much" or "how often", but discovering, understanding and gaining insights into what occurs in a setting, then it has been recognised that it is necessary to choose respondents from whom one can learn the most (Patton, 1980, cited in Merriam, 1988, pp. 48). Informants were chosen across a range of status, gender, ethnicity and experience within the setting. To ensure credibility, information was taken from many different points of view. Those known or liable to have distinctly different opinions and understandings of a topic were deliberately sought out by the researcher. Interview transcripts demonstrated that a high proportion of the staff and students recognised that the interview process was the first time they had reflected on some of the issues raised, and in many of these cases their observations were at the surface level of describing behaviours and practices. Several respondents had a more insightful view, however, and were able to reflect and articulate "the way we do things round here", often continuing discussions past the first interview, which resulted in them becoming key informants.

In my study, the relationship between myself and my interviewees was critical to the nature of the data I gained. The goodwill and trust with which students appeared to view me was evidenced in the depth of personal exposure many of them provided in their interviews. I would be the first to acknowledge, however, that response to factors such as my age, sex and role within the institution may have provided me with different data to that collected by another researcher. This is inherent in the subjective nature of this mode of data collection. Merriam (1988, pp. 85) and Trowler (1998, pp. 147) both commented that informants are consciously or unconsciously selective in their choice of words, providing an individual perspective rather than facts. Through triangulation I was able to validate interview data by comparison with accounts from other informants, participant observation and other sources of data. Statements such as "our class was such a closed group" could be checked against the accounts of other classmates and my own observations. Another example, the comment "my class only had three girls" threw an

instant spotlight for me on a biased perspective (that class had 20 female students of whom only 3 were of NZ European ethnicity). I was also aware, warned by the ethnographic literature, that my own non-verbal signals such as body language might be interpreted as encouraging or discouraging students and even staff to continue a particular line of thought.

Although informal contact with the first-year students interviewed for the study continued throughout their degree and several continued to be key informants, continuing formal interviews past the year 2000 was deemed invalid and unethical as the researcher's status within the institution changed to one of authority, which had the potential to bias student responses. Consequently student interview data was predominantly from final-year graduating students, and students at the end of the common first year.

2.3.3 Participant observation

Participant observation has been described (Merriam, 1988, pp. 89) as the technique of choice in an interpretive case study, when behaviour can be observed firsthand and where access is possible over extended periods of time. In this case I was working as what Merriam (1988) described as a "participant as observer", where my research activities were known to the group but subordinate to my established role within the institution. In my observer role, I watched for the cultural contexts of behaviours and practices, looking for those mutually understood sets of expectations and explanations that enabled me to interpret what was occurring and what meanings were probably being attributed to events by those present.

I kept a field-notes diary from late 1996 to the end of 1999, in which I recorded same-day observations from formal and informal meetings, conversations and interactions with both staff and students. Clearly, I did not record every conversation or happening, but my discrimination grew, alongside the growth in my understanding, in terms of which behaviours and practices were potentially culturally significant.

Over the period of the study I became increasingly aware of the importance of Merriam's suggestion that participant observation involves a balance or trade-off between the depth of information that is revealed and the level of trust and confidence in the promised confidentiality. In recognition of this need for trust, and with awareness of my ongoing commitment to working in the institution, I took care to distinguish my employed role and role as a researcher in conversations that appeared to be of interest for my study. I sought permission wherever possible to use a quote given in such informal situations and often emailed my understanding of the conversation to get confirmation or clarification.

2.3.4 Documentary evidence

In my study, the strengths and advantages of using documentary evidence as data could be summarised as they:

- were exact – precise and quantitative, containing exact names, references and details of an event
- provided broad coverage
- were unchanging and could be reviewed repeatedly.

I kept an inventory of all documents selected as potential sources of data for my study to provide an audit trail. The context and purpose of the documentation were important, and reporting biases were a potential limitation if insider knowledge was not available. Examples were the positive "best picture" bias likely in recruitment literature and documents prepared for an Accreditation Review, and meeting minutes that provided only the final decision, rarely containing details of contentious discussion or even that discussion had occurred.

2.4 Entering the field

Before entering the field to collect data, an essential step was to gain ethics approval from the appropriate authorising body at your institution. This can be a challenge, as I have found out in a more recent study. Current requirements at my institution require exact details of data collection; who, how, when, where and what questions will be asked, together with sample copies of information sheets that will be provided to participants on which they will give their signed approval; signed approval sheets from Heads of Departments; etc. The challenge arises in the iterative nature of qualitative research, where precise directions cannot always be discerned in advance. The purpose of ethics approval is, however, essential. It ensures privacy and an ethic of "do no harm".

On entering the field, data collection was not always conducted in a fixed time progression. The collection and preliminary analysis of data from final-year students and new graduates, for example, stimulated the further collection and use of other data collecting strategies with first-year students in an effort to chart the processes of enculturation. The timeframe for data collection was the years 1996 to 1999 inclusive, although participant observation and feedback from graduates and staff continued through iterative feedback processes until the submission of my study. Student data collection, via formal interviews, was unable to continue post-1999 due to my change in employment to a position of authority within the School of Engineering, a change which I believed had the potential to compromise the validity of student responses.

Data were stored and filed systematically, in both electronic and hardcopy formats as appropriate, adhering to "best practice" models (Miles &

Huberman, 1994) that would permit an audit trail of data collection and analysis.

2.5 Analysing data

At all times during data collection, the relevance of observations, documents and the like to the research questions were checked for potential cultural significance. In the interests of academic rigor, the research design and methodology were checked constantly against the four main criteria of validity and trustworthiness for qualitative research, namely (a) credibility, (b) dependability, (c) transferability, and (d) confirmability (Lincoln & Guba, 1985). Member checks and cycles of feedback at several points during data collection and analysis confirmed the degree of "truth' that the findings had for members of the culture

Initial analysis of the final-year student interview data, consisting of reading and re-reading transcripts, annotating them with potential themes and categories, led to the identification of four themes:

- Engineering was "hard".
- Friends and mates were very important and valued.
- Engineers had a strong sense of belonging to a collective identity.
- Engineers were taught and learned a common way of thinking.

As data collection progressed, and the quantity of data obtained from these multiple sources grew, the interconnections between themes and categories became quite complex. Again, a challenge presented itself: to continue with manual coding and data handling, or to implement one of the text coding software applications. After transcribing all the interviews personally, my intimate acquaintance with the data influenced my choice to continue with manual coding. A comprehensive and rigorous method of data analysis was necessary to establish a chain of evidence that was transparent and reliable. Inductive coding techniques suggested by Bogdan & Biklen (1982) were used to analyse the interview and questionnaire data. The categories shown in table 2 were used as starting points, and were a compromise between codes created prior to analysis based on experience and prior knowledge of the field, and inductive coding techniques.

The transcript text was examined line by line, allowing sub-categories or labels to emerge, a code applied and a comment identifying a possible shared understanding implied by that piece of text. Examples of coded pieces of text are given in table 3.

Table 2: Suggested categories for grouping codes for interview data (adapted from Bogdan & Biklen, 1982).

Domain	Data would describe
1. Setting/context	general information on surroundings
2. Definition of the situation	how people understand, define or perceive the setting
3. Perspectives	ways of thinking about the setting "how things are done here"
4. Ways of thinking about people and objects	understandings of each other, outsiders or objects in their world
5. Process	sequence of events, transitions, changes over time
6. Activities	regularly occurring kinds of behaviour
7. Events	specific activities, irregular
8. Strategies	ways of accomplishing things
9. Relationships	cliques, romances, friendships, enemies
10. Methods	problems, joys, dilemmas of research process

Table 3: Sample pieces of coded text.

Transcript text	Code	Comment
"also because it is a scientific course and the strength of wood is objective thing, whereas in Arts when you are studying Shakespeare, you get a million ideas and if you argue your point it is right"	EN_WAY	• Engineering is objective, not opinions
"I don't think I have ever seen any female who I would consider the practical sort who can look at something and say 'well this is pushing down here so this is happening up here' – but they get the maths – sort of more studious – most of the females"	GEN_SK	• Females are less practically skilled. • Females more studious and academic

Some data were clearly related to academic practices, such as course structures, the pervasive use of mathematics and the value placed on design courses. Others were related to social behaviours and practices both inside and outside the classroom, such as responses to the heavy workloads, the occurrence of binge drinking and the importance students placed on supportive relationships. From aggregation and initial analysis of this coded data, understanding evolved of: firstly, the sense of depth and interconnected layers within the outermost, observable level of culture; and secondly, the dynamic relationships between the levels of culture. An artefact such as a building, for example, gained cultural significance from the practices, behaviours and shared understandings that had developed around its use exemplified in comments such as: "I love coming into the engineering school. I feel at home there" and "It's almost like we're proud of not going to the rest of the university –across the road. We say 'Ooh, I'm crossing the road' as if it is sort of shameful ...".

Teaching practices in the form of curriculum, content and assessment items were available on websites, handouts and in handbooks, and may have been considered as physical artefacts, but for the purposes of this analysis were considered as Practices, closely tied to the understandings and meanings attributed to them by the members of the culture. Consequently Schein's model of culture analysis was amended to more clearly illustrate those understandings and the model presented in figure 1 guided the rest of the cultural analysis.

2.6 Shaping theory

The model illustrates that even within the first level of observed and experienced manifestations of culture there were levels of cultural knowledge and understanding. Firstly, there was the level visible to a visitor or newcomer; buildings, publications, dress, gender and ethnic composition. Secondly, after a longer period of observation and investigation the structures and practices, including those which were not written rules or regulations, were revealed. Thirdly, after trust had been established, insightful discussions with members of the culture provided information about behaviour patterns and the reasons behind them.

The first level of analysis was therefore divided into three overarching categories: Artefacts, Practices and Behaviours. In Artefacts, data referring to those cultural features that were visible, material manifestations and symbols of the culture – such as written documents, publications (both official and student-based), mission statements, buildings and styles of dress – were grouped together. Practices was defined in the context of this study as "the usual manner of doing something". Grouped together under the heading of Practices were data referring, for example, to curriculum, teaching practices, assessment practices, regular events and reward systems.

Similarly the psychological definition of Behaviours as "observable responses (of human beings) as reactions to the outer environment" was used to include responses to other people, systems and procedures, and, in the terms of this study, responses to the Practices and Artefacts. Behaviours included sections on:

- Behaviours in the academic learning environment – which included workload, cooperation versus competition, classroom behaviour and strategies for support
- Language – including humour, and the ways language reflected value systems either directly

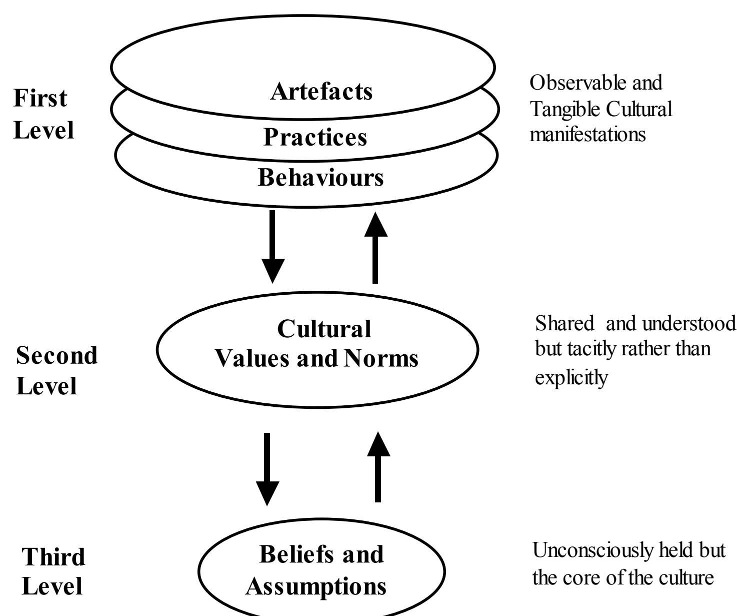

Figure 1: Theoretical model for cultural analysis (amended from Schein, 1985).

or indirectly, intentionally or unintentionally and its power to include or exclude from the culture

- Relationships – and their importance to academic and personal "success"
- Critical incidents – from time to time incidents occurred that brought responses that highlighted the values, beliefs and attitudes shared by the group.

In many instances, it seemed that the data grouped under Practices epitomised the formal delivery of the curriculum, whereas the data grouped under Behaviours had features that have been viewed as the "hidden curriculum" (Margolis, 2001). These were the lived experiences, the informal learning that took place – of strategies, techniques, and relationships.

The second level of analysis then sought to look underneath the observable artefacts, behaviours and practices, using the voices and experiences of members of the culture to interpret which cultural norms or shared values were being manifested. For each of the groupings of Artefacts, Behaviours and Practices, shared values and norms were listed, with pointers to the sources of data from which they had been inferred. As explained above, a building in itself, whether it be ugly or beautiful, does not confer "a sense of belonging", but with continued association understandings can form such that the building becomes a symbol for members of the culture, contributing to the cultural norm of "a sense of belonging and collective pride as engineers". As an example, figure 2 illustrates other sources of evidence compiled for this norm.

Analysis, even to this level, revealed information, firstly, about whether espoused values and goals had become embedded in cultural norms, and secondly, the enculturation processes by which students developed shared understandings and learned cultural norms from the daily reinforcement of artefacts, behaviours and practices.

The third level of analysis was based on the premise of the suggested model that the observable and tangible manifestations, and cultural norms identified in the first two levels of analysis had developed from shared beliefs and assumptions that had formed over time.

Schein had suggested that these shared beliefs and assumptions were personal and collective answers to issues such as "How do we communicate?", "How do we deal with authority and our peers?" and "What are appropriate levels of co-operation or competition?", but he also suggested that a culture's beliefs and assumptions could be grouped in more abstract dimensions such as the nature of reality and truth, time, space, human nature, human activity and human relationships.

Distilling from the values and cultural norms identified at the second level of analysis, beliefs and assumptions apparent for engineering education at the case study institution, and thinking how they might fit with Schein's abstract dimensions led to the proposal of the six dimensions named below. For each dimension shared beliefs and assumptions had formed around questions, such as those provided as examples, which positioned the culture of engineering education as manifested at the case study institution.

(i) *The Engineering Way of Thinking*. What kinds of knowledge were valued? What was perceived as truth? Was there a prevalent way of thinking? What constitutes reality?

(ii) *Relationship to the Environment*. What was the relationship of the culture of engineering to the

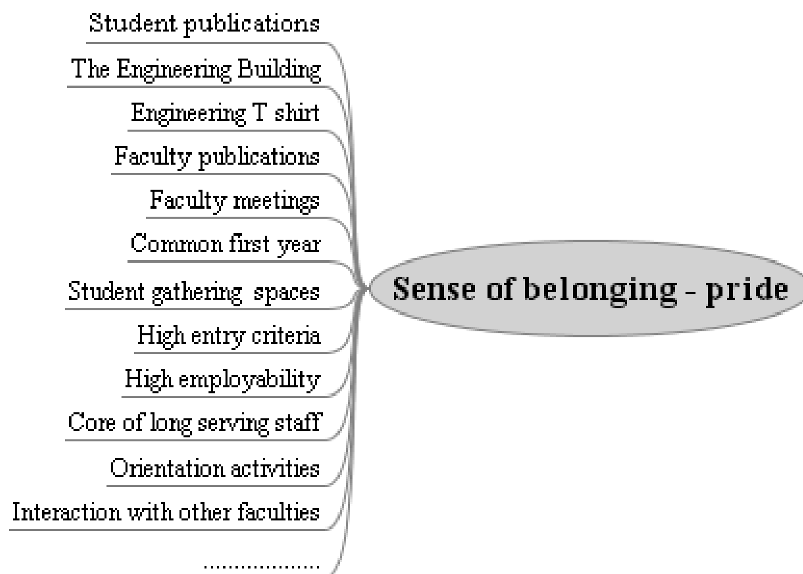

Figure 2: Sources of evidence for a cultural norm identified as "a sense of belonging and collective pride as engineers".

rest of the university and academia in general, the profession and community?

(iii) *The Engineering Way of Doing*. What was the primary task? How was it to be accomplished? Was there a "right" way to teach/learn?

(iv) *Relationships*. What was the nature of relationships in this culture? Was there a "right" way for people in this culture to relate to one another?

(v) *The Engineering Identity*. Were there attributes and qualities inherent in being "an engineer"? Who fitted in and was successful?

(vi) *Homogeneity*. Was it seen as desirable or necessary to have homogeneity or diversity in the members of the culture? How was difference accepted?

The beliefs and assumptions associated with each of these dimensions in my study will be specific to engineering education at the case study institution at a particular point in time. They were distilled from individual Artefacts, Behaviours and Practices with their associated shared values and cultural norms as features of "a" culture of engineering education, rather than "the" culture of engineering education. Similar processes would occur in any institution or discipline in which a history of shared experience and stability had allowed a distinctive culture to emerge. It is proposed that these dimensions form the framework within which cultures of engineering education can be positioned.

3 REFLECTIONS

I have described my journey in exploring the culture of engineering education via a road map of my research study, together with some of the challenges I faced working in a qualitative research paradigm. One goal for my study was that it should be accessible and acceptable by engineering educators, for whom the interpretivist research paradigm was non-traditional. I have discussed some of the ways in which I endeavoured to ensure that my study could be evaluated on the basis of the integrity and soundness of the analysis.

A criterion of credibility or internal validity is the degree of confidence in the "truth" the findings have for the participants in the case study institution. A reliable interpretation of the participants' lived experience was assisted by my prolonged engagement with the site and personal relationships with many of the participants. This allowed for ongoing feedback and discussion to clarify and verify interpretations. Member checks, feedback seminars and circulation of preliminary "research in progress" papers were invariably greeted with "uh huh" or "yeah, that's right", or even more detailed commentaries, providing confirmation for my interpretations.

External validity or transferability is concerned with the extent to which the findings of one study can be applied to other situations. My aim in this study was not to generalise the unique culture of this institution to other institutions. Rather, my aim was to provide an in-depth analysis of the engineering education culture at one institution from which I could define the dimensions of the discipline culture and ultimately expose the interaction of gender within that culture. The transferability of my research lies in my development of a model for cultural analysis, and a set of cultural dimensions for engineering education, which have the potential to enable other institutions to similarly examine their own unique manifestation of the discipline culture.

If engineering education reformers are to seriously address cultural change, they will need assistance in traversing the "webs of significance" that make up the complexity of that culture. Perhaps the greatest reward in research for me has been to recognise gradual shifts in the discourse; to see a recognition of the need to address values, beliefs and attitudes if behaviours and practices are to be shifted; and to know from communications and citations that my research has made a contribution, albeit small.

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