Session 2630

A Theoretical Model of the Engineering Education Culture: A Tool for Change

Elizabeth Godfrey
The University of Auckland

Introduction

The call for "a culture change in engineering education, ultimately to extend throughout the profession" in the Australian Review of Engineering Education: *Changing the Culture*[1] threw a spotlight not only on the need for change but the need for change in the culture. In recommending a "more outward looking culture attuned to the real concerns of communities", better communication skills, and political and social awareness, the Australian review echoed discussions occurring simultaneously in the UK, USA and Canada. Increasingly in the last seven years, the term "culture" has entered the engineering education discourse and it seems implicitly understood that engineering education has a distinctive culture, recognizable to all its practitioners. The unitary and homogeneous nature of this culture is itself open to question, but engineering educators undoubtedly recognize practices and behaviors, that transcend differences in engineering specialization and institutions and even national boundaries. Most courses have in common features such as the immutable nature of curriculum content, little choice in selection of subjects, a mechanistic rather than holistic approach, and a high emphasis on problem definition and solution within specific criteria - usually involving the appropriate application of mathematical equations[2] .

A perceived flaw in the calls for cultural change is the assumption that engineering educators are familiar with the theories and models of culture and cultural change, which have their origins in anthropology and sociology. Engineering educators are much less likely than social scientists to have common understandings of the relationship between the concept of culture and observable behaviors and practices. The Australian Review highlighted a need to recognize "the differences between the values that underpin the existing culture and the espoused values to which it aspires"(p. 21) but did not make clear what those current underlying values were and stated that it was "imperative to question implicit assumptions, priorities and practices (p.5).

It is argued in this paper, that for long term cultural change, engineering educators need an understanding of not only, how (or if) the espoused values and ideals of engineering education are manifested in the lived experience that forms the current culture, but how that culture is formed and maintained. A theoretical model for the culture of engineering education is proposed which provides an analytical framework to identify the basic beliefs, values and assumptions held by both staff and students, and reveal how they combine with the construction of the discipline to guide actions.

Theoretical background

A wealth of definitions for culture abound in the literature relating to culture, but Schein's influential model[3] provides a useful starting point, because of its clear delineation between three levels of culture: the observable manifestations of culture (artefacts), the values and behavioral norms that underlie them and at the deepest level a core of shared beliefs and assumptions. 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, p.12*

The most accessible and visible elements of a culture, the artefacts, encompassing day-to-day behaviors and practices as well as physical objects, are viewed as furthest from the core of the culture. Artefacts can be seen as just phenomena but when members of a group have a history of shared experience, and develop shared values and norms which guide behaviors and practices these phenomena have cultural significance. A cultural study requires looking beneath observable practices, behaviors and other visible cultural manifestations to the tacit knowledge, shared values and understandings that guide and direct them. Schein went further to name the core of unconsciously held, basic assumptions, which nurture and support values and cultural norms as the essence of a culture.

Methodology and Analysis

The findings presented in this paper form part of a study to define the dimensions of the culture of engineering education exemplified in a multidisciplinary School of Engineering at a large, well established New Zealand university and, in so doing, develop a model that could be used to position specific cultures at the discipline or institutional level. Twelve years of close association by the author with the chosen site provided the mix of closeness and distance viewed as ideal when Trowler[4], discussing cultural studies of higher education, proposed that "an insider account based on multiple methods of data collection had the potential to not only uncover the meanings, understandings and intentions of the members of a culture, but give insight into the structural contexts in which they operate and the unintended consequences of their actions"(p.148).

An interpretive (theory building) case study methodology[5] was therefore chosen, including, although not exclusively, ethnographic methods within an overarching interpretivist research paradigm. Multiple methods of data collection, which supplemented several years of participant observation and interviews with a range of staff and students, with questionnaires, focus groups, workshops, statistics, and a wide range of documents and publications, evidenced the use of methodological, data and time triangulation contributing to the credibility of subsequent theory development. These methods were seen to be 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”.

As data collection progressed, and the quantity of data obtained from multiple sources grew, it was coded using inductive coding techniques suggested by Bogdan and Biklen [6]. Some data were clearly related to academic practices, such as course structures, the pervasive use of mathematics and value placed on design courses, and others related to social behaviors 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 initial analyses 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, behaviors and shared understandings which had developed around its use. Teaching practices in the form of curriculum and content, provided on websites and handbooks, may have been considered as physical artefacts but for the purposes of this analysis were considered as practices which were 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 cultural analysis.

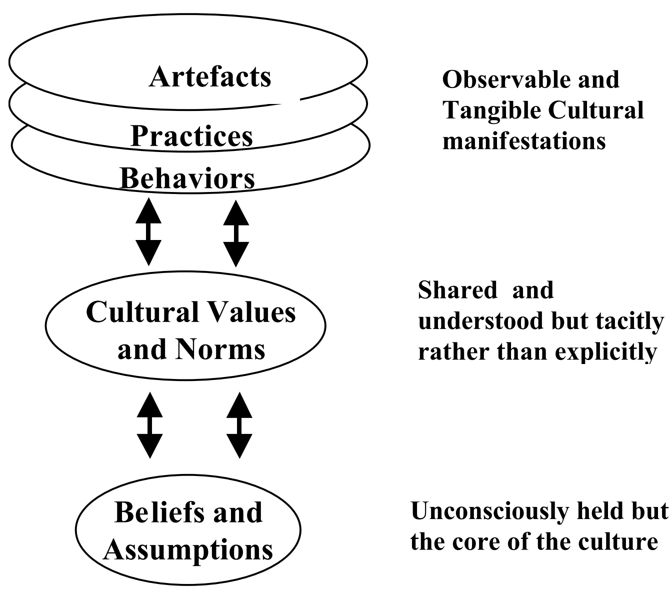

Figure 1 Theoretical model for cultural analysis

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 and thirdly, after trust had been established, insightful discussions with members of the culture provided information about behavior patterns and the reasons behind them.

The first level of analysis was therefore divided into three overarching categories, Artefacts, Practices and Behaviors, for reporting purposes. In Artefacts, those cultural features which were visible, material manifestations and symbols of the culture such as written documents, mission statements, buildings and styles of dress were discussed. Practices were defined in the context of this study as "the usual manner of doing something" referring to those aspects of the culture which represented "the way we do things round here" and included curriculum and teaching practices, assessment, regular events and reward systems. Similarly the use of behaviors was clarified by reference to the psychological definition of "behaviors" as "observable responses (of human beings) as reactions to the outer environment" therefore including responses to other people, systems and procedures and, in the terms of this study, responses to the "practices" and "artefacts". Of cultural significance in this category were responses to the academic environment, relationships, language and humor. In many instances the grouping Behaviors encapsulated the "lived experience" or "enacted" aspects of the culture.

Bringing together evidence from a variety of data sources, gathered under each of Artefacts, Practices and Behaviors, values and shared cultural norms were identified as the second layer of analysis. An earlier presentation [7] described in detail the interpretation of values and norms from Artefacts in this study.

This second level of analysis was particularly revealing of enculturation processes. Tonso[8] had described engineering education as "enculturation into a well-established system of practices, meanings and beliefs" as students "learn what it means to be an engineer" (p.218) and a wealth of examples demonstrated how students interpreted day-to-day practices and behaviors to determine what was valued and rewarded by academic and social success.

Some practices in the case study institution were the explicit manifesting of espoused values formulated during a major curriculum restructuring. As examples, two goals of this restructuring were: the valuing of communication and professional skills which were manifested by the inclusion of a Professional Development course in each year of the degree, and the valuing of a perceived "engineering way of thinking" manifested by implementing a restructured first year set of courses taught entirely "in-house" to replace a first year of fundamental science courses. As a consequence of making these values explicit in the curriculum and teaching practices, students developed shared understandings exemplified by these comments:

> *You do have to think about that, they have been drumming it into you. Engineering is communicating, you have to know how to write, and how to talk with people and communicate*
>
> *Angus, 1st year student*

> *Basically you are writing reports all the time - now when I have to write a report its just second nature - It was good*
>
> *Sally, 4th year student*

> *Diverse range of courses – not one overriding philosophy.* ***Some courses seem to be teaching us to think as engineers whereas others, rightly so, are concerned with basic knowledge, the calculations, the details***
>
> *Laurie, 1st year student*

> *Thinking like an engineer, kind of being taught it I suppose. The whole course is directed at making you think differently, that is how I feel it.*

John, 1st year student

Other cultural norms, such as the pervasiveness of mathematics as an efficient, effective means of communication throughout engineering education were tacitly understood although never articulated in strategic plans. Students and staff appeared to share understandings of the role of mathematics:

> *Engineers have to be able to, have a mathematical mind, and enjoy maths I guess or at least tolerate it. I think it is the most important thing*
>
> *Alex, 1st year student*

> *Maths is part of the route of the whole analysis whether it be structural or a circuit….*
>
> *Sstaff1*

> *Mathematics is a nice vehicle for delivering these ideas ….. I don't think you could really function without mathematics in these sorts of systems*
>
> *SStaff6*

> *We use maths like a language – a language to express ideas - so unless they can understand what the parts of the equation mean they cannot see how it can be manipulated and a higher level of understanding cannot be attained.*
>
> *JStaff4*

Tensions and contradictions were often revealed at this layer of analysis, as cultural norms revealed, not only by the practices and behaviors but the shared understandings of their significance, exposed a mismatch with espoused values. Assessment practices, for example, often revealed such mismatches, at a variety of levels. In individual assessment items practice was sometimes perceived as not matching goals:

> *The lectures in Geomechanics were really interesting and included stuff about the environment but the exams were all mathematical – easier to mark I suppose.*
>
> *Tash, 4th year Civil student*

> *The lecturer said the test would be based on understanding concepts and ideas and the test was all multichoice rote learning or numerical problems. Some people were a bit dismayed and asked "What the heck is going on"*
>
> *Laurie, 1st year student*

Course aims often emphasized "deep learning", the understanding and application of knowledge such as:

> *To understand the fundamentals and basic principles in the design and operation of heating, ventilating and air-conditioning systems…..*
>
> *MECHENG 411 handout*

but often resulted in perceptions of student learning reflecting an instrumentalist or surface learning approach, "go for grades", "find the answer", rather than understanding or extension of knowledge:

> *They won't do it if it doesn't count for a grade*
>
> *Jstaff3*

> *Sometimes we did not have the time to learn, just to hand in the assignments on the date they were due*
>
> *Questionnaire F18*

Too much in too short a time, we never had time to get into anything in depth

Questionnaire M3

The aim of this second level of analysis was to constantly seek underneath the observable behaviors and practices, using the voices and experiences of members of the culture to interpret which cultural norms or shared values were being manifested. 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, behaviors and practices.

The dimensions of the culture of engineering education

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 which had formed over time as engineering educators and students sought to find their personal and collective answers to issues which Schein[2] had named "issues of external adaptation and internal integration". These issues, for engineering education were seen as focused around the following questions:

- What kinds of knowledge were valued? What was seen as truth? Was there a prevalent "way of thinking?"
- What was the relationship of the culture of engineering to the rest of the university and academia in general, the profession and community?
- What was the primary task – how was it to be accomplished – was there a "right" way to teach/learn?
- What was considered the "right" way for people in this culture to relate to one another?
- Were there attributes and qualities inherent in being "an engineer"? Who fitted in and was successful?
- Was it seen as desirable or necessary to have homogeneity or diversity in the members of the culture? How was difference accepted?
- How was time managed? Was the use of time seen as important?

Using these questions as a base, shared beliefs and assumptions distilled from the values and norms identified at the second level of analysis were grouped into seven dimensions. These were named as:

1. The Engineering Way of Thinking
2. Relationship to the Environment
3. The Engineering Identity
4. The Engineering Way of Doing
5. Relationships
6. Time
7. Homogeneity

Some features of the culture at the case study institution may have been unique, such as the tradition and valuing of integration between the sub-disciplines, and the School of Engineering's sense of identity and isolation from the wider university but many of the beliefs and assumptions identified in these cultural dimensions appeared to be the source of practices and behaviors commonly identified in the international research literature.

Two of these dimensions, the Engineering Way of Thinking and the Engineering Way of Doing, and the shared beliefs and assumptions linked to them are discussed in further detail as exemplars of this third level of analysis.

The Engineering way of thinking

The evidence presented in this study emphasized that, despite individual differences, there were shared beliefs and assumptions around the questions: What kinds of knowledge were valued? What was perceived as truth? Was there a prevalent "way of thinking?" which were named "The engineering way of thinking". It was observed that these beliefs and assumptions were rarely discussed, appearing to be unconsciously held and taken for granted by both engineering academics and professional engineers.

The first of these was that engineering dealt with a tangible, definable, measurable, quantifiable reality. Valued knowledge was seen as relevant to real life. "What would we use this for?" was the justification for learning. It was found that abstract, philosophical concepts, such as ethics and sustainability were unacceptable to both staff and students unless taught in a practical, relevant context.

In this discipline, truth and reality were proven and described by mathematics. Is the bridge safe? Will the structure cope with an earthquake measuring 8 on the Richter scale? Can the functionality and efficiency of this product be improved without increasing costs, or losing quality? Mathematics was the tool and language by which these and other questions were answered. Within engineering a shared set of understandings based on common knowledge and practice resulted in comments such as this one:

> *"The line (1)* $\Sigma F_y = m\,a_c$ $200g - T_c = 200(a_c)$ *in the model answer was as good as a sentence to me"*
>
> *Jstaff10*

The inextricably pervasive nature of mathematics within engineering was so essential as a key to access, understanding and thinking like an engineer, that it was used and sometimes recognized, as a language:

> *...we use maths like a language – a language to express ideas - so unless they can understand what the parts of the equation mean they cannot see how it can be manipulated and a higher level of understanding cannot be attained.*
>
> *JStaff4*

The need to work with the definable and measurable was reflected in the prevalence, not only of mathematics and its symbolic language, but also the use of diagrams and graphics to communicate, rather than a reliance on words. Even when using the written word, there was a tendency within engineering to emphasize logical directness and order rather than opinion, argument or ideological reflection, sometimes recognized as "*thinking in bullet points*".

Secondly, the "engineering way of thinking " was focused around problem solving and design. Problem solving was dominated by reductionist and top down methodologies - breaking complex systems down into separate modules, and often invoking mathematical formulae or estimation. Design in particular appeared to epitomize the essence of what staff and students believed to be the "engineering way of thinking", that which made engineering distinct from pure or applied science. The engineer's role developing optimal, innovative solutions to real rather than theoretical problems was a source of passion and pride illustrated by the value placed on Design courses and competitions in the case study institution. Design education introduced the concept of engineering as working with constraints and compromise, having to provide pragmatic, cost effective, timely and "best", rather than perfect, solutions to questions and problems that were rarely defined by engineers themselves. A basic assumption was that any solution must work, it could not be hypothetical. It must do the task specified, within the limits specified.

Thirdly, the engineering way of thinking appeared to accept that there were not always "right" answers. Much of the education process, especially the fundamental engineering science courses, assumed the certainty and indisputable nature of the formulae and knowledge underpinning analysis and the need for exact calculations in situations such as calculating the load bearing capacity of a beam, or the aerodynamic lift under a wing. Open-ended problem solving was, however, an important component of the program at this institution as demonstrated by a commitment to problem and project-based learning. Exact calculations on load bearing capacity, for example, would be expected but the choice of beam type might itself be a variable. Students would be requested for the "best" choice according to prescribed constraints such as cost, weight, materials, required load, construction time etc., with the expectation that they could validate their choice by the application of appropriate mathematics. No two design solutions were likely to be exactly the same.

The focus on problem solving, and in particular the pragmatic necessity within an educational system to provide very well defined problems within distinct educational modules (courses), appeared to lead to a general lack of recognition by both staff and students that engineers also had a role as "problem framers". The education process appeared to turn out graduates who saw themselves as society's problem solvers without recognizing that, not only were these problems often defined by non-engineers, but that they, as engineers, might have a unique and valuable perspective on the nature of the "problem".

Johnston, Lee and McGregor [9] suggested that bounded and constrained tasks and problems were prevalent in engineering education. Although these were evident in the early years of the program, apparently for simplicity's sake, once problems and systems became more complex it was rare for them to be solved without making assumptions at problem definition stage and judgments at choice of solution stage. Rather than objectively dealing with the measurable and quantifiable, as appeared to be assumed in Engineering, a level of uncertainty and subjectivity was inherent in these assumptions and judgments that was rarely acknowledged.

Within engineering there was an unquestioned assumption that the knowledge, the mathematical procedures and scientific processes, and the laws on which problem solutions were based were race and gender free. No recognition appeared to exist that the ethnocentricity and masculinity of the sources of engineering knowledge and procedures might affect not only problem definition but also accepted methods of problem solution, teaching or assessment. Problem solutions were expected to meet the needs of the community, with culturally appropriate solutions viewed as just one of the constraints engineering solutions must work within, rather than a recognition that alternative epistemologies might exist.

The Engineering way of doing

The shared beliefs and assumptions around how the questions; What was the primary task and how was it accomplished? What was perceived as the "right" way to teach and learn?, were answered in this disciplinary culture were named as the Engineering Way of Doing.

In 1997, the Mission of the School of Engineering was to be the pre-eminent engineering school in New Zealand and one of their primary tasks was to educate and graduate students with a professional engineering degree. In other words Teaching and Learning goals were primary tasks.

From the detailed evidence of behaviors and practices, it was inferred that one of the most basic assumptions underpinning the way engineering was taught was the belief that anything worthwhile was hard. The theme of "Hardness" permeated discussions conveying worth and status, with a devaluing of content or subject areas which were seen as "easy" or "soft". The heavy workload spoken of in many other studies was evident in this study as part of the "challenge and stretch" approach to teaching that seemed to be taken for granted. This teaching paradigm valued pushing or pulling students to new limits. The strength and ability to "take it" and succeed within this paradigm appeared to contribute to the pride and sense of achievement that students spoke of as an outcome of completing the degree:

> *The high workload and its difficulty means that you get a kind of 'shared hardship' - which ends up bonding people together.*
>
> *Brian, 1st year student*
>
> *Looking back, you have achieved so much. It was so tough but you managed to get through it. And you got pretty good grades and it was like the greatest achievement*
>
> *Mei, 4th year E&E*

This equating of "learning" with "shared hardship" appeared to be assumed as part of the educative process that developed and strengthened attributes perceived as needed by a professional engineer. Even teaching was enacted as "learned the hard way", by learning on the job rather than by specific professional development.

Although individual features of the curriculum were influenced by pragmatism and compromise with resource issues, the curriculum content, teaching and assessment had evolved from beliefs and assumptions around the "right" way to teach and learn engineering. In common with international degree structures a sizeable core of technical content was deemed essential in the engineering curriculum. While the compulsory content, with its lack of flexibility, may have existed in response to the requirements of professional accreditation, it was deeply entrenched in the beliefs of the academic staff. The latter found it very difficult to consider reducing or leaving out sections of material. Much of this "essential content" was taught by traditional, lecture based courses and was seen as the fundamental knowledge that distinguished engineers as experts in their field.

Core activities of engineering education at this institution were Design courses and project based learning. These courses modeled the activities that would be required of students when they went out and worked as professional engineers with problem solving their major task. This focus on problem solving appeared to have led to a belief, firstly, that for every problem a solution existed, possibly only a "best" solution, rather than a perfect one, but a solution nevertheless and secondly, that with the appropriate expert knowledge and "toolbag" of skills and procedures, they, as engineers, could solve anything.

The long history of incorporating professional development and communication skills including management, social and environmental responsibility into the curriculum was another unique feature of the case study institution. Most staff held a shared belief in the need for these courses as part of the students' preparation for the profession. There appeared to be however, a tendency for the material to be marginalized in these courses and spoken of, by both staff and students as "soft" compared to the more technical "hard" courses.

Within this culture both competition and co-operation were perceived to be important as appropriate forms of behavior. The aims of individual academic excellence and achievement of a qualification are widely seen to be integral to the nature of a university, with the result that competition for grades was a basic assumption about the nature of human activity. Ruthless competition was the exception rather than the norm and co-operation and collaboration were valued highly. The evidence suggested that co-operation and collaboration were, not only encouraged and valued as preparation for a professional working style, but seen as essential for optimal learning and academic survival.

External factors in the last decade had resulted in some values and cultural norms, such as an instrumental attitude to learning, becoming part of the essence of the culture even though they did not match espoused values and goals. These external factors included large increases in tuition fees and student loans, increased diversity in prevalent learning styles and the pressures of growth in student numbers, not matched by growth in resources. The processes of education appeared to be increasingly seen by students as the pathway to a qualification, a piece of paper, rather than to a profession. The assumption, seemingly shared by a large proportion of students, that the goal of their learning was to pass rather than to understand, was manifested in the "go for grades" attitude and desire for "spoonfeeding". This attitude was in direct contradiction to the beliefs and assumptions staff held about the goals of their teaching being for understanding as well as knowledge.

Learning the Culture

Inherent in the concept of a culture is the understanding that new members entering the culture undergo a learning process, an enculturation into a well-established system of practices, behaviors, values and norms. In contemplating cultural change, the use of the proposed model demonstrated that for new members learning the culture was a top-down process. From the observable and tangible manifestations of the culture, the day-to-day practices and behaviors, contained in teaching and assessment practices of first year classes and events such as Orientation, students learned how to operate successfully within the learning environment.

Data sources for this study included observations and end of year interviews with first year students who had gained a significant understanding of the "engineering way of thinking and doing". With final year students, a notable feature of the data, both questionnaires and interviews, was the level of commonality in attitudes and beliefs which cut across both gender and ethnic differences.

When first year students entered the university, they were not coming as empty vessels waiting to absorb new knowledge, values, beliefs and attitudes. They already inhabited the "multiple worlds" [10] of family, peer groups, school, and church communities with an understanding of the cultural knowledge, values and attitudes required to move between those settings. From the first day at orientation, they moved into another "world", that of the university, and in particular the School of Engineering, a community that had its own distinctive knowledge, language, criteria of validity and reliability, traditions and values.

Figure 2 illustrates the enculturation process based on the proposed model of culture.

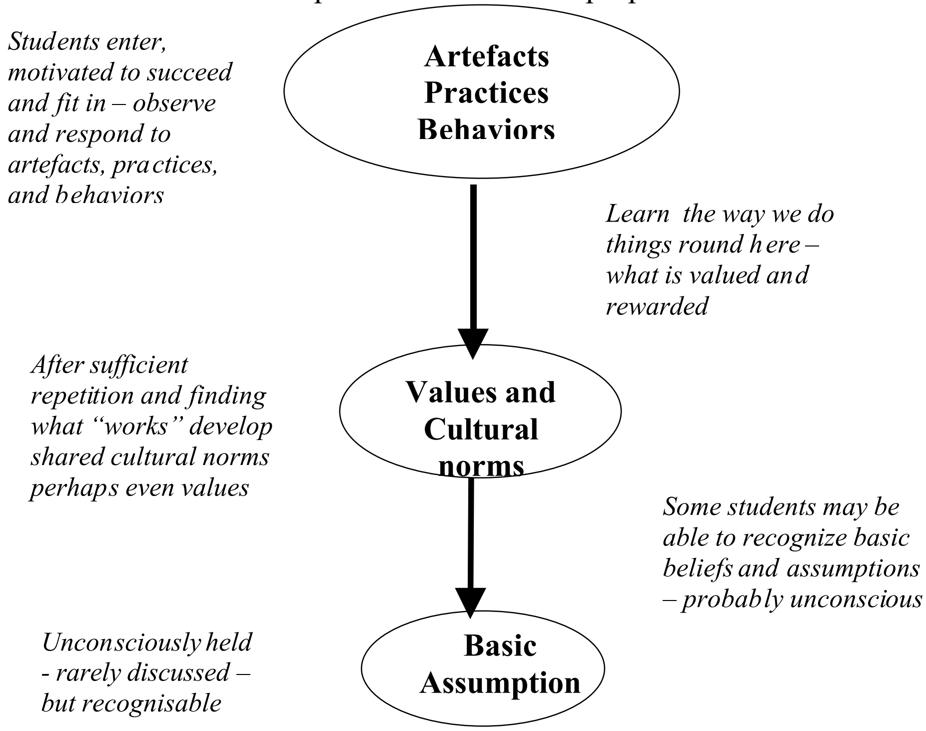

Figure 2 Learning the Culture

Artefacts, Practices and Behaviors were influenced and modeled primarily by staff who were the major transmitters of the academic side of the culture. Senior students also had a role to play in transmitting cultural values and norms but if left to senior students it was doubtful whether the culture would be as stable as it appeared to be. The transient nature of student cohorts who stayed four to five years limited their ability to learn and then transmit cultural values and norms. The staff, most of whom had themselves been through an engineering degree were more stable and shared understandings of the "engineering way of thinking and doing". They had the power to set curricula and pedagogy, affirm culturally appropriate behaviors and reward, using assessment, ways of thinking and reporting. The students' peer group also contributed, by affirming appropriate behaviors and practices, particularly in the formation of task-oriented friendships and support strategies.

As students moved through the degree program, the process of repeatedly finding out what "worked" and was rewarded, led them to learn and identify with the values and cultural norms which they perceived as congruent with the identity "engineer". These values and norms were well entrenched in this very stable academic discipline and were rarely open to change by students. There were instances where cultural change had come from the students, as when student values and norms persisted which did not match those espoused by the staff, leading to changes in both teaching and learning practices and behaviors. One example was the response to the cultural norm for high on-course assessment and the "challenge and stretch" pedagogy. When this workload was perceived as excessive by the students it appeared that the valuing of individual integrity became a lesser priority than gaining a successful academic result and cheating practices became a cultural norm. Assumptions of academic honesty were overturned resulting in a shift in assessment methods from those of the ideologically preferred project based learning to supervised, timed tests.

Changing the Culture

Having suggested that cultural change must be based on an awareness of the basic beliefs, values and assumptions held by both staff and students, and an understanding of how they combine with the construction of the discipline to implicitly guide actions, Figure 3 is presented to demonstrate how cultural change, if desired, might be effected. Sustained systemic cultural change is seen as supported by shifts at the deepest level of shared beliefs and assumptions, followed by changed values and cultural norms. Planned change might be initiated by strong and motivated leadership able to articulate beliefs and assumptions, and the values and cultural norms which would manifest them. In practice, change emanating from shifts in shared beliefs and assumptions appears idealistic, and cultural change is more likely to come from strategic planning at the level of espoused values. Even at this level, vision needs to be coupled with the power to put in place changed artefacts and practices which would enhance the development of behaviors which once sustained, learned and shared by members of the culture would complete the cycle by becoming cultural norms and ultimately the assumptions of the whole group.

The most important step in effecting change is seen as lying in the manifestation of espoused values at an operational level. It is suggested that it is from the top level of behaviors and practices that newcomers initially learn what is valued in a culture, and unless these behaviors and practices reflect desired values and norms, sustained cultural change will not occur.

An example in the case study institution of cultural change emanating from a leader with strongly held beliefs in equal educational opportunity and diversity is illustrated by this model. A new

Vice-Chancellor with a vision and belief in the increased participation of under-represented groups, used his authority and persuasion to ensure that mission statements and strategic plans across all faculties included clear statements valuing the participation of all sections of the community. Annual reporting of operational practices in support of these strategies was then required. A variety of initiatives ranging from scholarships, outreach activities, mentoring schemes, and peer tutoring networks were funded manifesting the espoused values. After several years, these initiatives have become accepted as cultural norms. It would be inaccurate to say that the beliefs of the leader have become shared by all at this stage, but pride is developing in the university's role as a leader in the field of equal educational opportunity.

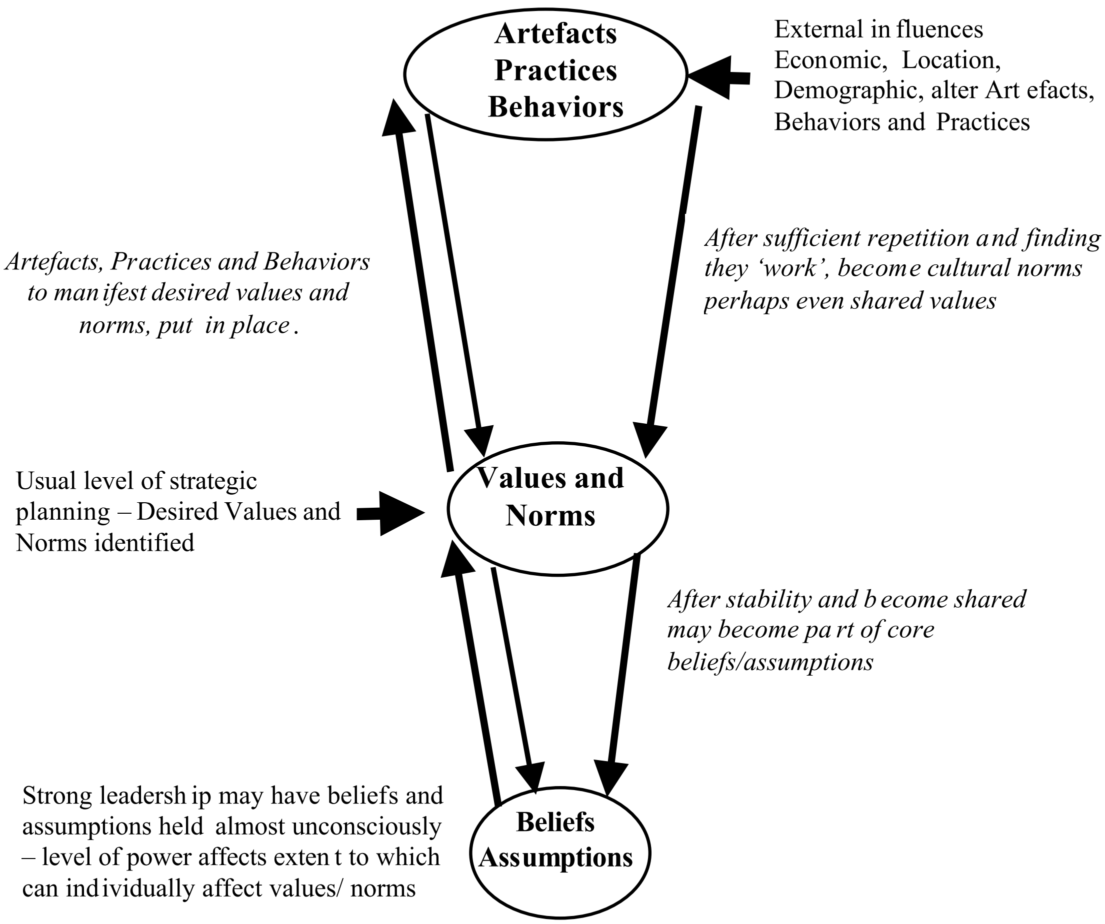

Figure 3 A model for cultural change in engineering education

The call for a change in the culture of engineering education contained in the Australian Review[1] mentioned at the beginning of this paper, contained curriculum recommendations which were coincidentally addressed during the 1996 restructuring of the BE degree at the case study institution. The Review called for engineering educators to produce graduates with an appreciation of the social, economic and environmental consequences of their activities, and increased communication skills. If these generic skills were valued then it is clear that students must have opportunities to not only acquire them, but also to appreciate their value. As mentioned earlier, communication skills were explicitly included in the curriculum, teaching and assessment practices, the first level of culture, of the Professional Development courses at the case study institution. As a result, this study found that both written and oral communication skills were not only valued and had become cultural norms, but they had "become second nature" – which appeared to imply that shared understandings and assumptions had developed at the third level. A course in Engineering Sustainability was required for students across all of the engineering disciplines, once again, manifesting the value placed on environmental awareness.

A third example of using this model to understand and affect cultural change could be seen in the valuing of teaching. If excellence in teaching is valued and part of the culture, rather than a goal aspired to in mission statements and publicity material, then that valuing must be embedded as a cultural norm in the reality of university practices. Reward systems such as public recognition and promotion could be viewed as indicators to staff of those practices which were valued, just as good grades in assessment led students to understandings of what was valued in their learning. The feedback from staff in the case study institution indicated a mismatch between this espoused value and the norm of research-focused promotion systems. Just as the students, mentioned earlier, responded to a high workload with an instrumentalist attitude and loss of integrity, staff in engineering education were not slow to learn which practices were rewarded, and used their scarce time-resource accordingly.

Cultures are dynamic systems of meaning, and responsive to changes in the world. Unplanned, rather than planned, change can come from external influences such as a change of location, changes in selection criteria, change in ethnic mix of students, increased tuition fees, and growth. These can all stimulate rapid changes in artefacts, practices and behaviors. If these changes are sustained, without intervention, different cultural norms may emerge, which may or may not be in conflict with espoused values. After some time, there is the potential for some cultural features to become embedded at the base or core level of beliefs and assumptions.

In the case study institution rapid growth due to high demand for the degree, and increasing ethnic diversity in the student population over the last five years was an example of unplanned cultural change. This rapid growth has resulted in geographical fragmentation as some departments were required to relocate, and changing teaching practices required by larger classes which were not matched by increasing resources. As a consequence close-knit interdepartmental links and sense of "family" are being lost, and a more competitive environment is appearing, with the potential for change in beliefs and assumptions about appropriate forms of relationships.

Conclusion

A theoretical model for cultural analysis has been proposed in this paper as accessible in theory and discourse to engineering educators. Applying this model in a multidisciplinary School of Engineering as a case study, basic beliefs and assumptions grouped around seven cultural dimensions were identified as the core of the culture of engineering education. It is suggested that this model provides a tool that can be used at strategic and operational levels to assist researchers, practitioners and policy makers to "bring to the surface" the essence of the culture at any engineering institution, and the processes by which cultural change might be effected and sustained.

BIBLIOGRAPHY

1. IEAust, "*Changing the culture: Engineering education into the future,*" Institution of Engineers Australia, ACT 1996.

2. J. C. Lucena and G. L. Downey, "Engineering cultures: Better problem solving through human and global perspectives?," in *Annual Meeting of the American Society for Engineering Education*, 1999, Session 1461.

3. E. H. Schein, *Organizational culture and leadership*,2nd ed. San Francisco: Jossey-Bass, 1992.

4. P. R. Trowler, *Academics responding to change: New higher education frameworks and academic cultures*. Buckingham: SRHE and Open University Press, 1998.

5. S. B. Merriam, *Case study research in education: A qualitative approach*. San Francisco: Jossey-Bass Publishers, 1988.

6. R. C. Bogdan and S. K. Biklen, *Qualitative research for education: An introduction to theory and methods*. Boston: Allyn & Bacon, 1982.

7. E. Godfrey, "Defining Culture: The way we do things round here," in *American Society for Engineering Education Annual Conference & Exposition*. Albuquerque, NM, 2001.

8. K. L. Tonso., "The impact of cultural norms on women," *Journal of Engineering Education*, vol. 85, pp. 217-225, 1996.

9. S. Johnston, A. Lee, and H. McGregor, "Engineering as a Captive Discourse," presented at Society for Philosophy and Technology Conference: The City and the Suburb, New York, 1995

10. P. Phelan, A. L. Davidson, and H. T. Cao, "Students' Multiple Worlds: Negotiating the boundaries of family, peer and school cultures," *Anthropology and Education Quarterly*, vol. 22, pp. 224-249, 1991.

ELIZABETH GODFREY
Elizabeth Godfrey is currently the Associate Dean Undergraduate at the School of Engineering at the University of Auckland after a career that has included university lecturing, teaching and 10 years as an advocate for Women in Science and Engineering. This paper stems from her recently completed PhD dissertation in Engineering Education on the topic of "The Culture of Engineering Education and its Interaction with Gender".