

Making Engineering Students—Making Women: The Discursive Context of Engineering Education*

HEATHER STONYER

Faculty of Science and Engineering, Auckland University of Technology, Auckland, New Zealand.

E-mail: hstonyer@aut.ac.nz

Using a contemporary feminist framework, professional engineering education is located in the intersection of three discourses—the scientific discourse, the managerial discourse and the liberal education discourse. Within each of these discourses, ways of understanding engineering are articulated. This articulation occurs through practices, values, pedagogy and available knowledge(s) of engineering education. Centred in these discourses are particular normalised ways of understanding the engineer—these are the engineering identities of the scientist, servant and citizen. These are successful identities available to women (albeit with some restrictions). A number of practices, contexts and interactions, which create identities for women ‘outside’ engineering—the almost guys, helpmate and power-puff girls—are also identified. While advocacy can ‘learn’ from both the strategic compliance, at times, and the relative ease of some women’s ‘fit’ into ‘normal’ engineering identities, in the women’s experiences there remains a prevalent theme of ‘not belonging’ in the engineering community ‘as of right’. It is argued that for full and effective participation in the engineering community we need to begin to explore how this asymmetrical relationship between men and women continues to be reiterated through the context of engineering education, particularly in engineering knowledge(s). In view of this, feminist advocacy needs to forge new partnerships with men in engineering, to ensure together that they achieve their intended goal of equity and equality for women in engineering.

INTRODUCTION

WOMEN (in western society) are considered estranged from engineering. Engineering is viewed in the public sphere as masculine, competitive, objective, impersonal—qualities that are at odds with our images of what women are. The more masculine the branch of engineering (e.g. mechanical) the less likely it is that women will like it or do well. Women prefer engineering to be linked to social context and needs (e.g. environmental engineering) and to learn in cooperative classrooms that encourage engagement with peers. Although women may prefer small groups they are left to the role of scribe or report writer because men tend to take charge, manipulate the equipment or control the task outcomes. Women engineering students find ways of ‘surviving’ their education. Women are disadvantaged in engineering before they even get to university because they do not have experience of ‘tinkering’ [1].

We have heard these themes and stories many times. Each is well known and supported by literature reporting the findings of associated research [2–4]. Until recently, these themes have been the dominant ways of approaching the problem(s) of women and engineering. Strategies

which have emerged from these themes mainly focus on ‘women’—early school intervention, recruitment, retention, and student-centred inclusive learning approaches. More recently a growing body of research has focused on the ‘engineering culture’ [5–7]. It is of little surprise, given that the engineering culture is traditionally male-dominated and hence male-oriented, that the culture is described as ‘incorporating masculine values, norms and assumptions, not only at the level of social interaction and discourse, but at the deeper level of knowledge generation and transmission’ [8]. This literature attempts to understand the extent, effect and reiterative nature of this masculine culture through the educational experiences of students using a range of approaches offered by feminism, cultural studies, and education [5, 6, 8]. Through this understanding it is anticipated that alternative ways of working to change the gendered nature of engineering might be determined. This paper is presented as a contribution to this latter body of literature.

One aspect of this body of literature draws on situated learning theories [9]. Learning is more than simply acquiring understanding and knowledge of a discipline, rather it is governed or mediated by wider cultural access and assimilation within ‘communities of practice’. In this process of assimilation or enculturation into a well-established system of practices, meanings and

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beliefs [6], novices take up (or develop) identities congruent within the community. These identities must be consistent with the interpretative or reference frameworks of the community in order for novices to have access to the visible and tacit knowledge and skills essential to function as an effective member of the community. This means that for a student to learn engineering they must take up identities compatible with the engineering community. Significant for women's advocacy in engineering are findings which suggest how many of the on campus engineering identities continue to be exclusive of women [10].

In this paper, post-structural feminism is used to explore and name some of these interpretative or reference frames. The post-structural theories of 'discourse' is a way of understanding frames of reference and the identities (or ways of being a community member) they prescribe. Discourses are interrelated themes, statements, forms of knowledge, fundamental assumptions and ways of understanding or interpreting events. These interrelated themes and statements of discourse(s) can be 'read' in the events, actions and practices of the 'normal' community. Post-structural theories of the individual argue that identities are not necessarily a preformed category or a possession that one can have, but rather that these identities are constituted in the practices the community [11]. This implies that 'normal' community practices work to reproduce dominant identities and structures that use and regard these practices as 'normal' or 'given'. In this way, membership (and its related benefits, such as access to learning) of the engineering community can be seen as being governed by being, acting and thinking in 'normal' engineering ways. In the context of engineering education, many of the 'normal' engineering education practices can be interpreted as effectively 'disciplining' students to be, act, value, and think in proscribed ways. It is also possible to distinguish how alternative discourses (and their 'disciplinary practices'), which set out new ways of being an engineer are, or could, be formed. These alternatives may offer potential for defining how women in engineering advocacy can continue to transform engineering.

ENGINEERING EDUCATION AS A DISCURSIVE COMPLEX

Engineering education is a discursive complex [12] wherein engineering discourses offer competing ways of giving meaning to engineering and engineering knowledge(s) and of organising educational structures and pedagogy. Three dominant intersecting discourses [12–15] govern the formation of engineering education at the tertiary level: the scientific discourse of engineering, the managerial discourse of engineering, and the liberal education discourse of the university. There are other discourses (e.g. sustainability, ethics) giving form

to the complexity of engineering, however, for the purposes of this paper only the dominant discourses are addressed.

Engineering education is, therefore, not a 'given'. Rather it is a constructed response—'an invention'—of the tensions and contradictions, the different points of view and the fundamental assumptions in each discourse. These discourses exercise 'power' to justify and legitimate particular actions (e.g. 'the way we do things around here' [8]; the privileging of certain aspects of content in curriculum) and reproduce the 'culture' of engineering education in each institution, albeit with site-specific variations [8].

Making students 'engineers'

Within the intersection of these discourses particular meanings of 'being an engineer' are being contested and legitimated. In contemporary feminism, this contestation is significant as specific practices can be shown to define correct or acceptable masculinity and femininity and further, (re)produce it by creating gendered identities [10, 16]. Gender (in post-structural theories) is always a relationship constructed in binary terms: masculinity/femininity. Masculine and feminine identities do not 'exist' apart from (or prior to) this relationship. Each side of the binary exists only in relation to the other; however masculinity as the dominant term asserts 'power' or influence to control how its 'other' (i.e. femininity) can be defined. Several authors [10, 12, 14] argue that certain feminine identities in engineering are essential to sustain the dominant masculine engineering identities. Through examining the legitimate or 'acceptable' meanings of 'being an engineer' in the dominant discourses in engineering education and their associated discursive practices, the gendered identities (or ways of being an engineer) central to each of these discourses can be named.

Exploring the experiences of students, it is possible to name and frame the conditions [17] (e.g. education practices, students' attitudes, values, beliefs, etc.) which enable, and limit, how engineering and other alternative identities are formed. Individuals take up these gendered identities through three mechanisms: identification, counter-identification and disidentification [14, 18]. Counter identification (or rejection of dominant discourses) is unlikely to unsettle the power relations which form gendered identities, but through disidentification and forming alternative discourses, new meanings can be offered which potentially may transform existing 'normal' practices and identities [14]. Renegotiation of new meanings can also occur through a dialectic process of accommodation and resistance to dominant identities [19, 20]. That is, while the individual accommodates or conforms to the status quo, they can also invent, invert and break old structures and patterns and discourses and, thus, form and transform other engineering identities [20].

In this way, post-structural theories offer a framework for re-exploring and reconceptualising our understandings of gender and engineering. Using this framework, it is argued, engineering education makes certain meanings available to women engineering students, which regulate what women can/cannot do and be. That is, women have limitations on the ways available to them with which they can interpret experiences at a personal or 'lived' experience level [6]. Further, these meanings come to be located as truth and embodied in structures and mechanisms in educational practices. This 'truth' operates (re)productively in the identity/identities women students gain through their educational experiences in engineering. Women, however, are not necessarily completely constrained by these identities, and can work strategically to optimise opportunities for changing the range of meanings of 'engineer'.

DATA AND METHODOLOGY

This paper draws its data from two formal research projects (1995, 1998–2000) in two New Zealand universities exploring the experiences of 21 women in engineering. These studies intentionally sought a diverse range of voices and stories from within the engineering community—the women were not a homogenous group varying across ethnicity, engineering disciplines, entry pathways, exit locations and age; and the universities differed: one was an established School of Engineering with a long tradition of quality professional engineering education, the other a 'new' university with a strong tradition of engineering technician level education and engineering degrees offered since 1998. The women's stories provide opportunities to explore how specific identities were constituted in and by significant events, attitudes, emotions and understandings relating to their experiences [21].

The findings presented are necessarily tentative, exploring the women's experiences from a gender perspective only (in part to ensure anonymity of the women), and should not be interpreted as representational of all women's experience of engineering education. However, in the women's stories of their experiences there were 'multiple echoes' [21] between both the women and institutional groups suggesting there will possibly be similar echoes in the experiences of other women engineering students [5, 22].

CENTRED IDENTITIES IN ENGINEERING

The scientific discourse of engineering

Although today's scientists and engineers pride themselves on 'multi-disciplinary' approaches to problem solving and encourage teamwork, engineering science is one of the critical foundations of engineering. Science is a way of thinking based on

reason—induction, deduction, logic, analysis and synthesis [23]—and engineering science is accepted as a 'major source of scholarly authority in engineering education' [12] defining the boundaries and conditions of engineering problems and their solutions. The women's stories reveal how the scientific discourse of engineering works both to make themselves, and exercises influence over their choices to make themselves, into the 'scientist'.

The reductionism inherent in engineering curriculum provides tangible evidence of the presence and power/influence of this discourse. The women reflected on the way the content and structure of curriculum limited how engineering problems and possible solutions are conceived. This practice excluded (and effectively silenced by this exclusion) other 'operational realities' of engineering (e.g. ethics, social responsibility, statutory obligations, and consequences). The students also spoke about the 'hardness' of engineering [22]. Hardness for most of the students revolved around high workload (and subsequent lack of time to question any assumptions) and the amount of content they were expected to learn in 'the one right way' (Nessie, 1998). Hardness expressed in these terms is, perhaps, more about disciplining the student's thinking and behaviour in the 'right' way of engineering, rather than providing opportunities to develop some other abilities and attributes (e.g. critical reflection) [24].

The dominance of content and 'right' ways of thinking at the expense of learning processes and wider issues becomes, for students, the expected 'norm' of education. When moved from the engineering way to different learning contexts, students were often scathing in their attacks of the 'waffly' learning expectations and outcomes of different disciplines, giving unqualified preference for 'having an equation for everything and being able to graph it all'. Commenting on the prevalence of the didactic lecture style, particularly in first year compulsory classes, the women appear to be passive and obedient to the way 'engineering is'—having no idea of what these compulsory subjects involved, 'just writing down all the notes even if you are lost', of bingeing on coke and chocolate to 'load up and sit there for another two hours' (Ashleigh 1995; Nessie, Bobbie 1998).

The acceptance of the separation of engineering knowledge from self (viz issues of personal understanding and preferences are ignored or minimised) and from socio-historical location (viz wider operational context of engineering) are attributes of the 'scientist'. Some of the women, however, felt they did not 'belong' in engineering because they were not affirmed as being academically able (usually by male peers and lecturers):

'I often come up [against], I don't know if it was because I was female or just my manner, cause everyone [male peers] thought I was dumb, or something, but when I tried to say something . . . it's like you weren't quite given your credits worth.' (Sarah, 1995)

“They [male peers] were into accepting your help in tutorials and all that, but in the end, the feeling, the general feeling is your place is not here.” (Pattie 1998)

These forms of refusal to recognise women as engineers is not simply a ‘problem with the boys’ but rather that ‘on-campus engineering culture can not recognise women as engineers’ [10]. Feminist critiques of science [11, 25–27] have demonstrated how this scientific individual is male, that ‘scientific reasoning’ is profoundly masculine, effectively precluding women from *full* participation in its community. This is not to say that women cannot be knowers of science, but being gendered as woman, in and by science, can make it difficult for women to be simultaneously the ‘scientist’ and ‘women’.

Not surprisingly, the women employed various strategies to make themselves like the ‘scientist’. Libby (1995) recalled how she actively liked to divorce the technical (academic) and personal (e.g. overwhelmed by workload, issues of difficulty and perceived inability to ‘ever’ understand it), to keep them separate in her head and act on each quite differently. Such a division is not easy for all women to achieve—the women spoke about not being able to have life problems or personal problems because ‘we are engineers in here’. In order for Diane (1995) to be this ‘engineer’, she deliberately chose to separate herself from the ‘personal’:

‘Do it the way the boys do it, well that was the other thing I decided to do in my last year. I’d be one of the boys in terms of everything. You know I’d just be cold and not caring, loving or anything.’

The managerial discourse of engineering

Engineering practice is, to a large degree, regulated and controlled by corporate/commercial decisions that define and limit, how and where engineers use their engineering skills and knowledge [28, 29]. In this context, engineers are not free, creative agents—rather, they are ‘servants’ to a broader ‘commercial reality’. This ‘captivity’ of engineering influences engineering education particularly in areas of curricula content and research opportunities [28].

In areas of curricula content, these decisions regulate and affirm essential or necessary knowledge(s) required by practising engineers. The desire for multi-disciplinary graduates has seen a top-down loading of curricula content requiring strategic ‘selectivity’ [30] of particular aspects of technical knowledge and economic activity, to the almost total exclusion of aspects not included. For example, an effect of ignoring or silencing the socio-historical origins of specific technology is that education functions to produce useful ready-to-go engineers who have limited critical analysis skills beyond the boundaries of the technical. Indeed this understanding is enshrined in students’ views and actions about themselves as engineers: they are ‘problem solvers’ (Diane, 1995) not ‘problem framers’ [31]. Students learned the importance

of ‘compliance’ [13] to the ‘job’: ‘to do a job as a professional person’ and ‘to cut it in industry’.

Research teams in engineering provide a mechanism through which ‘compliance’ can be learned. Belonging to a research group [32] (albeit on the margins) provides students with additional benefits (e.g. funding, mentoring, specific knowledge) (Debbie, 1995; Sandie, 1998). Yet, while research projects exist prior to the arrival of a ‘research’ student, the women actively choose to remain ignorant of the socio-political and economic considerations which justified the project and its funding. Compliance works to limit an individual’s potential to challenge or change aspects of the profession.

For many of the women in this study, positioning in this subjectivity was particularly rewarding. For Sarah (1995) and Nessie (1998) the fit between their experience as a student and the expected experiences of the ‘servant’ was close, and there was little tension present in their stories. Generally, they embraced engineering as ‘unproblematically good’ effectively minimising their need to challenge established ‘ways of doing things around here’. The ‘servant’ afforded a zone of safety for some women who, at times faced a hostile environment for themselves as women (e.g. gender harassment from both male lecturers and peers). As the ‘servant’ some found they could challenge (effectively at times) the behaviour of their peers when they deemed it ‘unbecoming’ to ‘the profession’ they served. Yet, while offering some success and safety for women, their male peers continued to construct them as not belonging to professional engineering (even as a ‘servant’) because of their gender:

‘... we can manage the work and we can manage the professional side of things but then in the guy’s mind we are still a girl. You get that in class a lot, in class from a few people.’ (Pattie, 1998).

The liberal education discourse of the university

The governing discursive context of the university in which professional engineering education is located is the discourse of liberal education [15, 34]. This discourse produces the engineer as ‘citizen’ [15]—the confident, well-educated professional engineer who is capable of making informed decisions and acting in ways enhancing and progressing social ‘good’. The influence of liberal-progressive educational philosophy (formed within the liberal discourse) through specific practices of engineering education can be observed in the provision of ‘social and professional’ education to produce the ‘well-rounded’ or ‘holistic’ engineer [34].

Many of the women found the intersection of the liberal discourse into engineering in ‘engineering and society’ type of papers particularly inspiring, even romantic. They fully supported and were passionate about their potential role in working towards a sustainable future for the earth. The passion expressed by the women seems to be

related to the lack of tension in their experience between the engineer as citizen and their own identity as 'women' (as constructed in this discourse). Women in this discourse were identified as being 'different' in a positive way: more systematic, better at listening and taking notes, more selfless and having different goals for engineering.

Yet it seems that for the women, while the liberal discourse provided a sense of a place to stand in engineering as a woman, again it was not without contradiction. Gender-inclusive strategies [35] promote women as having 'preference and ability to excel in group work'. However, some women's experience of group work served to reiterate: firstly, their difficulty in positioning as a legitimate knower of engineering knowledge; and secondly, the group served to privilege western, ethnocentric, male-lead initiatives. Whether these reforms, while reaffirming women as different to men, actually give women a truly viable alternative to dominant engineering masculine engineering identities is problematic.

'OTHER' IDENTITIES IN ENGINEERING

The women enjoyed experiences consistent with the dominant identities—scientist, servant and citizen—which are an important part of what it means to be a 'normal' and successful student. These identities, based as they are on the rational, autonomous individual of Western society, are gendered as 'masculine'. The women's stories also indicated women may feel unable to take up 'as of right' these 'normal' masculine engineering identities. For women there appear to be other identities proscribed for them outside 'normal' engineering.

Almost guys

Femininity is commonly constructed on masculine terms in the engineering classroom—the women speak of being 'one of the guys . . . we just weren't looked upon as women' (Monique, 1995). Not surprisingly, positioning in this subjectivity was beneficial for the women, as it seemed to reduce the tension in the women's identification with the masculine identities of engineering. It enabled them to be 'good' students:

' . . . [on joking] you learn to be pretty witty and snap back . . . they don't mind, they've got a laugh. My marks are sort of slightly above average, I guess . . . nobody ever says, 'oh, you just fluked that or whatever, because you're a girl'. Nobody says anything like that. I managed to beat them. But I've thoroughly enjoyed being an engineering student; it's been good.' (Nessie, 1998)

However, it appears that for some women being 'almost guys' involved learning to discipline their behaviours, actions and responses in particular ways. Sandie (1998) while recognising the joking and sexist behaviour of the guys was 'too hard

skinned to notice'. Three women spoke about never crying in front of the boys—'we are engineers in here, we don't have life problems'. In order to be like them their tears were hidden and rendered invisible from the male gaze.

In spite of these forms of accommodation (and indeed, the need to do so in order for some women to survive), being 'one of the guys' was essentially unattainable. At best, they were only '*almost guys*' (Monique, 1995). 'Almost guys' did not offer new meanings or understandings to what it might be to be an engineer and therefore did not contest dominant masculinity, rather it affirmed its dominance.

Help-mate

Another feminine subjectivity read in the women's stories was the woman as 'help-mate', similar to 'hairspray girls' [22]. There was a very real sense that the women felt confident they would contribute something different to engineering 'from a women's point of view' which would be important for the future of both industry and the profession, and as such there was strong affinity with the 'citizen'. They would work behind the scenes to ensure the learning outcomes of team-based projects were achieved—their project posters being the more visually captivating due to the long hours the women put into the 'finishing touches'. Help-mates are essential in reiterating heterosexuality as part of dominant masculinity [22]. While counter-identifying with 'normal' engineering identities by asserting their 'difference' as women, their actions do little to introduce alternative identities in engineering.

Power-puff girls

The women also spoke with some degree of passion and enthusiasm of their pride and confidence in engineering—they were and felt 'powerful'. While the ideas of being visible, strong and confident are attributes which have traditionally been identified in feminist education discourses as masculine, the women in this study were also being constructed in these ways through their relationships with their male peers:

' . . . going into the place as a woman and knowing that you will be different . . . you had to have a certain strength . . .' (Libby, 1995)

Power-puff girls seem to be moving beyond counter-identification. This identity offers students a significant position from where they can begin to resist dominant identities and speak and act alternative identities into existence. However, in reading these stories there was a strategic 'no-go' zone for these confident, capable women to speak from—feminism.

' . . . they're just joking [sexualised humour] generally . . . the guys don't actually realise that it may not be funny for other people and so if you start complaining about it, they just think 'oh what's your problem, it's just a joke' and then you end up getting friction there

. . . if you start standing up and saying 'hey, that's sexist, I'm this that and the other thing' and they start thinking 'oh a raving feminist', they get all anti and you loose friends that way.' (Nessie, 1998)

There is a sense in the women's experiences that the dominant engineering discourse, aware of the challenges to gendered power relations inherent in feminist discourses, strongly opposes women who cross the boundaries into feminist discourse. For some women the consequences of this boundary crossing have been significant. One of the reasons a woman withdrew from an engineering programme (as cited by other women) was an inability to cope with the joking. She would 'just blow something [a joke] completely out of proportion' and was 'always getting herself into trouble [with her male peers]'.

This is not to say that feminism cannot inform these women's actions and behaviours in ways which work to disidentify dominant identities and discourses. Contemporary feminist theory maintains 'gender is always a relationship . . . gender does not pertain more to women than to men' [36]. It seems apparent for advocacy that any reconceptualisation of gendered identities in engineering must involve working with our relational partner 'men' in this endeavour. Recently published work [37] attest to this move towards uniting on the basis of 'coalition—affinity, not identity' [36]. Such moves can be particularly rewarding for women in engineering, particularly when their male lecturers are willing to position themselves as affirming feminist perspectives:

'He [the lecturer] came up with all the right arguments and things and he really believed them and meant them . . . what it [sexist language] means and what effect it has. And because I had been in some arguments with some of my classmates . . . and feeling really frustrated and it was this incredibly positive experience to have this like-minded person who was a male. And that was amazing . . . it was quite surprising that it happened in engineering school.' (Suzanne 1995)

CONCLUSIONS

The windows on the women's stories presented in this paper are not intended to provide accurate descriptions of women's experiences in engineering education. Rather, they attempt to construct a different set of boundaries and possibilities for what can count as knowledge in our understandings of the 'problem of women and engineering education'. I argue there are specific dominant socio-historical engineering identities within engineering which, given the traditions of engineering, are gendered as masculine. The women in these studies enjoyed access to and the benefits of, albeit restricted, centred identities of the scientist, servant and citizen. Yet, some of the women's experiences of engineering education can also be read from identities contested predominantly in the margins

of engineering—the almost guys, help-mates and power-puff girls. The degree to which these contested identities actually disrupt the dominant masculine identities in engineering is problematic.

The women's stories not only destabilise current strategies and accounts of women's experiences, but the stories, and women themselves, provide advocacy with different strategies for change. Recognising the origins of the tension within their experience(s) can enable women to take up strategic positions (as Diane did) in order to enjoy success in engineering. Similarly, working alongside and empowering women who embrace understandings of difference (such as Suzanne) can optimise opportunities to contest what is accepted as 'normal' in engineering. Identifying how certain pedagogical practices reproduce the 'engineer' in specific ways can enable strategic targeted reform within curricula.

For lasting change, it is critical that these strategies offer new meanings for being an engineer. Stories of 'survival' are still being told by women students in engineering education revealing practices, particularly related to peer communities, constructing women outside the boundaries of engineering. The prevalence of women as different to men, the strong association of masculinity and men (and not women) with engineering, and in particular engineering thinking, continues in contemporary engineering education. The heart of engineering—the body of scientific knowledge and associated ways of thinking itself [12]—profoundly influences the meanings we give to 'women' and 'men' [38–40]. Some of the strategies for change in engineering education need to work within this body of knowledge. Scientific rationality is acceptable 'to the extent that it reflects a relatively stable consensus achieved by means of a public, inclusive, critical and responsive dialogue in a relevant scientific/engineering community' [41]. Our students and wider community should be able to trust and observe that such consensus (and our own part in this consensus) reflects good epistemic grounds and not the imposition of one point of view on others or the exclusion and marginalisation of some members of the engineering community. Therefore, it must reflect the partnership of men and women in engineering. Currently, the partnership, as lived in the experiences of many women engineering students, continues to be asymmetrical and hierarchical. It is imperative a new partnership is forged which while accepting the social, cultural and economic complexities of the engineering community, orders difference as a mode for alliance, while fully recognising the role and power contemporary discourses of engineering give men. Perhaps then, we will see more women enjoying success and fully participating in engineering education.

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Heather Stonyer works in the Faculty of Science and Engineering at the Auckland University of Technology in the position of Academic Staff Developer. She works alongside staff in areas of professional development—teaching, research and professional leadership. Her background is in mechanical engineering, and tertiary education. Her research interests are mainly concerned with science and engineering education at the tertiary level (particularly teaching and learning and curriculum development) and the development of research related capabilities for staff and students.