Challenging Practice Traditions to Embed Education for Sustainable Development within the Engineering Curriculum

S. Trad[1], R. Goldsmith[2], R. Hadgraft[3] and A. Gardner[4]

[1]School of Civil and Environmental Engineering, University of Technology Sydney, Australia

Sloan.Trad@uts.edu.au

[2]Academic Language & Learning Team, University of Technology Sydney, Australia

Rosalie.Goldsmith@uts.edu.au

[3]Director, Educational Innovation and Research, University of Technology Sydney, Australia

Roger.Hadgraft@uts.edu.au

[4]Head, School of Professional Practice and Leadership, University of Technology Sydney, Australia

Anne.Gardner@uts.edu.au

Abstract

There has never been a more pressing time than now for Engineering Education for Sustainable Development (EESD). However, Education for Sustainable Development (ESD) remains invisible in most Australian engineering curricula. A common narrative from engineering academics is that ESD is covered by someone else, elsewhere in the curriculum. A similar narrative prevails among 20 interviewed engineers working on an infrastructure project in regional Australia - it's someone else's responsibility. This paper builds on the authors' previous work, which identified a striking resemblance between engineering perceptions of sustainability in an Australian university and on an infrastructure project. The Theory of Practice Architectures (TPA) is used as a conceptual framework to examine the sayings, doings and relatings of 20 engineers and 10 engineering academics interviewed as part of this study. The study found that practice traditions, including masculinity, hierarchical workplaces, and an emphasis on technical competence, constrain sustainability integration in engineering curriculum and in engineering practice. These practice traditions also enable the continuation of narrowly defined engineering work practices, which resist the incorporation of a more holistic approach. Changing practice traditions is not an easy task; however, it is a necessary first step to incorporating ESD within the engineering curriculum.

1 Introduction

As we write this paper, a group of more than 200 scientists forward an open letter to the Australian Government linking climate change to bushfires, and urging our politicians to take immediate action to reduce global warming (Murphy 2020). According to a study recently published by the Climate Council, "The catastrophic unprecedented fire conditions currently affecting NSW and QLD have been aggravated by climate change" (Climate Council 2019). The public sector should not be expected to do all the heavy lifting when it comes to taking action on climate change. The private sector should equally contribute to existential challenges facing our societies. This is especially true for our universities, as universities have a societal moral obligation to graduate students including engineering students capable of tackling the world's complex problems (Trad, 2019).

Our university, University of Technology Sydney (UTS) recently signed the Climate Emergency Declaration. The university pledged to increase the delivery of sustainability education across the curriculum. However, initiatives within the faculty of engineering and IT are still limited to ad hoc approaches within a handful of existing subjects. The engineering curriculum is overcrowded with technical subjects targeting passive learners. Many Engineering academics view students as "empty vessels" to be filled by whatever they can supply (Friere, 2017) leaving little place for Education for Sustainable Development (ESD). Fitzpatrick, (2017) questions if engineering academics are producing "technically competent barbarians": engineers who are accelerating humanity along an unsustainable path.

2 Literature Review

2.1 Technical rationality and Masculinity as dominant features of engineering curriculum

Engineering is typified as a masculine culture (Godfrey 2009), involving 'an ideal of manliness, characterised by the cultivation of bodily prowess and individual achievement' (Wajcman 2010, p.144). Given that the engineering identity centres on the primacy of technical knowledge (Trevelyan, 2012), engineers with a holistic and collaborative approach to problem-solving may be considered as 'other' in part because the image of a human-centred, collaborative engineer conflicts with the idea of the engineer as a solitary, male, technical rationalist, tinkering with technology and communicating via calculus. In order to understand how holistic approaches to engineering education and 'creative visions of engineer' (Tonso 2006, p.300) are often marginalised in the dominant engineering curriculum, it is useful to explore some ideas of engineering identity, in addition to consider how engineers view the knowledge of their discipline (Goldsmith, Willey & Boud 2018).

The narrowness of the engineering identity emerges in studies of student engineering identities, which reveal strikingly similar images of technical expertise and limited social skills –referred to as 'the traditional stereotype of the asocial geek' (Wulf & Fisher 2002, p.36). A student's perspective on engineering identity, and one which sees 'othering' of those who do not conform to the dominant model, is provided by Karen Tonso (2006), who conducted a study of how engineering students form their practitioner identities. Tonso's study, based on a US engineering school, reveals a male-dominated culture where students who did not fit the images of an engineer as constructed by the campus were 'othered' (2006, p.295).Tonso notes that the campus engineer identities emphasised engineering science, which she terms 'academic science', and a masculine culture. Her observations about the 'male-identified ways of life' (2006, p.298) are reflected in Walker's study of male and female engineering students in the United Kingdom (2001), Hacker's research on engineering and desire in the USA (1989) and Lee and Taylor's critique of the masculinised engineering curriculum in Australia (1996). The masculine qualities of the engineering identity contrast with those seen as desirable by employers, as pointed out in the introduction: collaboration, intercultural competence, and strong oral and written communication skills. Tellingly, Walker notes: 'Interestingly, these qualities are often characterised as feminine areas where girls and women are assumed to be more capable than boys and men' (Walker 2001, p.78).

2.2 Hierarchy and authoritarianism as key features of engineering practice

Hierarchical organisational structures have existed for thousands of years. Manassee, (2019) defines hierarchal organisational structure as:

> "an organisational system where employees are ranked according to status and development of superior and subordinate relationships is critical for organisational success. A workplace that is run on fear and dominance to control subordinates….To increase efficiency and exert control, hierarchical organisations tackle predetermined problems through repetitive stock standard solutions."

Engineering has streaks of hierarchy in its DNA (Morgan 2002). A hierarchal workplace is characterised by lack of communication, rivalry, inflexibility, threats and intimidation embracing hierarchy and resisting change (Adorno, Frenkel-Brunswik, Levinson, & Sanford, 1950). According to de Pellis & de

Pellis, (2008) several studies have found strong traces of authoritarianism in the form of hostility to women and resistance to diversity within engineering classroom and curricula (Chesler & Chesler, 2002; Elaine, 1995; Gallaher & Pearson, 2000; NAS, 2006; O'Halloran, 2005; Roberts & Ayre, 2002; Burack & Franks, 2006).

2.3 Technical rationality, hierarchy, authoritarianism and masculinity

"Engineers value social hierarchy on a continuum giving most prestige to scientific abstraction, least to feminine qualities" (Hacker, 1981). Such values are transmitted to engineering students through engineering curricula. These values can also be interpreted as norms: "norms regarding what it means to be 'manly', are enacted in plain sight in the field of engineering but are treated as invisible and go largely unchallenged" (Akpanudo et al., 2017, p.2). The practice traditions of engineering curricula and engineering practices which enshrine masculinity, hierarchy and technical rationalism as the dominant way of being an engineer: enable certain practices while constraining others. We argue that the straitjacketing of cultural and language practices in these practice traditions thus constrain the integration of sustainability into the curriculum and into workplace practices respectively; there is no language with which to speak about sustainability as a valued concept, approach, or practice. It is constantly 'othered', referred to as an externality, as something to be taught outside of the engineering science subjects of the curriculum, to be spoken of only as a cost, or in dollar terms in engineering workplace practices, to be regarded as something that will 'muddy the waters', or hamper the delivery of technical solutions.

3 Methodology/methods

The study uses the Theory of Practice Architectures (TPA) as a conceptual lens to compare engineering curriculum and practice. TPA has been previously used to understand complex phenomena such as professional learning (Kemmis et al., 2014), curriculum renewal (Goodyear, Casey & Kirk, 2016) or team and project work in engineering practices (Buch & Andersen, 2015).

TPA has evolved from Schatzki's practice theory (Mahon et al., 2017), where the focus is on the site of practice, how the practice is conducted, its temporal and physical location, and the arrangements that hold it in place. TPA can allow investigators to see not only what is happening in a practice, but how this has come to be and why certain practices become 'the way we do things around here'. In keeping with Schatzki's understanding of the localised nature of practices, TPA is used to analyse a site of practice; a site of practice is 'that realm or set of phenomena of which it is a part' (Schatzki, 2003 cited in Mahon, Kemmis, Francisco, & Lloyd, 2017, p. 9).

In this study, sites of practice are the engineering subjects taught and the construction of an infrastructure project delivered by the participants respectively. To change a practice, a better understanding of the unfruitful practices and how they came about is required.

According to TPA a practice is held up by the following three pillars that exist simultaneously in a practice:

- *Sayings:* What is said and understood about a practice forms resources made possible by cultural-discursive arrangements
- *Doings:* What is done in a practice, including the physical environment, financial and temporal resources, forms resources made possible by material-economic arrangements
- *Relatings:* The power in relationships amongst participants and non-human objects in a practice, forms resources made possible by social-political arrangements

Culture-discursive, material-economic, and social-political arrangements should not be considered or analysed separately; rather they are bundled together to prefigure (but not predetermine) the happenings of a site of a practice.

4 Findings

The following table analyses the similarities between the engineering curriculum and engineering work practices, through a TPA framework.

Table 1 Masculinity Enacted in curriculum and project

Curriculum	Practice
Sayings	
Masculine identity; speaking of 'hard skills' vs 'soft skills'; 'referring to mathematical and interpersonal skills as 'hard and 'soft' respectively reinforces the idea that mathematical skills are connected to intellectual rigor as well as to masculinity and virility, while interpersonal skills are less important, and related to weakness and impotence' (de Pillis, E., & de Pillis, L. 2008)	Masculine identity: teasing a colleague for driving a sedan rather than a utility vehicle;
Doings	
The focus on advanced mathematics, with its intense workload as part of the student engineering identity	Technical competence and physical endurance; driving a utility vehicle;
Relatings	
The 'weeding out culture' - more pronounced in the engineering curriculum than in other STEM disciplines (Seymour & Hewitt 1997); a culture which valorises masculine qualities of competitiveness, high marks for mathematical & scientific knowledge; '[s]tudents more likely to perform creative visions of engineer were also less likely to be thought of as engineers who should be part of determining what "real" engineering might be' (Tonso 2006, p.300)	masculinised relationships (sustainability othered or left at the door); the dominance of the site manager 'laying pipes' rather than the project manager on the water project

Table 2 Technical rationality enacted in curriculum and project

Curriculum	Practice
Sayings	
'it's not my job to teach writing'; 'sustainability is taught somewhere else';	'If they are not concrete outcomes they are not outcomes'

Doings	
Engineering science curriculum which focuses on mastery of technical knowledge; exam-focused teaching – emphasises reproducible knowledge; results focus of engineering group work projects leads to a 'divide and conquer orientation' to studying, resulting in a strong emphasis on individual work (Gonsalves et al. 2019, p.14).	Arriving late to sustainability meetings only. Missing sustainability meetings 'for more important work'; Sustainability is omitted from client-contractor contract
Relatings	
The transmission of knowledge from the knowledgeable lecturer to the ignorant students creates a relationship where the lecturer holds the power and is in a dominant position; students are then constructed as docile and passive recipients (Lee & Taylor 1996) of knowledge (Goldsmith 2018)	Omitting sustainability from contract upon contractor request eliminates contractual responsibility increasing power of contractor to control project sustainability while reducing accountability.
Trevelyan argues that '[b]uilding students' capacity for solitary technical problem-solving remains the central objective of engineering education' (2012, p. 4).	Incentivising sustainability rather than making a responsibility paints a picture that is something nice to have

Table 3 Hierarchy and Authoritarianism enacted in curriculum and project

Curriculum	Practice
Sayings	
'My subject does not need to change';	Lack of communication; 'The doors are always open from the inside'
Doings	
Class configurations; Emphasis on assessments, rewarding and punishing students; Inflexibility in subjects; Marks used for behavioural control rather than achieving learning objectives.	Office configurations with Project Manager having an office overlooking engineers; Going to breakfast with senior engineers only on a daily basis; Buying coffees for engineers with higher status only
Relatings	
Resisting change to subjects as a form of control of curriculum giving academics power over curriculum; Clear power differential between academics and students through hierarchal relationships; control over teaching and assessment assigning most of the power to academics in the engineering student-lecturer relationship	"Engineers value social hierarchy on a continuum giving most prestige to scientific abstraction, least to feminine qualities" (Hacker, 1981).

5 Discussions/Recommendations

Engineers Australia's Code of Ethics clearly mandates Australian engineers to '*promote sustainability*'. Through responsible engagement and sound engineering practice, engineers are expected to '*balance the needs of the present with the needs of future generations*'. Universities have a pivotal role in shaping the graduate engineer identity; however the study has shown that real EESD is not happening at Australian universities, perhaps for the following reasons:

1. Engineering curricula are overcrowded with technical subjects, which are mostly theory-based and emphasise analysis rather than design
2. There is a clear academic hierarchy, with senior engineering academics exercising authority over discipline subjects and
3. EESD is othered, with most academics stating that it is '*someone else's problem'*.

Challenging the dominant masculine engineer identity and integrating sustainability into engineering practice and curriculum is not an easy task. Ad hoc approaches to incorporating sustainability into the engineering curriculum and small steps in greening the built environment continue to fall short from what is required to safeguard the planet for future generations. Shifting current structures holding engineering education and engineering practice in place, is fundamental to incorporating sustainability in curriculum and practice.

From TPA's perspective, the notion of ecologies of practices arises here. Practice ecologies are a series of interconnected webs (Sayings, Doings and Relatings arrangements) essential to sustain a practice. Kemmis et al. (2014, p. 50) note that 'practices can sustain or suffocate other practices, and different ecologies of practices may be hospitable to some practices and not to others'. The practice of "engineering" dominates and dictates sub-practices (EESD and engineering practice for sustainability), bringing to mind the concept of whether EESD can actually exist within a traditional approach to engineering. This theory is bolstered by the fact that most sustainability consultants on infrastructure projects come from disciplines other than engineering.

An initial step to overcome this issue would be to acknowledge sustainability as part of the engineering discipline – a sub-practice – and not something exterior.

Engineering curricula need to adequately cover sustainability. Technical and sustainability competencies should be covered in the same subjects, providing real life examples to students that sustainability is not just 'a nice thing to have'.

Students are not naïve empty vessels and should not be indoctrinated by technical experts. Rather, upon entering university, engineering students should be given the power to judge academic credibility. After all, it is their own future they will engineer.

6 Conclusions

The dominance of hierarchy, technical competence and masculinity within engineering curriculum and practice continue to lead engineering down an unsustainable path, a path leading to a world that is not worth living in. Changing engineering education is required right now to improve engineering's social and environmental impacts moving into the future.

Changing a practice by adding more stuff to do or asking practice participants to know one additional thing does not lead to change. For change to happen the practice architectures that are in place need to be challenged. If the practice is the curriculum or engineering practice ad hoc approaches will not work. This is not a new concept though and has been around for a long time. The culture-discursive, material-economic and social-political arrangements will need to shift to allow ESD to be thought of and spoken of as integral to engineering studies and work practices, to be enacted as part of what engineering is, and to be valued as a core tenet of engineering teachings and practices.

References

Adorno, T. W., Frenkel-Brunswik, E., Levinson,D. J., & Sanford, R. N. (1950). The authoritarian personality. New York: Harper

Akpanudo, U.M., Huff, J.L., Williams, J.K. & Godwin, A. 2017. Hidden in plain sight: Masculine social norms in engineering education, Proceedings of the Frontiers in Education Conference 2017.8

Burack, C., & Franks, S. E. (2006). Telling Stories about Engineering: Group Dynamics and Resistance to Diversity. In J. M. Bystydzienski & S. R. Bird (Eds.), Removing Barriers: Women in Academic Science, Technology, Engineering, and Mathematics (93–107). Bloomington and Indianapolis: Indiana University Press.

Buch, A., & V. Andersen. 2015. "Team and Project Work in Engineering Practices." Nordic Journal of Working Life Studies, 5 (3a), 27–46

Chesler, N. C., & Chesler, M. A. (2002). Genderinformed mentoring strategies for women engineering scholars: On establishing a caring community. Journal of Engineering Education.

Climate Council 2009, 'This is Not Normal': Climate change and escalating bushfire risk, Australia, November 2019, Briefing Paper, viewed 03 February 2020, <https://www.climatecouncil.org.au/wp-content/uploads/2019/11/bushfire-briefing-paper_18-november.pdf>

de Pillis, E., & de Pillis, L. 2008. Are engineering schools masculine and authoritarian? The mission statements say yes, Journal of Diversity in Higher Education, 1 (1), 33-44.

Elaine, S. (1995). The loss of women from science, mathematics, and engineering undergraduate majors: An explanatory account. Science Education, 79 (4), 437–473.

Fitzpatrick, J.J. 2017, "Does engineering education need to engage more with the economic and social aspects of sustainability?", European Journal of Engineering Education, 42 (6), 916-926.

Freire, P., & Ramos, M. 2017, Pedagogy of the oppressed. London, England: Penguin Books.

Gallaher, J., & Pearson, F. (2000). Women's perceptions of the climate in engineering technology programs. Journal of Engineering Education

Goodyear, V. A., A. Casey, and D. Kirk. 2016. "Practice Architectures and Sustainable Curriculum Renewal." Journal of Curriculum Studies.

Godfrey, E. 2009, 'Exploring the culture of engineering education: the journey', Australasian Journal of Engineering Education, 15 (1), 1-12.

Godfrey, E. & Parker, L. 2010, 'Mapping the cultural landscape in engineering education', Journal of Engineering Education, 99 (1), 5–22.

Goldsmith, R., Willey, K. & Boud, D. 2018, 'Investigating invisible writing practices in the engineering curriculum using practice architectures', European Journal of Engineering Education, published online 16 November 2017.

Gonsalves, A.J., Silfver, E., Danielsson, A. & Berge, M. 2019, "It's not my dream, actually": students' identity work across figured worlds of construction engineering in Sweden. International Journal of STEM Education, 6 (13)

Hacker, S. 1989, Pleasure, power and technology: some tales of gender, engineering, and the cooperative workplace, Unwin Hyman, Winchester, MA.

Kemmis, S., J. Wilkinson, C. Edwards Groves, I. Hardy, P. Grootenboer, & L. Bristol. 2014. Changing Practices, Changing Education. Singapore: Springer

Lee, A. & Taylor, E. 1996, 'The dilemma of obedience: a feminist perspective on the making of engineers', Educational Philosophy and Theory, 28 (1), 57-75.

Manassee, J.M. 2019, 'Trust in hierarchical leadership: The moderating effect of need for cognition', Master thesis, Azusa Pacific University, California

Morgan, L. M. 2002, 'The Moral Ethos of Managing in an Engineering Culture', PhD Thesis, The University of San Francisco, San Francisco

Mahon K., Kemmis S., Francisco S. & Lloyd-Zantiotis A. Introduction: Practice Theory and the Theory of Practice Architectures. In: K. Mahon, S. Francisco & S. Kemmis (Eds.), Exploring education and professional practice: Through the lens of practice architectures. Singapore: Springer, p. 1-30, 2017

Murphy, K. 2020, 'Scientists call on MPs to urgently reduce Australia's emissions amid bushfire crisis', The Guardian, 02 February, viewed 03 February 2020, <https://www.theguardian.com/australia-news/2020/feb/03/scientists-call-on-mps-to-urgently-reduce-australias-emissions-amid-bushfire-crisis>

NAS. (2006). Beyond Bias and Barriers:Fulfilling the Potential of Women in Academic Science and Engineering. Retrieved February 20, 2007, from http://www.nap.edu/catalog/11741.html#toc.

O'Halloran, J. (2005). Mentorlink: Changing the Culture of Engineering. Retrieved April 1, 2005, 2005, from http://mentorlink.ie/pubs/johart.pdf

Rieckmann, M. 2012, "Future-oriented higher education: which key competencies should be fostered through university teaching and learning?", Futures, 44 (2), 127-135.

Roberts, P., & Ayre, M. (2002). Did she jump or was she pushed? A study of women's retention in the engineering workforce. International Journal of Engineering Education, 18 (4), 415–421.

Roorda, N. 2013, "'A strategy and a toolkit to realize system integration of sustainable development (SISD)", in Caeiro, S., Filho, W.L., Jabbour, C. and Azeiteiro, U.M. (Eds), Sustainability Assessment Tool in Higher Education Institutions Mapping Trends and Good Practices around the World, Springer International Publishing, Basel, 101-119.

Schatzki, T. A Primer on practices. In J. Higgs, R. Barnett, S. Billett, M. Hutchings & F. Trede (Eds.), Practice-based education. Rotterdam: Sense Publishers, 2012.

Tonso, K. 2006, 'Student engineers and engineer identity: campus engineer identities as figured world', Cultural Studies of Science Education, 1, 273-307.

Trad, S.P. 2019, "A framework for mapping sustainability within tertiary curriculum", International Journal of Sustainability in Higher Education, 20 (2), 288-308.

Trevelyan, J. 2010, 'Mind the gaps: engineering education and practice', Proceedings of the 2010 AAEE Conference, Sydney, 5-8 December.

Trevelyan, J. 2012, 'Why do attempts at engineering education reform consistently fall short?', Proceedings of the 2012 AAEE Conference, Melbourne, Victoria, 3-5 December.

Wajcman, J. 2010, 'Feminist theories of technology', Cambridge Journal of Economics, 34, 143-52.

Wulf, W.A. & Fisher, G.M.C. 2002, ‘A makeover for engineering education’, Issues in Science & Technology, 18 (3), 35-39.