Engineers' Professional Learning: A Practice Theory Perspective

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Abstract

With the increasing challenges facing professional engineers working in more complex, global and inter-disciplinary contexts, different approaches to understanding how engineers practice and learn are necessary. This paper draws on recent research in the social sciences from the field of workplace learning, to suggest that a practice theory perspective on engineers' professional learning is fruitful. It shifts the focus from the attributes of the individual learner (knowledge, skills and attitudes) to the attributes of the practice (interactions, materiality, opportunities, challenges). Learning is thus more than the technical *acquisition* and *transfer* of knowledge, but a complex bundle of activities that is social, material, embodied and emerging. The paper is illustrated with examples from a research study of the learning of experienced engineers in the construction industry to demonstrate common practices—site walks and design review meetings—in which learning takes place.

Keyword

Engineers' practice; professional learning; workplace learning; practice theory; engineering education.

1. Introduction

Engineering education research has largely focused on pre-service education of engineering students, and on the application of sciences to technological design (Downey, 2014). Although valuable to the ongoing development of educational

provision, the increasing complexity of engineering problems has raised demands for 'emerging professionals who can deal with complexity, flexibly adapt to new situations, and bridge disciplinary boundaries to integrate technical and non-technical considerations, manage trade-offs between inter-disciplinary criteria, and innovate' (Adams and Forin, 2014, p. 101). These challenges have resulted in a trend in engineering education research to focus on industry and professional bodies, and engineers' continuing professional learning. Further, as a response to these demands for emerging professionals, Trevelyan (2014, pp. 35–36) posits four key features arising in the field of engineering education:

1. There are different conceptions of engineering practice such that 'engineering practice is dominated by intellectually challenging socio-technical activity that cannot easily be reconciled with earlier descriptions of engineering based on solitary technical design and technical problem solving activities' (p. 36).
2. Traditional education does not prepare engineers well for work.
3. The humanities and social sciences bring powerful new explanatory powers for engineering practice.
4. Engineering practice is dependent on localised social, economic and political factors.

This paper draws on a research study in one of Australia's largest engineering companies to bring a new perspective to engineering education that addresses these four emerging features. It uses an approach from the social sciences whose strength is to focus on the *everyday practices* of professionals in workplaces and the learning that occurs as they practice. More specifically *a practice theory perspective* (Schatzki, 2002; 2006; 2012) drawing on recent research in professional and workplace learning is taken to understand the increasingly complex, global demands of engineering and how engineers' learn this emerging practice. We argue that these new perspectives for understanding engineers' practice and learning will contribute to the development of these 'emerging professionals', by providing a different way of understanding practice and the learning entwined in this practice. This perspective is in distinct contrast to the more common use of 'traditional' approaches to understanding engineer's work – as a set of competencies or skills and knowledge (see for example, Male, Bush and Chapman, 2011). It moves away from models of

continuing professional learning which assume that the professional is in 'deficit' and has a lack of certain skills and knowledge (Boud and Brew, 2012).

We contend that the recent research in workplace and professional learning (see Malloch, Cairns, Evans and O'Connor (eds.), 2011 and Hager, Lee and Reich (eds.), 2012) suggests these models do not adequately take account of the complex, socially contextualised and collective nature of professionals' practices or how they learn these practices. It is particularly the *practice theory perspectives on professional learning* in workplace and professional learning research which attends to this complexity, collectivity and socio-materiality rather than reducing learning to simplistic and atomised skills and knowledge of the individual professional. A *practice theory perspective* (described in detail in section 4) focuses on the *practice* as the primary unit of analysis (rather than just the individual or their psychological/ cognitive functioning or behaviour) and examines the mundane aspects of practice and the learning entwined, which is performed collectively, in relation to other professionals and material objects, regulated by rules, policies etc and emergent in non-predictable ways.

This paper seeks to offer insights from this recent research in workplace learning, and practice perspectives on professional learning, as a contribution to these emerging understandings of engineering education, particularly engineers' continuing professional learning. Commencing with an overview of recent literature in the engineering education field looking beyond higher education to the workplace, this article then reviews the shifts in understandings of workplace learning. It presents practice perspectives being taken up by professional learning researchers to shine a different light on how professional engineers practice and learn. To illustrate this, the paper provides examples of how this perspective was used in a particular study, focusing on two practices which emerged from the data — site walks and design review meeting. Finally, it concludes with a discussion of the implications for engineers' continuing professional learning and for the field of engineering education.

2. Engineering education and practice – recent literature

Some researchers in engineering education have recently argued that professional engineering practice is shaped by many factors currently absent from the 'contemporary discourses of engineering education and practice' (Trevelyan 2014, p. 33). In their research they have attempted to -

> make visible what is hidden by the dominant, linear image of engineers drawing on the engineering sciences to design new technologies. … [They] frame their studies in ways to persuade you not only that engineering is much more, and much more interesting, than the straightforward application of sciences to technological design. They also want to help you use their findings and insights to rethink and potentially transform relatively standardized ways of teaching and learning engineering. (Downey, 2014 p. vii)

Engineering education researchers who share this approach, which emphasises the complex social interactions between 'heterogeneous actors' (Kaplan and Vinck, 2014, p. 63) both human and non-human, include Hubert and Vinck (2014) and Kaplan and Vinck (2014). They researched engineering practice from the practice-based approach of actor network theory (ANT)[1]. They examined how engineers are enrolled in networks of 'intersecting influences that span actions, disciplines, time and space' … [and how organisations in which engineers work are not rational organisations but rather made up of]… 'complex social dynamics … [which] shape the technical constraints impinging on their technical work – timescale, budget, resources, technology choices and instrumentation' (Williams, Figuerido and Trevelyan p. 2). Vinck (2011) and Johri (2011) also use actor network theory and a practice-based approach to think differently about the practices of engineers. Vinck (2011) examines engineering design practices and Johri (2011) the participation of 'newcomers' to a US research and development laboratory. Johri uses a practice-based approach to challenge previous narrow conceptualisations of the newcomer's 'entry' to the workplace as socialisation and shifts the research focus to how the engineers become participating members of communities. Other researchers use actor network theory to highlight the 'social landscape of engineers practice' (Williams and Figueiredo, 2014, p.4), while Itabashi-Campbell and Gluesing's (2014) study of engineering problem solving in social contexts provides another exemplar of the

usefulness of actor network theory to understand how engineers enroll other actors in the complex technical discourse of problem-solving.

In using contemporary theoretical and methodological 'lenses" from social sciences, our research approach has similar aims to bring a new perspective to engineering practice. It uses these approaches to 'offer informative explanatory insights into the many factors that shape the landscapes of practice' (Trevelyan, 2014 p.2), and to foreground engineering practice as linked to 'localised social, economic and political factors'. More specifically it contributes to this emerging field — by focusing on engineering practice as socio-technical activity, localised in specific social, cultural and historical contexts. It does this in two key ways —firstly, by contributing from the body of research on workplace learning (also referred to as researching work and learning (Fenwick 2006)), and secondly, through using recent theorisations on practice theory perspectives on professional learning.

We argue that practice theory perspectives and workplace learning research provide new understandings of the professional learning of engineers at work which has explanatory force for complex, dynamic, contingent and ever changing engineering practice. This complexity and contingency requires new conceptualisations of learning. In the sections below workplace learning literature and its contribution is discussed, followed by an overview of practice theory perspectives.

3. Workplace learning research

Workplace learning research has much to offer engineering education research as it seeks to refocus towards engineer's practice and learning at work. Over the past two decades workplace learning research has shifted from being about learning **for** work, away from formal educational institutions, to learning **in** workplaces. The bi-annual international conference, *Researching Work and Learning* [2] exemplifies the breadth of research in this field, with papers reporting research in different workplaces and professions – engineering, medical and health, accounting, social welfare, pharmacy, teaching, etc.

This body of research identifies different understandings of adult and workplace learning which have emerged over the decades[3], from a focus on individual learning in formal settings, to a focus on informal learning contexts and on multiple views of learning — organizational and group learning as well as individual learning. These learning theories can, following Hager (2011), be loosely grouped in three types: psychological perspectives, including behaviourist and cognitive; socio-cultural approaches; and thirdly, what Green calls post-Cartesian theories or Fenwick, Edwards and Sawchuck (2011) call socio-material perspectives. These different theories and perspectives, we contend, can assist researchers in engineering education to identify their own stances in relation to the theories of workplace learning underpinning their approaches to engineers' practice and learning.

Within the *psychological theory grouping* are the behaviourist approaches [4]so prominent in vocational education (See Hager (2011) for more detailed discussion). Behaviourist approaches in workplace learning understand learning as what can be directly observed and thus requires jobs to be specifiable as a series of operationally codified behaviours, which trainers stimulate and reinforce for workers to learn these specified behaviours. The limitations of behavourism in accounting for human learning (see Kalantzis and Cope, 2009) led to a resurgence of *cognitive* theories of learning focusing on some of the 'unobservable learning' — thinking, reflection and understanding. Notable workplace theories from this perspective include that of Arygris and Schön (1974, 1978), with key concepts of single loop and double loop learning and theory-in-use, theories-in-action, reflective practitioner, reflecting-in-action and knowing-in-action. Another significant contribution was by Marsick and Watkins (1990), who identified informal and incidental learning, learning which was experienced-based, non-routine and often tacit. These theories have in common:

- a focus on individual learners
- rational, cognitive aspects of workplace performance are stressed
- performance of work is represented as thinking (or reflection) followed by the application of this thinking (or reflection) …
- the concept of learning is assumed to be unproblematic. Learning is treated as a 'thing'
- the significant role of the social, cultural and organisational factors in workplace learning is underestimated (Hager, 2011 p. 19).

Two more psychological theories relevant to workplace learning are the cognitive psychological research focusing on expertise (see Athanasou 2008; Tennant and Pogson 1995; Dreyfus and Dreyfus 1986) and the knowledge creation theories of Nonaka and Takeuchi (1995). These theories share a common concern with the individual as the unit of analysis for understanding learning; learning as a product or 'thing', and learning as independent of context (Hager 2011).

The second group of theories described by Hager (2011) are *socio-cultural theories*. In contrast to the psychological theories, socio-cultural theories emphasise the social nature of learning; learning as an 'ongoing process of participation in suitable activities' (Hager, 2011, p. 23) and the importance of social, organisational, cultural and other contextual factors. Significant theories taking this perspective include Lave and Wenger's (1991) communities of practice with its concept of legitimate peripheral participation; Engeström's (1999, 2001) activity theory; and Billett's (2002) workplace affordances. The third group of more recent theories share a focus on workplace learning as 'emergent from its context in unanticipated and unpredictable ways" (Hager, 2011, p. 27). This group includes social-material perspectives such as actor-network theory (ANT) used by the engineering education researchers described above in section 2, complexity theory (see Fenwick, Edwards and Sawchuck 2011 for an explanation of these perspectives) and practice theory perspectives (see Hager, Lee and Reich 2012), outlined in more detail in the following section.

These shifts in theoretical approaches of workplace learning have also been understood as a change in metaphors on learning — from learning as a product or thing, to learning as participation, to learning as emergent, becoming or engagement (Hager and Hodkinson 2009). Commonplace understandings of learning are, it is argued, underpinned by metaphors of the *acquisition* of knowledge into a container, out of which it is *transferred.* This reinforces understandings of learning as a product or thing, which is moved from place to place and is independent and separated from its context (Hager and Hodkinson 2009). Some of the socio-cultural theorists discussed above have taken on the metaphor of 'participation'. This challenges the substantial literature on knowledge and skill transfer which underpins many current

policies in vocational and education and training and has important implications for engineering education in more effectively facilitating the transition from education to work (see Hager and Hodkinson 2009 for a more detailed explanation).

Focusing more specifically on continuing professional development, Boud and Hager (2012) suggest that the acquisition and transfer metaphor of learning in relation to professional development implies:

- the 'pre-specification and standardization of the content of what is learnt' (p. 20);
- the over-simplification of the nature of professional practice by privileging formal courses and devaluing learning from practice;
- privileging 'experts' and content usually delivered in more formal courses; that is divorcing CPD from practice; and
- focusing exclusively on individuals and individual learning. (See Boud and Hager (2012) for a detailed account of the implications for CPD programs and professional bodies).

In the field of academic development work, Boud and Brew (2012), discuss the utility of reconceptualising academic work as professional practice, and how this opens up new ways of focusing academic development work through the everyday practices of developers. This work has contributed to developing more complex theorisations of how workers learn at work as they *practice.* It is to an understanding of practice that we now turn, suggesting that a practice theory perspective on professional learning provides new theorisations useful to understand the professional practice and learning of engineers.

4. Practice theory perspectives on professional learning

Our research has taken up a specific practice theory perspective to understand professional learning and in this case, experienced engineers' practices. Such practice theory perspectives are part of the 'practice turn' (Schatzki, Knorr Cetina and von Savigny, 2001) — a turn in humanities and social sciences away from discourse as the primary locus of research to understanding practices as the key unit of analysis.

The practice turn has been taken up in a variety of fields, e.g. science and technology studies and more recently organizational studies. Gherardi (2008) suggests that practice–based studies in the organisational studies field has been influenced by cultural and aesthetic approaches, activity theory, actor network theory, situated learning theory and workplace studies.

Although practice is talked about constantly - engineering practice, design practice, literacy practice, teaching practice, and so on, the emphasis has been on the domain – for example, engineering, design—with practice being largely taken for granted. As Green (2009, p. 2) suggests, practice is

> a term that circulates incessantly, and seems constantly and sometimes even compulsively in use, without always meaning much at all. Rather it seems to float across the surface of our conversations and our debates, never really thematised and indeed basically unproblematised, a "stop-word" par excellence.

Practice theory perspectives unpack the taken for granted notions of practice and use them to gain new insights on professional learning. Kemmis (2005, 2009) and Green (2009a) have outlined the practice literature within professional practice and Hager, Lee and Reich (2012) across disciplines – organisational studies, workplace learning, higher education and philosophy, to illuminate the relations between practice, learning and change.

The work of Ted Schatzki (2006; 2012) has been influential on the empirical work emerging in the professional and workplace learning literature. For Schatzki a practice, 'is an open-ended, spatially-temporally dispersed nexus of doings and sayings' (Schatzki 2012, p. 15). It is open-ended in that activities and actions that make up a practice are not specified, it is defined in space and across time, and made up of the activities and actions at the nexus of doings and sayings. Schatzki suggests that at the base of practices are those doings and sayings that can be described as basic activities, which are often bodily activities – such as typing. These basic activities are attached to further activities, such as preparing a word document and to 'higher level' purposeful activities or teleological action hierarchies, such as preparing a design report. Practices are organised by practical rules (explicit

instructions or directives), understandings (that is how to do the actions through doing and sayings), teleoaffective structures (the ends or projects, including the affective- emotions and moods which are acceptable to the practice), and general understandings (abstract worth or value inscribed in the doings and sayings) (Schatzki 2012). But practices are not isolated but bundled with material arrangements so that 'practices effect, use, give meaning to, and are inseparable from arrangements while … arrangements channel, prefigure, facilitate, and are essential to practices' (Schatzki, 2012, p. 16).

Building on Schatzki's work and recognising the differences amongst practice theorists, Hager, Lee and Reich (2012) suggest five principles for theorising practice, outlined below.

1. Practice is more than the application of knowledge or product of learning but a complex process of *knowing-in-practice*. Furthering the parallel argument outlined above that learning is more than what happens in people's heads, practice is a complex process of *knowing-in-practice* which shifts static notions of knowledge, as a product to be passed on or transferred, and organisations as bounded rationality, to processes of knowing and organizing in practice. Knowledge is something that people do together (Gherardi 2009) — a situated activity in the body, in language, in the dynamics of interactions and in physical contexts. It links, in complex ways, knowing, with practising, organising, learning and innovating.

2. Practices are *socio-material.* As both Schatzki (2012) and Gherardi (2009) note, practices occur with human and non-human (e.g. tools, technologies, objects) actors in space and time. These material arrangements and non-human actors constitute the practices. For example, in a classroom, practices are constituted by the material arrangements of desks, whiteboards/ smartboards, books, ipads etc. (For a fuller discussion of the sociomateriality of practice, how material things are interlaced in practice and how they affect action and learning see Fenwick, 2012a; Fenwick, Edward and Sawchuck, 2011 and Fenwick and Edwards 2010).

3. Practices are *embodied and relational.* Practices happen not just in people's heads as 'packaged' knowledge, but with their bodies. Engineers walk, drive, use machines in particular ways. Practices are also relational – with human and non-human actors. Increasingly professional practice is performed with other professionals and with clients in ways in which they are actively 'co-producing' products and processes (Fenwick 2012b).

4. Practices *exist and evolve in historical and social contexts*. Practices do not happen in isolation. As Trevelyan (2014 p. 36) quoted above notes, 'engineering practice is dependent on localised social, economic and political factors'. Engineering practices happen in complex organisations, with a wide range of professionals, contractors, clients, etc. all influenced by social, cultural and political circumstances, and located in the histories of past practices.

5. Practices are *emergent,* that is that the way practices change is not fully specifiable in advance but rather emerges in the practice. For example, Fenwick's research on police in rural northern Scotland illuminates how their practices have evolved to operate in isolated towns with only one police, while protocols require two arresting officers (Fenwick, 2012b). Complexity theory has been taken up by some researchers of practice and learning to help understand how practices emerge and evolve (see Fenwick and Edwards, eds, 2012, Fenwick et al 2011, Lancaster 2012, Davis, 2012).

We are not the first to look at engineering and related professions with a practice lens. Bjørkeng, Clegg and Pitsis (2009) undertook a longitudinal study of a leadership team in a construction company to provide an account of the unfolding of a practice. Gherardi and Nicolini (2003) provide an account of the circulation of safety knowledges within an organisation in the building industry, developing comprehensive conceptualisations of practice in the process. Suchman (2000) employs a practice-orientated approach to investigate bridge building in order to contribute to understandings of organisational knowledge and acting. Each of these studies provides a helpful example of the utility of practice theorisations in empirical studies. However, while they contribute to management and organisational learning, the research

reported here is specifically focused on the continuing professional learning of experienced engineers. In this way we position the study alongside empirical studies in health professions, community services and other fields, that have taken up theorizations of practice, learning and change. However, recently some researchers in workplace and professional learning have also researched engineers' practice using practice theory perspectives. For example, Scoles' (2013) study researched the 'entangled' engineer from a socio-material approach using actor network theory (ANT) and using Gherardi's 'knowing-in-practice' to understand how professionals are working in an emerging sector – renewable energy – in messy, fluid and ever-changing networks. Maki (2013) used ethnographic methods and cultural-historical activity theory (CHAT) to investigate the daily work of engineers on a construction site and the learning and challenges in using a new tool BIM (building information modeling), while Nerland (2013), studied the epistemic networks of four professions including engineers in Norway. Many of these studies move to a quite different kind of configuration from the conventional educator's focus on the competences of individuals and the knowledge and skills they can acquire. Such theories allow for, or indeed insist on, relationality of practice to be considered together. These studies, in the workplace learning field, are using similar theoretical approaches (e.g. actor-network theory, activity theory) as some researchers in engineering education described in section 2 above, and refocusing their research to engineers' practice and learning in workplaces.

5. Using practice theory perspectives to see engineers professional learning differently

This section discusses the partnership project undertaken by our interdisciplinary team in one of Australia's largest engineering companies and provides two examples of practices that emerged from the ethnographic data – what we have identified as the site walk and the design meeting. It describes how site walks and design meetings can be understood as practices that are materially enacted, embodied, site specific, socio-material and emergent.

The reported research investigated continuing professional learning (CPL) and was conducted by a team consisting of researchers from two faculties at the University of Technology, Sydney— Arts and Social Sciences, and Engineering and Information Technology.-The organisation's remit included work in the areas of social infrastructure and building, civil engineering, water and environment, rail, aviation, tunneling, mining, communication and energy. It employed engineers with a variety of specialties and various years of experience. It invested considerable time and money in comprehensive graduate programs for new engineers. For its experienced engineers, professional learning was recognised and rewarded against a capability framework through its performance management processes.

The research broadly aimed to explore continuing professional learning of experienced engineers. A more particular aim was to identify practices that underpin quality continuing professional learning by experienced engineers within the context of their typical working life.

5.1 Methodology

The research which illustrates this paper was a theoretically motivated, qualitative study that focused on producing detailed descriptions of various types of practices and identifying learning rich practices that arose within professional engineering work. The research involved the development of a informative account of professional learning that was sufficiently detailed to support in-depth analysis and theory development.

To provide a focus for this 'rich' account (Denzin and Lincoln, 2000), the project comprised two phases of data collection — identification and elaboration. In the identification phase researchers analysed documents provided by the company and conducted focus groups and semi-structured interviews with experienced engineers within the company. The purpose was to create an initial set of practices that constituted the work of experienced engineers. In the second phase the identified practices were elaborated and additional practices noted as they became apparent. This was achieved through unstructured observations at a construction site, as well as a second round of focus groups and semi-structured interviews with the engineers

concerned. The methodology used was both iterative and generative in that it remained open to the identification of further practices (which were subject to elaboration and identification, and so on).

5.2 Site walk

One of the engineering practices identified was site walk practice (see Rooney, (2014) for further details). We use this to illustrate a practice theory perspective on engineering practice, around the five principles for theorising practice described above.

For site engineers, the site walk is the routine way to start the day. The site engineer looks for anything that has changed overnight, e.g. excavation collapse/erosion, vandalism, protective covers dislodged by wind, rainwater damage or ponding, because the results of any of these may have to be rectified or 'made good' before any progress can be made:

> *We usually go for a site walk prior to the men* [sic] *starting the day. Go around, look for issues, especially with the weather...* (Denis – Site Engineer)

The site walk practice was illustrative of *knowing-in-practice.* Despite extensive design and planning, 'knowing' the practice is enacted in the site. As one engineer stated, a site walk undertaken as part of the tender preparation phase of a project:

> *...most engineering jobs you can't price, unless you've seen the site. That's the most important thing. The plans only tell half the story to what's actually out there. Because the plans tell you what it's going to look like when it's finished. They don't tell you what it looks like when it starts...* (Tim - Estimator).

This 'knowing-in-practice' was often a collective 'knowing–in-practice' undertaken with a client or as part of a project milestone meeting:

> *So the client and I, after the meeting, had a one-on-one walk through the job and we both expressed some concerns that we have with each others' team and made*

promises to each other to fix things… Then I went and walked the job again with the project manager and shared a little bit of the conversation that I'd had with my owner rep and the action items that I believed that came out of this meeting that should be addressed. (Gordon – Senior Division Manager).

The *collective and socio-material* nature of their practice was evident in the array of human and non-human actors involved in the site walk. The *human actors* included a diverse range of people from the senior supervisor, various consultants, an environmental team or scientists, construction manager and the client, to the foreman, service managers, labourers, diggers or leading hand, a blast crew, project manager, production superintendent and so on. This diversity of actors and disciplines contributed not only to the everyday practice of the site walk, but was an important site of professional learning — in which project managers learnt from the environmental scientist, the engineers from the boilermakers and welders, and so on. The *non-human actors* also shaped the site walk practice in significant ways. For example, the change from written diaries to Blackberries and laptops changed the way the site walk is enacted and recorded. But other non-human actors included less tangible actors, such as policies, regulations, codes of practice, mandatory standards that similarly shape the enactment of the site walk and are influenced by the particular *historical and social contexts.* For example, the particular economic and social context may put additional pressure on companies' finances and therefore the availability of certain solutions to problems encountered. The rise of safety concerns on building sites and the increased regulation increased the focus on safety. More recently environmental concerns have come to the fore.

Site walks can also be regarded as *embodied* and *relational.* They involve more than the thinking and cognitive processes in people's heads and the 'static ' knowledge of engineering design. They involved bodies —the movement of walking, driving and even sometimes flying over the site. Site walks were enacted with other people and were *relational* — with the non-human and complex networks of human actors – other engineers, site manager, contractors and sub-contractors, client, environment scientists, etc. This reflected engineering practice as dependent on 'localised social, economic and political factors' (Trevelyan, 2014, p. 36) practicing in complex organisational structures, governed by multiple regulations and legislation of local,

state and Federal governments and authorities, and answerable to international standards.

Finally site walks were *emergent.* They emerged without determinancy or predictability to be able to specify changes in advance. As the engineers and their fellow participants were going around the site they used their professional knowledge of the site but needed to take account of changes daily, based on many extraneous factors - the weather, the work undertaken the previous day, the plans for the next steps and so on.

The site walk practice seen through a practice theory lens is seen not as a 'straight-forward', static and easily defined practice. As illustrated above, it is shaped by human and non-human actors, historical and social contexts, materiality and the highly relational nature of the practice; it is also emergent and not predictable in advance. The site walk practice is also an important site of learning as the engineer's learning is enmeshed in the relational practices with many other professions and occupations. It requires the 'emerging professional', as described in the beginning of the article by Adams-Forin (2014), to be able to deal with complexity, adapt to new and changing situations, and bridge disciplinary boundaries and criteria.

5.3 Design/end of month review meeting

Another shared practice among the engineers in the study was what was referred to as 'reviews' or review meetings. These are regular meetings between major stakeholders in a project to compare current actual progress to the planned progress – both in timing and in money spent. Having design review meetings is a way to minimise the risk of going over time and over budget. As one engineer suggested,

> *There's quite a bit of governance work associated with a hundred million dollar job. You have to look - you have to approve payments. You have to review quality. You have to - you just got to keep up with it and since you're only down there - or I'm only down there twice a month - it's also just a very good time to make sure my client's happy*.

Meeting review practice can be viewed as *socio-material and embodied.* For the design review stakeholders are present in that time and place, some travelling a significant distance for that purpose e.g. Gordon, a Senior Division Manager, flying to a regional city. As Anthony commented:

> *actually what you do for a review meeting is that you'll get an electronic version of the plan and you'll put it up on the projector on the screen. That way you can control what we're talking about and also, everybody can see it. Because as soon as you have something flat on the table, then only the four people who are right next to that part of the table can actually see it, so we usually try to – it's not necessarily a PowerPoint presentation, but we'll just get the PDFs of the drawings and we'll just extract the ones that we want to talk about or are best representative of the things that need to be talked about and they get thrown up on the screen, so that everybody can stand. That way, whoever wants to stand up and point to something, can stand up and point to what they want to talk about. So that's what we normally use as a review tool.*

Similarly the design meeting practice is not confined to the particular time and space of the allocated 'meeting'. Much work related to the meeting practice happens before and after a particular meeting. For example several staff commented on the internal meetings held prior to the review meeting with the client being critical to the meeting practice:

> *So I went and met with my folks for about an hour and a half, said hello to all of them, how's things going? ... Anything you want me to bring up in this meeting that I need to know about, or - probably the most important question I was asking them, is there anything that the client's going to bring up at this meeting that I don't know about, because if there is, tell me right now so I can prepare for that discussion* (Gordon).

This practice is *mediated by materiality*. The 'things' at a design review included specifications, drawings "*Basically going through stacks of plans*" (Tim), work schedules, budgets, laptops, iPads, PowerPoint slides, Blackberries, mobiles, pens and diaries (to name just a few). However, again, as described in the site walk practice, less tangible things also mediate practices, for example, contractual relationships,

regulations, organisational procedures and individual and collective cultures and dispositions. All of these influence the practice in particular ways.

This practice is also *relational*. It occurs in relation with others involved in the practice. These 'others' represent a range of roles within the project (e.g., clients, sub-contractors, designers, site managers, etc.). The meeting practice is not static, bounded and predictable. Engineers with different job classifications attend design reviews at different stages of projects. For example, an estimator attends the pre-construction review meetings, a project engineer may only attend review meetings that occur during the construction stage of a project, and a site engineer may not attend a review meeting at all but will typically provide information for the project manager to take to the meeting:

> *That will vary with everybody's different roles where a site engineer may only be looking at a short space in time whereas the project engineer is more looking a couple of months at a time and then your manager might be looking at the whole project and that's fed down amongst everybody and then is fed back up as well, higher in the works."(Simon)*

Finally, these practices are *emergent*. Practices exist, they evolve over time and over contexts; they change in the light of circumstances. As one engineer stated,

> *Every job's different, every job has a different contract and every job has a different relationship between the contractor, the design and the client.* (Scott)

New challenges require new ways of practising. Practices emerge in unpredictable and unanticipated ways. As Rick stated:

> *But even, say like my boss, he was actually heavily involved in the talk and he's a project engineer on the job. But there are some things you can't anticipate. Like we didn't anticipate that residents are going to block us out and have stand down, have to build a road to go in from the back. You don't anticipate koala habitats emerging, things like that. Even at the talk stage, the person who's got all the knowledge and about to do*

the work, you don't have all the knowledge then and there, things just pop out of nowhere.

Scott summed up the complex and changing — or emergent — nature of engineering practice: "*So things are always changing*." However, Schatzki's work helps us to understand that while practices are changing, they also 'go on'; there is continuity with past practices and future plans.

Implications

The research team posits some implications of using a practice theory perspective for an understanding of engineers' professional learning and as a contribution to the field of engineering education.

First, the focus of research and examination of engineers' continuing professional learning should be the actual practices in which engineers engage. As outlined in the overview of the workplace learning and professional learning and practice literature above, and the study's data, it is through practices that opportunities for learning arise and are enacted. In other words, engineers learn through practice about practice.

Second, common practices have within them multiple opportunities for learning as they involve new materiality, new people and new purposes. As Schatzki (2012) suggests practices go on and change simultaneously and it is in these instances that learning happens. However, simply practicing a routine per se does not provide enough stimuli for change. It is the differences, what Marton and Booth (1997) identify as the experiences of variation in critical features, which create the possibilities for learning and change. Thus, learning can be fostered through exposure to new situations and challenges that prompt reappraisal of existing knowledge or actions or ways of thinking in consort with others. But these may not be 'large' changes — such as the introduction of new technology—learning may occur for example when an engineer 'works around' a specific problem on a site walk with an environmental scientist.

Third, this practice approach to professional learning provides a new perspective on how continuing professional learning occurs. It requires thorough analysis of

embedded practices in workplaces and the entwined learning opportunities. This shifts the focus of understandings of continuing professional learning of engineers from attributes of the learner (knowledge, skills, attitudes) to the attributes of the practice (challenges, opportunities, interactions, etc.). It thus positions learning itself not as a technical matter of knowledge acquisition, but a complex act involving the social, the material and the cultural, all of which are necessarily implicated. This is the new challenge of continuing professional learning.

Conclusion

With the increasing complexity of engineering practice and demands for 'emerging professionals' who are adept in complex inter-disciplinary situations, previous approaches to engineers' continuing professional learning are no longer adequate. Approaches that focus on the deficits of engineers knowledge and skills will not embrace these future requirements. Rather, taking up approaches from the social sciences, in particular a practice theory perspective and the research on workplace and professional learning, can provide a new direction for engineering education research. These bodies of literature as outlined above, can make a useful contribution to the trends in engineering education that utilise different conceptions of engineering practice and which position engineering practices in their localised social and economic contexts (Trevelyan, 2014). While these changes also have considerable implications for pre-service engineering education, they are beyond the remit of this paper.

References

Adams, R. S., and T. Forin. 2014. "Working Together across Disciplines." In *Engineering Practice in a Global Context*, edited by Bill Williams, José Figueiredo and James Trevelyan, 101–27. Leiden, The Netherlands: CRC Press/Balkema.

Argyris, C., and D. A. Schon. 1978. *Organizational Learning: A Theory of Action Approach*. Reading, MA: Addison Wesley.

Argyris, C., and D. A. Schon. 1974. *Theory in Practice: Increasing Professional Effectiveness.* San Francisco: Jossey-Bass.

Athanasou, J. 2008. *Adult Education and Training*. Macksville, NSW: David Barlow Publishing.

Billett, S. 2002."Toward a Workplace Pedagogy: Guidance, Participation, and Engagement." *Adult Education Quarterly* 53 (1): 27–43.

Bjørkeng, K., S. Clegg, and T. Pitsis. 2009. "Becoming (a) Practice." *Management Learning* 40 (2): 145–59.

Boud, D., and A. Brew. 2012. "Reconceptualising Academic Work as Professional Practice: Implications for Academic Development." *International Journal for Academic Development* 18 (3): 17–30.

Boud, D., and P. Hager. 2012. "Re-Thinking Continuing Professional Development through Changing Metaphors and Location in Professional Practices." *Studies in Continuing Education* 34 (1): 17-30

Davis, C. 2012. "Practice as Complexity: Encounters with Management Education in the Public Sector". In *Practice, Learning and Change: Practice-theory Perspectives on Professional Learning, edited by* P. Hager, A. Lee and A. Reich, Dordrecht:133-150. Springer.

Denzin, N. K., and Y. S. Lincoln. 2000. "Introduction: The Discipline and Practice of Qualitative Research." In *Handbook of Qualitative Research*, edited by N. K. Denzin and Y. S. Lincoln, 1–28. Thousand Oaks, CA: Sage.

Downey, G. L. 2014. "Foreword." In *Engineering Practice in a Global Context*, edited by Bill Williams, José Figuerido and James Trevelyan, vii–x. Leiden, The Netherlands: CRC Press/Balkema.

Dreyfus, H. L., and S. E. Dreyfus. 1986. *Mind over Machine. The Power of Human Intuition and Expertise in the Era of the Computer*. Oxford: Blackwell.

Engeström, Y. 1999. *Activity Theory and Individual and Social Transformation*. Perspectives on Activity Theory. edited by Yrjö Engeström, Reijo Miettinen and Raija-Leena Punamäki Cambridge: Cambridge University Press,.

Engeström, Y. 2001. "Expansive Learning at Work: Toward an Activity Theoretical Reconceptualization." *Journal of Education and Work* 14, (1): 133–56.

Fenwick, T. 2006. "Tidying the territory: Questioning terms and purposes in work-learning research." *Journal of Workplace Learning.* 18, (5).

Fenwick, T. 2012a. "Matterings of Knowing and Doing: Socimateial Appraoches to Understanding Practice". In *Practice, Learning and Change: Practice-theory Perspectives on Professional Learning, edited by* P. Hager, A. Lee and A. Reich, Dordrecht: 67-84. Springer.

Fenwick, T. 2012b. "Co-production in Professional Practice: A Sociomaterial Analysis". *Professions and Professionalism,* 2.

Fenwick, T., and R. Edwards, eds. 2012. *Researching Education through Actor-Network Theory*. London: Wiley.

Fenwick, T., R. Edwards, and P. Sawchuk. 2011. *Emerging Approaches to Educational Research: Tracing the Sociomaterial*. Abingdon, UK: Routledge, Taylor and Francis.

Gherardi, S. 2008. "Situated Knowledge and Situated Action: What Do Practice-Based Studies Promise?". In *The Sage Handbook of New Approaches in Management and Organization*, edited by D. Barry and H. Hansen. London: Sage.

Gherardi, S. 2009. "Introduction: The Critical Power of the 'Practice Lens'." *Management Learning* 40: 115–28.

Gherardi, S., and D. Nicolini. 2003. "To Transfer Is to Transform: The Circulation of Safety Knowledge." In *Knowing in Organizations: A Practice-Based Approach*, edited by D. Nicolini, S. Gherardi and D. Yanow, 201–24. New York: M.E. Sharpe, Inc.

Green, B. "Introduction". 2009. In *Understanding and Researching Professional Practice*, edited by Bill Green, 1–18. Rotterdam: Sense.

Green, B, ed. 2009a. *Understanding and Researching Professional Practice*. Rotterdam: Sense.

Hager, P. 2011. "Historical Tracing of the Development of Theory in the Field of Workplace Learning." In *The SAGE Handbook of Workplace Learning*, edited by M. Malloch, L. Cairns, K. Evans, and B. N. O'Connor, 17-32. SAGE Publications.

Hager, P., A. Lee, and A. Reich. 2012. "Problematising Practice, Reconceptualising Learning and Imagining Change." In *Practice, Learning and Change: Practice-Theory Perspectives on Professional Learning*, edited by P. Hager, A. Lee and A. Reich. Dordrecht: Springer.

Hager, P., A. Lee, and A Reich, eds. 2012. *Practice, Learning and Change: Practice-Theory Perspectives on Professional Learning*. Dordrecht: Springer.

Hager, P., and P. Hodkinson. 2009. "Moving Beyond the Metaphor of Transfer of Learning." *British Educational Research Journal* 35 (4): 619-38.

Hubert, M., and D. Vinck. 2014. "Going Back to Heterogeneous Engineering: The Case of Micro and Nanotechnologies." In *Engineering Practice in a Global Context*, edited by Bill Williams, José Figuerido and James Trevelyan, 185–203. Leiden, The Netherlands: CRC Press/Balkema.

Itabashi-Campbell, R., and J. Gluesing. 2014. "Engineering Problem-Solving in Social Contexts: 'Collective Wisdom' and '*Ba*'." In *Engineering Practice in a*

Global Context, edited by Bill Williams, José Figuerido and James Trevelyan, 129–57. Leiden, The Netherlands: CRC Press/Balkema.

Johri, A. 2011. "The Socio-Materiality of Learning Practices and Implications for the Field of Learning Technology." *Research in Learning Technology* 19 (3): 207–17.

Kalantzis, M., and B. Cope. *New Learning: Elements of a New Science of Education.* Cambridge University Press: Cambridge

Kaplan, F., and D. Vinck. 2014. "The Practical Confrontation of Engineers with a New Design Endeavour." In *Engineering Practice in a Global Context*, edited by B. Williams, J. Figuerido and J. Trevelyan, 61–78. Leiden, The Netherlands: CRC Press/Balkema.

Kemmis, S. 2005. "Knowing Practice: Searching for Saliences." *Pedagogy, Culture & Society* 13 (3): 391–426.

Kemmis, S. 2009. "Understanding Professional Practice: A Synoptic Framework." In *Understanding and Researching Professional Practice*, edited by B. Green, 19-38. Rotterdam: Sense Publishers.

Lancaster, J. 2012. "The complex systems of practice". In *Practice, Learning and Change: Practice-theory Perspectives on Professional Learning, edited by* P. Hager, A. Lee and A. Reich, Dordrecht:133-150. Springer.

Lave, J., and E. Wenger. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.

Male, S. A., M. B. Bush, and E. S. Chapman. 2011. "Understanding Generic Engineering Competencies." *Australian Journal of Engineering Education* 17 (3): 147–56.

Malloch, M., L. Cairns, K. Evans, and B. N. O'Connor, eds. 2011. *The Sage Handbook of Workplace Learning.* London: SAGE Publications.

Marsick, V. J., and K.E. Watkins. 1990. *Informal and Incidental Learning in the Workplace*. London: Routledge.

Marton, F. and S.Booth. 1997. *Learning and Awareness*. Mahwah: Lawrence Erlbaum.

Mäki, T. 2013. "Site Manager's Work and Bim: Related Collaboration on Construction Site." In *RWL8: 8th International Conference on Researching Work and Learning 2013*. Stirling: University of Stirling.

Merriam, S.B., Caffarella, R.S.and L.M. Baumgartner. 2007. *Learning in Adulthood: A Comprehensive Guide*. San Franscisco: Jossey-Bass.

Nerland, M. 2013. "Sociomaterial Knowledge Practices between the Universal and the Local: Emerging Responsibilities in Professional Work." In *RWL8: 8th International Conference on Researching Work and Learning 2013*. Stirling: University of Stirling.

Nonaka, I., and H. Takeuchi. 1995. *The Knowledge-Creating Company: How Japanese Companies Foster Creativity and Innovation for Competitive Advantage*. New York: Oxford University Press.

Rooney, D., Willey, K., Gardner, A., Boud, D., Reich, A. and T. Fitzgerald. 2014. "Engineers' professional learning: through the lens of practice". In *Engineering Practice in a Global Context*, edited by B. Williams, J. Figueridoand J. Trevelyan, 265–283. Leiden, The Netherlands: CRC Press/Balkema.

Schatzki, T., C. Knorr Cetina, and E. von Savigny, eds. 2001. *The Practice Turn in Contemporary Theory*. London: Routledge.

Schatzki, T. 2002. *The Site of the Social: A Philosophical Account of the Constitution of Social Life and Change*. University Park: Pennsylvania State University Press.

Schatzki, T. 2006. "On Organizations as They Happen." *Organization Studies* 27: 1–14.

Schatzki, T. 2012. "A Primer on Practices: Theory and Research." In *Practice-Based Education: Perspectives and Strategies*, edited by J. Higgs, R. Barnett, S. Billett, M. Hutchings and F. Trede. Rotterdam: Sense Publishers.

Scoles, J. 2013. "The Entangled Engineer: A Sociomaterial Approach to Knowing in an Emerging Sector." In *RWL8: 8th International Conference on Researching Work and Learning 2013*: Stirling: University of Stirling.

Suchman, L. 2000. "Organizing Alignment: A Case of Bridge-Building." *Organization* 7: 311–27.

Tennant, M., and P. Pogson. 1995. *Learning and Change in the Adult Years: A Developmental Perspective*. San Francisco: Jossey-Bass.

Trevelyan, J. 2014. "Towards a Theoretical Framework for Engineering Practice." In *Engineering Practice in a Global Context*, edited by B. Williams, J. Figueridoand J. Trevelyan, 33–60. Leiden, The Netherlands: CRC Press/Balkema.

Vinck, D. 2011. "Taking Intermediary Objects and Equipping Work into Account in the Study of Engineering Practices." *Engineering Studies* 3 (1): 25-44.

Williams, B., and J. Figueridoo. 2014. "Finding Workable Solutions: Portuguese Engineering Experience." In *Engineering Practice in a Global Context*, edited by B. Williams, J. Figueridoand J. Trevelyan, 159–84. Leiden, The Netherlands: CRC Press/Balkema.

Williams, B., J. Figuerido and J Trevelyan. Eds. 2014. *Engineering Practice in a Global Context*. Leiden, The Netherlands: CRC Press/Balkema.

[1] See Fenwick and Edwards, 2010 for examples of the use of ANT in educational research.
[2] See website for papers http://www.rwlconferences.org/)
[3] Similarly, a recent collection of research on workplace learning, the *SAGE Handbook on Workplace Learning* (Malloch, Cairns, Evans, and O'Connor 2011), provides a useful overview of the field internationally.
[4] Behaviourist approaches to workplace learning are prominent particularly in vocational education. These approaches use behaviourist psychological theories, developed by researchers such as Guthrie, Hull, Pavlov, Skinner, Thorndike, Tolman and Watson to understand human learning as limited to behavior change which can be observed (See Merriam, Caffarella and Baumgartner (2007).