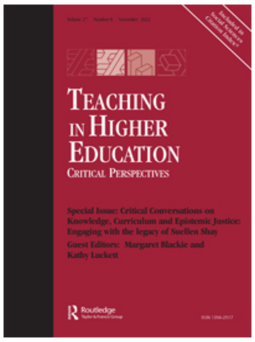

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Karin Wolff & Chris Winberg

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Curricula under pressure: reclaiming practical knowledge

Karin Wolff [a] and Chris Winberg [b]

[a]Dean's Division, Faculty of Engineering, Stellenbosch University, Stellenbosch, South Africa; [b]Professional Education Research Institute, Cape Peninsula University of Technology, Cape Town, South Africa

ABSTRACT

The increasingly complex socio-technical and economic challenges of our time place considerable pressure on engineering programmes. To ensure that graduates are well-prepared to address these challenges requires curriculum developers to select the appropriate knowledge for the engineering programme. A number of key theorists, notably from the sociology of education, have contributed to conceptualising forms of knowledge in different curricula, but the nature of practical knowledge in qualifications such as the engineering technician diploma has not adequately been theorised. Following Shay, we argue for the specialist value of practical knowledge in technical engineering curricula. Our purpose is to provide a more robust conceptualisation of practical knowledge that recognises its complexity and value. We argue that prioritising theoretical, abstract knowledge over practical knowledge has impoverished technical education.

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Practical knowledge; technical engineering; engineering technician; social realism; curriculum design

Introduction: technical curricula under pressure

Engineering programmes have always been responsive to external demands, but the challenges of the twenty-first century are considerably more complex, uncertain and volatile than those experienced by previous generations of engineering educators. Engineering educators need to know how to respond to these challenges, without over-burdening curricula with ever more outcomes, graduate attributes, and other regulatory requirements, if engineers of the future are going to address the major challenges facing people and the planet in the twenty-first century.

This paper is a conceptual study in which the focus is on 'the integration and proposing of new relationships among constructs' (Gilson and Goldberg 2015, 127). We draw on Shay's (2013; 2014; 2016) work on vocational curricula, to address the question: How do we establish a principled and knowledge-informed basis for curriculum decision-making in technical higher education contexts? We engage in theory-building by applying and extending Shay's concepts to our own field of study, technical engineering curricula in South African universities of technology.

Shay's key contribution is her problematisation of the drivers and implications for 'outward-facing curricula' (2016, 770). We pick up this theme and sketch the nature,

CONTACT Karin Wolff wolffk@sun.ac.za Dean's Division, Faculty of Engineering, Stellenbosch University, Stellenbosch, South Africa

sources, and implications of different forms of pressure on the curriculum, using Shay's four-part knowledge-mode curriculum typology (2016, 774). Shay draws on Bernstein's (2000) concepts of regionalisation and recontextualisation to demonstrate the dangers of the gaps in which ideology can play as disciplinary boundaries weaken through the selective, context-specific knowledge selection processes entailed in the construction of different kinds of curricula. Using these concepts, we show how practical knowledge in technical engineering programmes is increasingly complex and what this means for engineering educators. Enabling a more nuanced understanding of the complexity of practical knowledge in the twenty-first century is vital for its status in technical education.

Why technical engineering curricula?

In South Africa there are shortages across all engineering fields and qualification levels, but there is a greater need for technicians, due to the fact that the country is a user and adaptor of advanced technology rather than a technology innovator (Blake 2010). Diploma programmes, usually offered by universities of technology, educate technicians, whose skills are critical for developing economies (Banks and Chikasanda 2015). Technicians manufacture components and sub-assemblies or build, calibrate, and operate machines across engineering fields. While tools, techniques and technologies vary considerably, engineering machines have become increasingly sophisticated, computer-integrated, networked systems.

Technical engineering studies have become increasingly complex as technologies have evolved, and the technician profile has grown to include a range of more complex professional graduate attributes. Technicians consistently appear in the top ten of global scarce skills lists (WEF 2020), surpassing engineers. Probably most concerning is the fact that South Africa's infrastructural and energy supply woes are exacerbated by the shortage of technical graduates (Tsikata and Sebitosi 2010). It is against this contextual background that we employ concepts from Shay's curriculum differentiation work to conceptualise the nature of practical knowledge in the technical engineering curriculum.

Using shay to unpack the engineering technician curriculum under pressure

The pressures on technical engineering programmes come from many different directions and for different reasons: from students, from professional bodies, from the constantly changing field of practice, and from the aspirations of universities of technology to offer more 'academic' programmes (Tight 2015). These pressures could be understood in terms of demands and threats to technical curricula.

Shay's (2013) initial conceptualisation sees professional and vocational pathways sharing a common theory-practice professional orientation. This develops into relative degrees and different weightings of knowledge practice (Shay 2014) using additional descriptors that build on Muller's (2009) work on the contextual and conceptual coherence continuum. Drawing on Legitimation Code Theory (LCT) (Maton 2014; Maton, Hood, and Shay 2016), Shay (2016) synthesises additional theoretical tools to craft a nuanced view of higher education differentiation through its curricula.

We adapt Shay's (2016) four-quadrant curriculum model (based on LCT's semantic plane) to represent the pressures from specific stakeholders on technical engineering curricula (Figure 1). From the perspective of enhancing employability and in alignment with a global shift to holistic engineering graduate competencies, there is significant pressure from professional bodies to embed a range of 'graduate attributes' into the curriculum. Notably, these include awareness of the legal, social, and environmental impact of engineering activities as well as management, team-work and self-regulated learning attributes. These pressures stretch the technical curriculum into what Shay terms a 'generic mode' (Q1).

Employers call for improvement of engineering students' transitions into the world of work (Baldry 2016) through exposure to more industry-specific forms of technology and real-world project-based learning; this stretches the technical curriculum into increasingly regionalised and specialised modes characterised by Q3. Pressure from the field of practice requires the regular review and updating of curricula because of the rapid changes in technical environments (Banks and Chikasanda 2015). In the past, universities of technology were highly responsive to industry needs and graduates and, on average, secured employment within 3–6 months of graduation (Van Van Broekhuizen 2016), but this trend has reversed, and many diplomates currently struggle to find appropriate employment in the fields for which they are qualified. While many factors affect the employment of graduates, the mismatch between the skills that graduates develop in their university studies and those that employers require from graduates in the twenty-first century has been highlighted as a contributing factor (Pauw, Oosthuizen, and Van Der Westhuizen 2008). Kraak (2015) argues that this skills mismatch has exacerbated South Africa's skills shortages and adversely affected the employment prospects of diplomates more than other higher education cohorts.

While engineering educators are concerned about student employability, their concerns have been more focused on converting diploma-level qualifications to degrees, in an effort both to strengthen the scientific disciplinary knowledge base underpinning technical qualifications, and to offer more prestigious qualifications. This pressure

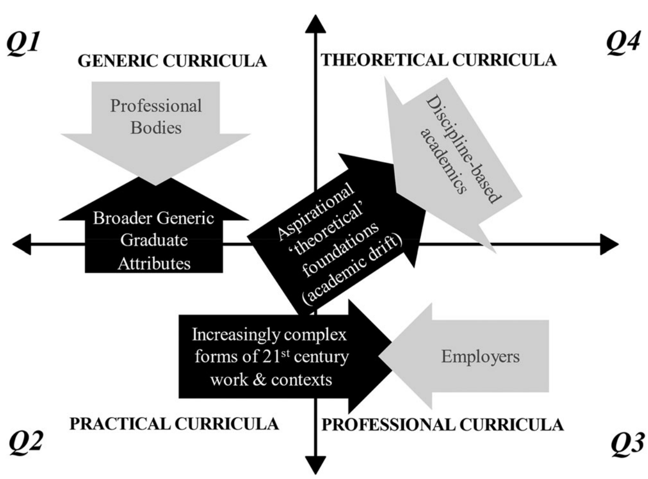

Figure 1. Stakeholder pressures on the technical engineering qualification.

stretches the technical qualification boundaries into the more theoretical Q4 quadrant, resulting in 'academic drift', largely attributed to university of technology aspirations (Tight 2015). Despite their aspirations, most of the programmes offered by South African universities of technology are diploma-level qualifications that prepare students for direct entry into labour markets, traditionally supported by practice-oriented curricula, internships, and other forms of work-integrated learning. These forms of practical training ensured that the predominantly 'proceduralised' forms of knowledge entailed in the technical diploma could stretch into engineering region-specific competencies through workplace exposure aligned to the traditional apprenticeship models of the global North. However, these traditional practices are under threat, as 'unlike many other industrialised countries, South Africa does not offer enough workplace placement opportunities for engineering students' (Mutereko and Wedekind 2016). Under pressure, it appears that it is the very distinctiveness of technical qualifications, namely practical knowledge, that is easy to discard. In the light of these multiple demands and threats, the development of appropriate curricula for engineering technicians poses significant challenges, and have implications for how we understand the key underpinning knowledge of practical curricula.

Reclaiming practical knowledge

In the face of increasing pressure on technical curricula, it is essential that the structures we put in place and agents – such as policy makers, academics and academic development specialists – recognise the value of practical knowledge. What is missing from Shay's work on conceptual curriculum differentiation tools (2013; 2014; 2016). and others in the knowledge space, is a refined conceptualisation of the nature of practical knowledge. While considerable work has been done on the nature and value of theoretical knowledge in technical education (e.g. Muller 2009; Wheelahan 2010), far less is known about the knowledge forms that enable practice or that emerge from practice. Perhaps because theorists and researchers are in the business of forming ideas and theories, they often treat disciplinary knowledge as being more valorised or 'prestigious', and do not particularly value the complexities and affordances of practical knowledge (Tight 2015). In researching universities of technology and their curricula we have come to believe that we require a principled account of practical knowledge, because without a strong understanding of practice-based knowledge there is a danger that the knowledge base of the university of technology sector will be further marginalised and undermined. The re-building of the university of technology sector needs theorists who value context and have a deep appreciation for the complexities of practice.

Perspectives on practical knowledge

Despite the implied convergence of thinking suggested by a term such as 'the practice turn' (Schatzki 2012), there is fragmentation in this field that has tried to combine many divergent, even if practice-related, concepts. This has created considerable confusion in conceptualising how practical knowledge supports and emerges from practice. There is nevertheless value in drawing together key strands on practical knowledge.

The ontological groundwork of practice theory was laid by Wittgenstein in *Philosophical Investigations* (1954/2010) in which he which he explains the 'rule-following' paradox, which is that no representation of practice can adequately describe the skills that it is intended to represent. Thus, the more we try to pin down what practical knowledge is (often by reductive lists of skills, competencies or outcomes) – the more difficult it is to get to the core of what it is. The reason for this, according to Heidegger (1978/2010), is that practice is founded on 'practical understanding' which is manifested in doing and the materiality of doing, but cannot be reduced to doing. Practical understanding develops in particular contexts through guidance and support (some might say acculturation) in the use of tools and equipment towards 'competence'. Ryle (1949/2009) captures both the cognitive and the non-propositional, non-procedural dimensions of practical knowledge in his well-known term 'know-how'. Know-how covers a wide range of practical knowledge from knowing how to fix a puncture to knowing how to solve a mathematical problem. To understand performance, Ryle argues, we have 'to look beyond the performance itself [to] the abilities and propensities of which … performance was an actualisation. Our inquiry is not into causes … but into capacities' (1949/2009, 45).

Bourdieu understands practice as the essential social phenomenon and thus central to our understanding of social life. He finds *habitus*, the internalisation of one's place in a social field, and its associated concept of 'practical logic' – to be the essential capacity for practice (Bourdieu 1977). While for many *habitus* suggests repetitive and habitual action, it offers a way of understanding how practical knowledge might develop through systematic and cumulative actions. Giddens (1984) takes issue with the adequacy of *habitus* (or practice itself being able to generate knowledge) and insists that practical knowledge is supplemented by propositional knowledge, reasons, and goals, in other words, 'practical consciousness' – suggesting that theory and practice might not be irreconcilable binaries.

Gibbons and colleagues (1994) develop a not dissimilar understanding of 'Mode 2 knowledge' (knowledge generated in the 'contexts of application') as not equivalent to 'applied science' but as a distinctive kind of knowledge. While this might not be a very sophisticated route out of the binaries, the idea of the distinctiveness of practical knowledge is important. This distinctiveness is convincingly argued by Layton (1974) who offers a more in-depth analysis of the differences between science and technology that are particularly pertinent for universities of technology and technical engineering.

Practical knowledge has been studied in a range of different contexts from the fine-grained studies of minutely observed activities undertaken by Chaiklin and Lave (2003) and Lave and Wenger (1999) to Latour and Woolgar's (1979) anthropological study of scientists' manufacture of scientific facts. Practical knowledge is, as these studies show, inextricably embedded in the materiality of its own particular contexts. Through these and other empirical studies' understandings of practical knowledge have shifted from the individual to the collective, epitomised perhaps by Engeström's (2001) concept of 'expansive learning', by which is meant the capacity of participants in an activity to interpret and expand the object of activity and respond to it in increasingly enriched ways. The richness and the materiality of the contexts in which practical knowledge is produced is important for understanding how practical knowledge might specialise through practice – for example through engagement with 'epistemic objects'

(Cetina 1999) or 'boundary objects' (Star and Griesemer 1989) and 'transaction spaces' (Nowotny, Scott, and Gibbons 2001) that can mediate between the not entirely separate worlds of theory and practice.

Theorising practical knowledge

Bernstein's horizontal and vertical discourse (1999), and its later manifestations as 'principled' vs 'procedural' (Gamble 2004) or 'conceptual' vs 'contextual' (Muller 2009) knowledge forms, places practical knowledge at the horizontal, contextual, procedural and generally less valued end of the continuum. It is 'everyday, context dependent, tacit, multi-layered, often contradictory across contexts but not within contexts' (Bernstein 1996, 170–171). Practical knowledge emerges from the conventions of local practice and procedures and derives its coherence from contextual effectiveness or procedural efficiency. Bernstein does however separate 'common sense' practical knowledge from more complex forms of practical knowledge. More complex forms of practical knowledge can be conceptualised as comprising two hierarchical, organising planes: the General Approach Plane (GAP) and the Specific Problem Plane (SPP) (1996, 173–174). Practice is dynamic, comprising interactions between the GAP and the SPP to extend the 'reservoir' (or the practical knowledge of a particular community) and develop the 'repertoires' (or potential practices) of individual members. Because practitioners address specific problems in specific contexts, 'the repertoires of members, whilst having a common nucleus, will be different, as a function of differences in their daily practice' (1996, 171).

Bernstein does not pay much attention to horizontal discourse, focusing instead on vertical discourse, which contains both vertical and horizontal knowledge structures. The internal and external referents of horizontal knowledge structures within vertical discourse have different strengths. Mathematics, for example, comprises 'strong grammars' that connect to precise empirical referents. Craft, which Bernstein includes in vertical discourse, has a horizontal knowledge structure comprising a 'weak grammar' and is 'the nearest to horizontal discourse emerging as a specialised practice to satisfy the material requirements of its segments' (2000, 169). Bernstein seems to position craft knowledge (which has much in common with practical knowledge) between horizontal and vertical discourse. For Gamble, craft knowledge comprises principled and procedural knowledge as 'its procedures can only be understood if 'interpreted' through a principle' (2004, 87). Horizontal and vertical discourses are ideal types that tend to blur on closer inspection.

'Grammaticality', which determines the capacity of knowledge 'to progress through worldly corroboration' (Muller 2007, 71) is similarly evident in the conventions, rules, and protocols of practical knowledge, even when it is deeply contextual. This suggests a version of verticality (internal, co-dependent referents) that is tightly bound to context. The materiality of complex practice suggests a constellation, that is, 'groupings … that appear to have coherence from a particular point in space and time to actors adopting a particular … worldview' (Maton, Hood, and Shay 2016, 247). There are thus likely to be hierarchical relationships between concepts of different relative values within complex practical knowledge.

Building on Shay's positioning of curricula on the semantic plane (2016, 774), and drawing on the arguments proposed by Bernstein (1996; 1999; 2000), Gamble (2004) and Muller (2007; 2009) above, we argue that the underpinning knowledge structures differentiating theoretical (Q4) and professional curricula (Q3) can also be used to describe grammaticality in the underpinning practical knowledge of practical curricula, which Shay positions in Q2 of the semantic plane (Figure 2).

We suggest that practical knowledge (Q2, Figure 2) mimics the nature of strong horizontal knowledge structures, but is located within horizontal discourse because practices are acquired through modelling or apprenticeship modes in the same way as Bernstein describes the circulation of strategies that constitute the building of the reservoir and repertoire in a horizontal discourse. As much as the explicit conceptual syntax in a horizontal knowledge structure with strong verticality and grammaticality cannot translate to other disciplinary contexts, we suggest the context specific and particular practices in, for example, manipulating a particular kind of tool for a specific purpose cannot necessarily translate across contexts. Similarly, employing Bernstein's horizontal discourse concepts of repertoires and reservoirs to address conceptual learning gaps within the vertical discourses (Wolff 2013) helps to overcome the pervasive binary distinctions and develop a more nuanced view.

Practical knowledge is acquired through practice, such as experimenting, testing, creating, inventing, and innovating and is through growing familiarity with technical practices that student technicians acquire not only the skills, but the values underpinning their work. Sites of practice are resources for the socialisation of engineering technicians, while the social practices of technical communities, and what these enable or constrain, are important for future practitioners' sense of themselves as engineering technicians. There are complex relations between different degrees of contextual and conceptual practice in engineering design, highlighting the significance of both the complexity of material artefacts as well as the importance of reflective reasoning for tackling of real-world problems characterised by uncertainty. It is precisely this increase in complexity in the twenty-first century that has driven a global contextual curriculum shift. Shay acknowledges this and concludes that the weakening of disciplinary boundaries can result in a strengthening of the interface between disciplinary knowledge and the great challenges of our time.

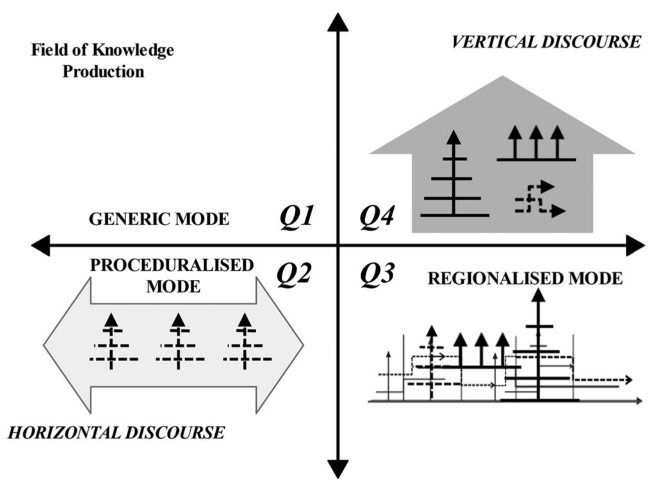

Figure 2. Conceptualisation of qualification mode knowledge structures.

Conclusion: practical knowledge in curriculum development

We set out to address the question: How do we establish a principled and knowledge-informed basis for curriculum decision-making in technical higher education contexts? Shay's work on curriculum differentiation enabled us to represent how pressures from different stakeholders impact the technical curriculum (Figure 1). In order to respond to these pressures in a principled and knowledge-informed way, it was necessary to theorise the practical knowledge underpinning practical curricula. We extended Shay's (2016) curriculum differentiation model to theorise different dimensions of practical knowledge and their interrelationships. The extended model enables engineering educators to 'defamiliarize' practice in order to understand its underpinning practical knowledge from different perspectives. We argued that practical knowledge comprises chains of logic, that approximate to strong horizontal knowledge structures (Q2, Figure 2). When these chains of logic are broken or undervalued, the strength of the technical curriculum is undermined. The extended curricular differentiation model makes visible the structures underpinning the technical engineering knowledge base and can be drawn on to guide principled curriculum decision-making.

The paper has implications for curricular practice. This is not to suggest that technical engineering educators would be expected to understand vertical, regionalised and proceduralised discourses, although they are likely to have a tacit understanding of how technical practices are represented in curriculum design. Academic developers and faculty teaching and learning specialists in technical fields do, however, need to understand the nature of these fields and the vertical and horizontal discourses that are drawn on in curricular selection. A deep understanding of practical knowledge should underpin academic developers' work in technical engineering education to enable them to advise on curricular matters in technical contexts. It is their role to understand the concepts that underpin curricular selection, and to make these ideas explicit, and to co-develop a shared language of description for curriculum development in technical programmes. Academic developers have a particular role to play in supporting the transformative possibilities of students engaged in technical higher education by understanding the curricular forms that enable engaged learning towards competent practice in technical fields. For students enrolled in technical engineering programmes, technical qualifications represent expanded life opportunities and possibilities of meaningful work.

Academics and academic developers who develop and research technical curricula have a role to play in developing a principled understanding of technical programmes because without this there is a danger that the most powerful knowledge base of the university of technology sector will be further marginalised and undermined. Universities of technology have powerful and rich ways of describing and analysing the knowledge resources of technical curricula. Reclaiming practical knowledge is a necessary step in re-building the university of technology sector.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Karin Wolff http://orcid.org/0000-0002-6150-8364
Chris Winberg http://orcid.org/0000-0001-6234-7358

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