A sociological analysis of engineering education

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Introduction

This paper discusses ongoing research that I am conducting towards a PhD in the sociology of education. I am conducting this social science research part time, while also working full time as a course director for an industry focussed engineering degree programme, an appointment that followed around twenty years in industry. I am deliberately writing this paper in the first person in order to make it clear that some of what follows, particularly in the first part of this paper, is based on my subjective personal experience. This is part of what is known in sociology as reflexivity [1] and is an essential part of subjective, qualitative research, requiring the researcher to become aware of their subjective position in relation to the data, and also to ensure that the reader is aware of the subjective elements. This is particularly relevant to the *autoethnographic* method [2] that I have used to capture my personal experience of lifelong learning and continuing professional development. Just because research is qualitative and subjective, does not exempt it from scrutiny and quality control, and while the traditional measures of reliability, validity and objectivity cannot usefully be applied to autoethnography [3, p. 70], these can be reconceptualised as trustworthiness, credibility, conformability, dependability and transferability/usefulness [4, pp. 19–21], [5], and measures including interviews and extant literature were utilised as part of this process. In addition to this, the subjective autoethnographical elements of the earlier part of my study, are complimented by the later Bourdieusian sociological analysis of engineering education discussed in the latter sections of this paper.

Autoethnography and epistemological epiphanies

Ethnography is an established method in social science which is related to anthropology, and involves the observation of cultural groups in society. It follows that the addition of *auto*, from autobiography, makes autoethnography an observation from the perspective of the self, and this method has been used in many fields to observe and analyse professional practice. Autoethnography can take many forms, but my methodology was influenced by an *analytic* form of autoethnography first proposed by Anderson [6], because I was interested in identifying issues of learning from the perspective of the learner, and relating these to existing literature and practice. My methodology also developed a grounded theory approach [7]–[9], which in practice meant that I wrote the autoethnography first without preconceptions, and only afterwards conducted a thematic analysis and literature survey to narrow the field of study and connect the data to the existing literature. I had originally expected this analysis to focus on education in general, perhaps related to why I had not been academically successful until later in life, but a number of aspects of my experience pointed towards what I would later refer to as a *disconnect between engineering education and practice*. This disconnect had first become apparent when studying underpinning concepts in ontology and epistemology at the beginning of the PhD. Ontology and epistemology are related to the way in which an individual views the world, and whether one is likely to take an objective, quantitative approach to knowledge, or a subjective, qualitative approach. I reflected that while I saw engineering academia as being very quantitative, objective and theoretical, I felt that conversely my experience of engineering practice was often qualitative, subjective and applied.

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I also reflected on my disengagement with secondary school mathematics, which meant that I would not have been qualified for, or interested in, a profession that was advertised as being intensely mathematical. When I later entered the profession through a practical route, and career progression required me to complete an engineering degree, I was surprised to find, given my existing experience in engineering related roles, that what I was studying was practically an applied mathematics degree. The level of mathematics required was extremely demotivating, and from my experience seemed largely irrelevant to practice, but I persisted and completed an MEng degree. The fact that I gained a distinction demonstrates that I eventually mastered the calculus and complex numbers, but after graduating I immediately started to lose this knowledge because I could find little use for it as a practicing engineer. I wondered why there was so much emphasis on handwritten, classical mathematics, when in my experience of engineering the mathematical work was almost always done using spreadsheet programmes or specialised engineering software.

Literature survey

Engineering is a very broad and varied field, and clearly I could not generalise from my experience alone, but the autoethnography had raised some serious questions that merited a review of existing literature. I was surprised to find so many examples of industry and institutional sources complaining about the pervasion of classical forms of mathematics in engineering degrees, with some practitioners going as far as to state that their University mathematics was a 'waste of time' [10, p. 76]. Mathematics researchers had also explored this topic, and as far back as 1989 some had suggested that the level of mathematics that students were being required to obtain, was 'completely unnecessary' [11, p. 28] and out of step with the way that engineers use mathematics in practice. Mathematics researchers Kent and Noss chose to study engineering because they *expected* to find a 'mathematically-rich professional practice', and were instead surprised when their survey returned comments such as:

> *Once you've left university you don't use the maths you learnt there, 'squared' or 'cubed' is the most complex thing you do.*
>
> *For the vast majority of the engineers in this firm, an awful lot of the mathematics they were taught, I won't say learnt, doesn't surface again.*
>
> *There is a whole lot of maths in what we do that we don't need to think about really, because other people have done it for us*
>
> [12, p. 39/1]

Another mathematics researcher Julie Gainsburg, highlighted the 'mismatch between the mathematics-oriented version of engineering design promulgated by schools and textbooks and design as practiced in the field' [13, p. 481]. While these challenges to engineering education were long standing and well documented, they appeared to have had little impact on engineering pedagogies, and most engineering academics appeared to be either unaware or unwilling to engage with the issue. In fact studies had found that engineering academics continued to stress 'the absolute importance of high levels of mathematical competence, some with the implicit meaning that this competence is necessary for students to succeed in their particular advanced course [10, p. 76]. As the disconnect between engineering education and practice was already established in published literature, my ongoing research is now focussed, from a sociological perspective, on *how* such a situation is maintained.

Bourdieusian analysis

Pierre Bourdieu developed a framework of sociological theories that have since been widely used in education [14], and in studies of professional practice [15], [16], but his concepts have received little attention in engineering education research. It has been suggested that this is because engineering education researchers tend to be primarily trained and focussed on technical and scientific knowledge [17], while the concepts that underpin Bourdieu's theories are drawn from philosophy, anthropology and sociology. On the other hand, sociological researchers are unlikely to have the required background knowledge and connections to the engineering profession. An in depth discussion of Bourdieusian concepts and methods are well beyond the scope of this paper, but I offer a very high level description of the concepts that are critical to my analysis of engineering education; those of capital, habitus, fields and doxa. The concept of economic capital and its relationship to Marxist economic theory are well known, but Bourdieu adds social capital, or *who you know,* and cultural capital, or *what you know,* to give a more complete way to describe power and society. Of these, cultural capital is arguably the most complex concept and Bourdieu stated that this can be embodied, objectified, or institutionalised [18]. Objectified capital can include art and fine wines, and is less relevant to this discussion, but embodied and institutional capital could respectively represent knowledge that an individual has internalised and knowledge that is represented by an academic qualification. Bourdieu argues that these various forms of capital, only have value within a specific *field* of power, so for example an engineering degree has little value in the field of nursing, but is a valuable currency in fields related to engineering. Sociological analysis through conceptualising a part of society as a field, is in some way analogous to systems engineering, and allows an in depth analysis of how exchanges of capital between individuals within that field affect both the field and the *habitus* of its members. Habitus is a vague and complex concept, but for the purposes of this paper can considered to be the window through which an individual views the world, and is the key concept that I refer to in my analysis. Finally, doxa, and doxic knowledge can be considered to be knowledge that is assumed, and therefore goes unchallenged.

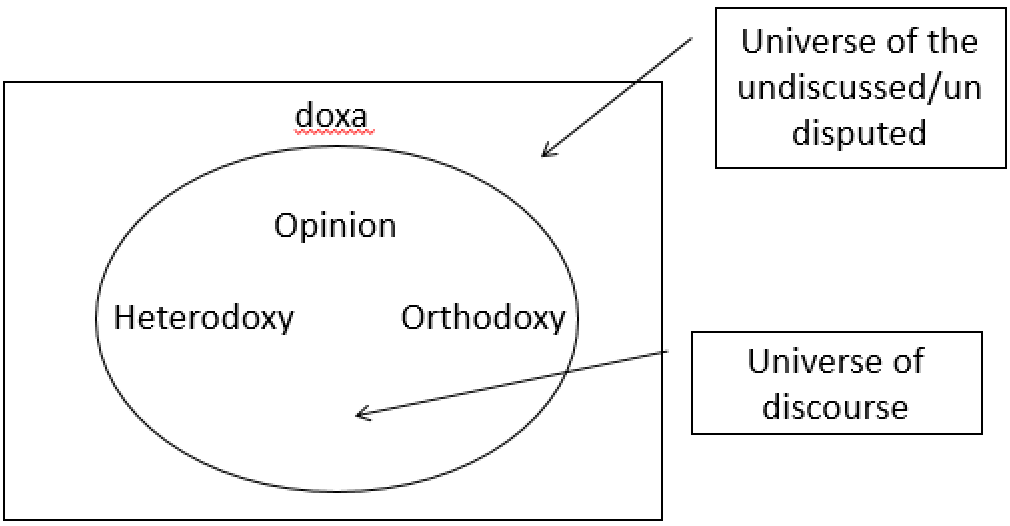

Figure 1: doxa

A doxic belief is an unquestioning belief, and part of my research explores whether engineering academics have a *doxic* belief that mathematics and engineering are inextricably linked, and that there is no other way to practice or understand engineering concepts. I use the term doxa here because I am suggesting that that this is an unquestioned belief, rather than an orthodoxy, because for many engineering academics their habitus will not have exposed them to an alternative view. According to Bourdieu, habitus is the embodied history of the individual and therefore is inextricably linked to the field in which that habitus was formed. The habitus of the engineering academic is largely formed within the field of engineering academia, and I argue that in many ways this field is disconnected from engineering practice. I have begun to conceptualise this in the figure below, where I also present engineering academia is part of a larger field of scientific research, and engineering practice as part of the larger field of industry and commerce.

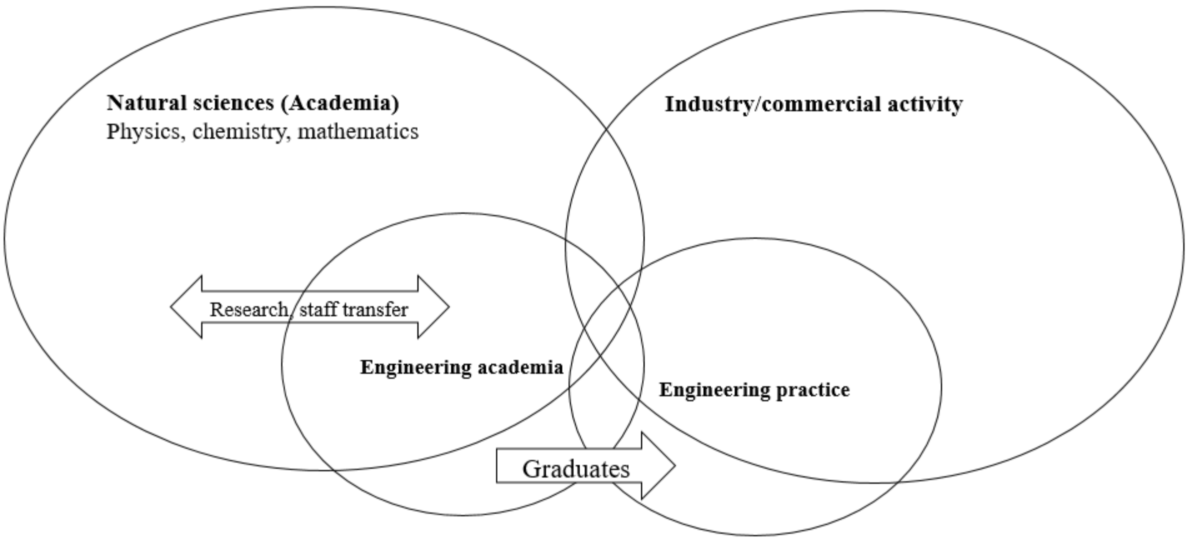

Figure 2: Engineering conceptualised as Bourdieusian *fields*

Arguably habitus not only informs what is taught, but also how it is taught, and what is seen as important. If an academic believes that mathematics and science are fundamental to engineering, they may imply that ‘high-status analytical courses are superior’ to those which ‘encourage the student to develop an intuitive ‘feel’’ for the ‘complexity of engineering practice in the real world’ [19, p. 168]. The concept of habitus can be used to explore why engineering academics might have a different understanding of engineering to practitioners, but as there is a deterministic element to habitus, it also explains why it is difficult to implement change.

Conclusions

It is beyond the scope of this paper to fully explain the concepts underpinning a Bourdieusian analysis, or to offer more than a cursory outline of the methods and data collection that have led me to my contention; that there is a serious *disconnect between engineering education and practice*. However, I would argue that the complexity of a Bourdieusian sociological analysis, provides a way to explore how social, economic and cultural factors combine to construct the fields of engineering academia and practice, and the habitus of the individuals within. If individuals can understand how their habitus has been formed, it can help them to understand their own actions and how their world view has been developed. For engineering education this has broad implications, because if the habitus of an engineering academic is significantly different from a practicing engineer, then their understanding of engineering is also likely to be different. Understanding how these differences are formed may be the first step towards resolving the *disconnect between engineering education and practice.*

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