Legitimating Engineering Education Research: A View from Sociology of Knowledge

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***Abstract**: Engineering education research has been frequently scrutinized to identify issues like who is producing research and with what methods. This paper is interested to explore what lies behind the level of interest in this topic. What explains the underlying focus on legitimacy – whether methodology, rigour, or who gets to call themselves an engineering education researcher? We analyze a selection of influential papers in this area. These aim to characterize the field of EER and make claims about what knowledge, and which knowers, are legitimate. For our analysis we introduce new conceptual tools from the sociology of knowledge to explain some of the observed tensions between fields of education, engineering, and engineering education. Finally, we make a preliminary analysis of different boundaries drawn around EER in the US and the rest of the world.*

Introduction

From the earliest establishment of formal qualifications in engineering, there has been a robust debate on how to improve educational practices. In due course, and at different points in different countries, reform efforts and their evaluation evolved into the idea of engineering education research as a distinct field of systematic inquiry. While this takes very different forms in different countries, there has been significant work to document the evolution of the growing field of engineering education research (EER), from analyses of publications (Koro-Ljungberg & Douglas, 2008), debates on methodologies (Case & Light, 2011; Malmi et al., 2018), definitions of rigour and quality (Borrego, 2007; Streveler & Smith, 2006) and characterization of research identities (Gardner & Willey, 2018).

What lies behind this intense focus on EER and its legitimacy, particularly in the eyes of the rest of the engineering education community? This paper argues that we need to draw on the sociology of knowledge to understand the competing claims about knowledge that underpin these debates around legitimacy. Specifically, we aim to identify the combination of epistemic relations (what type of knowledge) and social relations (whose knowledge) that exist in EER. In doing so, we unravel central contradictions underpinning the tensions within EER which refer back to core questions from the sociological literature: What happens when a professional field shifts the basis of its knowledge claims? What are the implications for identity and legitimacy?

While in this literature there has been some focus on the nature and structure of the field of EER itself (Borrego & Bernhard, 2011) and some identification of the disciplines that are drawn on, there has been limited work on the nature of knowledge being produced using the sociology of knowledge. This is not to say that sociological studies of engineering education are new. There are a small and growing number of engineering education researchers that have studied core EER topics using sociology of knowledge. This includes topics ranging from the importance of both conceptual and contextual details in engineering design education (Wolmarans, 2016) to different representations of thermodynamics knowledge in engineering compared to science curricula (Smit, 2018). Other analytical studies have

characterized debates about the engineering curriculum and debates between theoretical knowledge and the requirements of professional practice (Case, 2014).

This paper shares with those studies an ontological perspective of social realism, and draws on similar theoretical approaches including Basil Bernstein's sociology of education and knowledge and Karl Maton's Legitimation Code Theory. Where it differs is in the unit of analysis: We focus on EER itself as a global field of knowledge production, and apply concepts from the sociology of knowledge to develop a systematic approach to understanding knowledge structures in EER.

We start by introducing key concepts from the sociology of knowledge: the core Bernsteinian notion of classification, moving on to LCT's social relations and epistemic relations. In the process, we summarize past work that has characterized engineering and education as two distinct types of disciplines in terms of their knowledge claims, types of knowers, and functioning of disciplinary community. Second, we explain our methodological approach, which reviews and reinterprets influential studies that analyze the field of EER itself. Third, we represent our key findings in a chronological review of major arguments on the epistemic and social relations in EER. Finally, we conclude by drawing implications for actors within and without the field, and sketch out a future research agenda that includes an international comparative approach and an empirical component.

Conceptual framework – knowledge and knowers in engineering and education

Sociologists of knowledge often start by acknowledging that amidst much educational research, knowledge itself can often be taken for granted and thus neglected - Maton (2014) refers to this as knowledge-blindness. In this section we introduce three important ideas from the sociology of knowledge: The differentiated nature of knowledge; ways of characterizing academic fields and disciplines based on their organization of knowledge; and the types of knowers legitimated in different contexts.

The first important idea from the British sociologist Bernstein is that knowledge has different forms. Bernstein studied educational inequalities, starting with an analysis of class and sociolinguistics among working class children, later theorizing the nature of knowledge itself. Bernstein (1999, 2000) draws on Durkheim in distinguishing between everyday 'profane' knowledge that is limited to one context, and structured 'sacred' knowledge that is more abstract and generalized. The latter is academic knowledge. Bernstein further distinguishes between hierarchical knowledge structures that build sequentially as more advanced theories build on previous theories (physics is often presented as an archetype) and horizontal knowledge structures that build knowledge by adding new perspectives through specialized languages that do not necessarily build on each other (sociology and mathematics are common examples). Across all three types of knowledge (everyday, hierarchical, and horizontal) an important principle is the strength of boundaries - between everyday and academic knowledge, and between one knowledge structure and the others. Bernstein (2000) argues that power creates and legitimizes boundaries, and he uses the term 'Classification' to examine relations between different categories (whether knowledge structures, individual actors, or agencies).

The second important idea from Bernstein is that there are different modes of organizing knowledge. He defines *singulars* as individual bodies of knowledge (academic disciplines); *regions* as the link between academic disciplines and fields of practice that constitute applied knowledge; and *generics* as a market-oriented principle for selecting knowledge in an ad-hoc way according to employer requirements for knowledge. In broad strokes, singulars have the strongest classification, as the original academic disciplines of sociology, economics, physics, mathematics, etc. have clear boundaries. Singulars are associated with a strong inward-focus and identities - knowledge for its own sake. In contrast, regions have somewhat weaker classification as they bridge a connection between academic disciplines and an

occupational field of practice. Finally, generics are extremely weak in their structuring of knowledge, and identities are malleable and constantly changing to market demands.

Given our interest in engineering and education, it is useful to characterize both fields using these concepts. Engineering is frequently referred to as an 'old' region (or cluster of regions), having developed and solidified its knowledge base in the 1800s and 1900s (Hordern, 2016; Muller, 2009). Engineering draws on a combination of hierarchical knowledge structures from mathematics and natural sciences, and formulates a clear professional identity and occupational structure through professional bodies. Education might also be considered a region, drawing on more horizontal knowledge structures from sociology, history, anthropology and political science (Hordern, 2017). There is weaker classification in education, as identities are weaker, and loyalties divided between the parent singulars (e.g. sociology) and the emerging region. A simple comparison can suffice: It is normal and even expected to introduce Bernstein's work as coming from a sociologist *of* education, and yet it would be abnormal to think of engineering research conducted by a mathematician *of* engineering. Engineers have a stronger, more distinct identity than educators, which is a signal of stronger relations of classification.

What is interesting about engineering education is that it is the 'illegitimate child' of two regions. It has been suggested that we might term this a 'second order region' (J. Muller, personal communication, April 5, 2019). What is of interest is which elements, and with which weight, from each of the parent regions, come to determine the 'rules of play' in the offspring. As a region it faces inwards and outwards, but its inward facing is towards two parents, while outwardly it faces to the world of practice (the engineering classroom).

In all fields - whether singulars or regions - there are important differences between knowledge in research and knowledge in curriculum. Decisions must be made to select which aspects of knowledge are important, how to sequence those, what forms of pedagogic practice to use to communicate them, and what criteria to use to evaluate acquisition of that knowledge. This process of selecting, displacing, and transferring knowledge from one context to another (e.g. from research to curriculum) is called recontextualization (Hordern, 2018). This is of particular importance in regions, as by definition they involve recontextualizing knowledge from several different singular disciplines in order to prepare students for entry into the field of practice. This should resonate for engineering educators who have likely grappled with questions about the appropriate mix of mathematics, physics, computer programming and engineering design, and which should come first, second, and so on. Similar debates could be imagined among academics in an education faculty: How much sociology versus history of education? What research methods to emphasize?

The third major idea to make explicit is that knowledge is socially produced, but is not merely a social construction that can change on a whim. This is a distinct ontological assumption that characterizes the social realist group of scholars leading the Bernsteinian field of study (Case, 2013; Wheelahan, 2010; Young & Muller, 2010). Knowledge thus reflects the distributions of power among the groups that produce and legitimize it; but it also has its own intrinsic properties that are not reducible to power relations. The intrinsic properties of knowledge have already been elaborated in the discussion of everyday, hierarchical and horizontal knowledge structures, but can be more formally defined as *epistemic relations* between knowledge and its proclaimed object of study. Building on Bernstein's work, Maton (2014) added a second dimension to this analytical approach, investigating the *social relations* between knowledge and its authors or subjects. This was important for Maton (2014, Chapter 3) in moving from study of how knowledge becomes curriculum (Bernstein's emphasis) to studies of the *production* of knowledge itself, which is at the heart of this paper.

Different fields and disciplines have distinct approaches to knowledge production that can be characterized according to the strength of classification and framing of both their epistemic relations (ER+/-) and their social relations (SR+/-). Stronger epistemic relations (ER+) mean clear boundaries between academic subjects; while weaker epistemic relations (ER-)

indicate a blurring of boundaries. Stronger social relations (SR+) signal that particular groups of types of people have the power to define legitimate knowledge, while weaker social relations (SR-) have less emphasis on the type of knower. Maton (2014, p. 30) introduces these dimensions as two axes with quadrants representing four different 'codes' conveying the nature of power and legitimacy in different fields: knowledge, knower, elite and relativist.

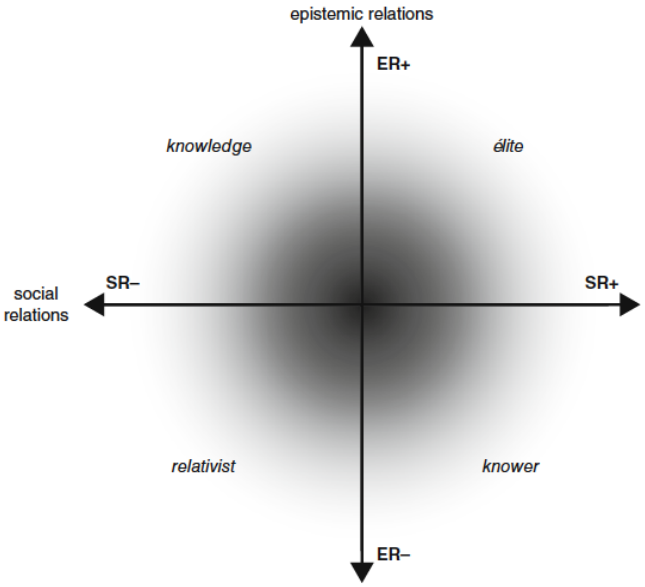

Figure 1: Epistemic relations and social relations (Maton, 2014, p. 30)

This adds another layer to our analysis of education and engineering as the key constituent fields underpinning engineering education research. While both are regions with varying strengths of classification (stronger for engineering than education), adding the analysis of their social relations reveals the opposite: education has stronger classification of social relations (who is producing knowledge matters) compared to engineering (what knowledge is more important than who). Thus, education would be characterized as a knower code whereas engineering would be characterized as a knowledge code.

The numerous concepts introduced here are more than simply an elaborate exercise in categorization. Ultimately, we are interested in understanding the competing claims to legitimacy made by different actors (academic and professional) in engineering education research and how these relate to scarce resources - both material and status. The above analysis shows differences in the 'codes' governing engineering and education that suggest that when actors from one field attempt to engage in the other, their socialized assumptions and norms about what is considered 'legitimate' might be mismatched. What is of particular interest is how engineering education, as a new and hybrid field, negotiates the different codes and values of its of its parent regions. Beyond their epistemic and social relations, what characterizes engineering and education is the nature of their respective 'regions' - they draw on very different disciplines and are responsive to very different fields of practice.

Research design

The purpose of this paper is to theorize engineering education research in order to make sense of some of the complex contradictions at the heart of our field. Our main research question is: What is the basis of claims for legitimacy of knowledge in EER?

We adapt an approach used by Hordern (2018) to characterize the field of educational research in the United Kingdom in terms of singulars, regions and generics. Our approach is to review seminal studies in engineering education that seek to define or analyze the state of the field itself, including theoretical emphases and potential gaps. Our paper seeks out key sources where claims to legitimacy can be identified. In EER we note that there has been

substantial literature that makes such claims, and thus we focus on selected key journal articles on this topic. Our selection criteria sought to balance visibility and prominence (indicated by a high number of citations) with clarity and quality of argument (regardless of citations). The 15 articles we have chosen are indicated with an asterisk in the references section. Some of the papers are editorials, others are empirical studies. They also differ in their normativity: some explicitly say what the field of EER should be doing, and others conduct surveys of the field and use this as an evidential basis for saying what should be done. Our analysis reinterprets these existing studies through a sociological lens. We read and coded each paper for statements and claims that refer to either social relations (SR) or epistemic relations (ER). In our analysis, we use these fragments of data to characterize the field of EER as a whole, applying the Bernsteinian concepts of singulars, regions and generics to make sense of EER, similar to Hordern (2018).

Findings

Across the articles surveyed, we note an ongoing debate (especially in the US literature) on whether EER can be considered a discipline and/or a field. In this regard, it is interesting to note just how many articles draw on a single paper by Fensham (2004) for analyzing science education research. Fensham references (1) structural criteria, including journals, associations and conferences; (2) research criteria, including use of theory and methodology; and (3) outcome criteria in terms of impact on practice. We did not see evidence of a consultation of a broader literature on this topic.

In our analysis in this paper we disaggregate these into epistemic and social relations, although of course they are relatively intertwined in discourse. We find strong classification across both of these aspects, as will be shown below.

We also observe that much of the literature is produced by American authors, writing about the US in the Journal of Engineering Education (JEE), often analyzing JEE papers as a core part of the methodology. We note the international voices that have become visibly only later chronologically in this debate, and as such we mirror this in our narration. In the sections below, we attempt to tell a global story about EER chronologically from the 2000s onwards as these arguments intensified, but without homogenizing. We thus pay attention to <u>who</u> is speaking and writing and <u>where</u> nationally based structures play.

Epistemic relations

From the early 2000s in the US literature on EER, strong claims emerged around what might constitute acceptable research in the field. Streveler and Smith (2006) drew on a set of guidelines around ‘Scientific Research in Education’ to propose characteristics of what they termed ‘rigorous’ research in engineering education. Beddoes (2014) traced the way this framing was initially enthusiastically adopted especially by US researchers. For example, referencing the Fensham criteria outlined above, Borrego (2007) writes:

> It might be said that engineering education now has the infrastructure but not the research consensus to be called a distinct discipline. In this case, calls for rigor would be an appropriate next step to developing the field of engineering education. (p. 6)

Following some critique, initially more informally and especially in international conferences, the language on ‘rigor’ became less prominent and supplanted by an embrace of ‘methodological diversity’ (Koro-Ljungberg & Douglas, 2008). All the same, in Beddoes’ analysis, the focus was on ‘methodology discourses’ which were used to establish boundaries of what was legitimate work in the field. This also links to the observation by Borrego and Bernhard (2011) that a focus on empirical aspects of research is more prominent in the USA compared to Europe, not only in EER but in social science research more generally. Beddoes (2014) summarises:

> The scholars cited in relation to the discourse of rigor are primarily from the United States, reflecting the fact that that is where the discipline-building efforts were originally based. Scholars cited in the methodological diversity section represent a more international group, coming from Europe, Australia, and South Africa. (p. 299)

Thus, it can be seen that the epistemic relations in this field are strongly classified, by reference to criteria for acceptable research, drawing on notions of scientific/rigorous research, and also by explicit reference to methodology. A crucial point here is the argument that EER needs to be its own distinct field separate from the broader field of education research. This is implicit in the statement by Lohmann and Froyd (2010):

> Currently, conceptual and theoretical frameworks and research methodologies in engineering education research show considerable similarity to those of educational research in general; a condition that reveals its lack of maturity. (p. 9)

Other manifestations of the structure of scientific research are also used to support claims of legitimacy, as seen especially in the many bibliometric and related analyses that have been published on EER, identifying patterns of citation, but also of co-authorship and research funding (Wankat, 2004; Wankat, Williams, & Neto, 2014; Williams, Wankat, & Neto, 2018). Another significant aspect of this work is the content analyses that have been produced of topics of research. A prominent article in this regard announced a 'research agenda' for the 'new discipline of engineering education' (Adams et al., 2006), outlining five research areas.

All the papers referenced thus far are from the US literature and by US authors, mostly published in the Journal of Engineering Education. The international literature on EER is striking for its relative absence of statements around what EER should look like. Claims for legitimacy in the European Journal of Engineering Education, which has a relatively global spread of authors as shown by Wankat et al. (2014), are occasionally made, but on a subtly different basis. Baillie and Bernhard (2009) presented a special issue of EJEE which sought qualitative papers with strong theoretical foundations and potential for impacting practice. They followed up (Bernhard & Baillie, 2016) with a publication which pointedly suggests that:

> For the development of high-quality research in EER in the future we argue that it is necessary that the EER-community *begin* to *negotiate* criteria for quality. (emphasis added, p. 2378)

A recent bibliometric analysis by Malmi et al. (2018) further demonstrates the somewhat different conceptualization of the field outside the US in terms of the objects of knowledge:

> Thus EER aspires to study the complex interactions between the central actors in the learning process, that is, students, teachers, teaching organisations and external stakeholders, as well as their relation to subject content. (p. 171)

Borrego & Bernhard (2011) attempt to bridge these differing claims for legitimation, noting firstly that the US community is more strident in its claims because of the more substantial resources at stake vis-a-vis NSF Funding. They note that while the US arguments have rested especially on methodology as noted by Beddoes, the European tradition for social research more generally privileges the significance of the problem context over the methodology. Other authors have lamented the way that this has resulted in 'silos' in the field (Jesiek, Borrego, Beddoes, Hurtado, & Rajendran, 2011).

Social relations

The US literature on EER is especially notable for its explicit statements around the social relations to knowledge, i.e. who is qualified to undertake this research and to produce this knowledge. From the outset, the distinction between engineers (those with engineering degrees, not necessarily professional registered) and non-engineers is emphasized. For example, Wankat (2004) writes:

> One remarkable aspect of engineering educators is their willingness to work with, listen to, and even reward non-engineers. The data in Table 4 shows that over the ten-year period 351 of the 1,470 authors (23.9 percent) did not have an engineering or computer science degree. (p. 18)

It is perhaps unsurprising that it is assumed that those leading EER will be engineering educators, typically holders of engineering qualifications themselves. From the outset there were disagreements over the role of collaborators with social science expertise.

However, in the US with the need to establish legitimacy for this field within engineering as such, there is a strong emphasis across these debates on who is doing EER and who are the leaders in the field. With the significant role of voluntary organisations in US public life, most prominently the ASEE in this context, the participation of office-bearers in such organisations was considered important. Thus, for example, Streveler and Smith (2006) make a claim for the legitimacy of the argument for 'rigorous' research based on the constitution of the group that authored it:

> The RREE Executive Committee, a multidisciplinary group composed of members of the American Society for Engineering Education (ASEE), the American Educational Research Society (AERA) Professions Education Division, and the Professional and Organizational Development Network in Higher Education (POD), tackled this problem when revising RREE for 2005. (p. 104)

However, early on, recognition was made that the training held by engineering educators in their formal studies was not necessarily appropriate for conducting education research. Thus, claims were made that EER researchers need to be adopting new approaches. Baillie and Douglas (2014) are gently encouraging on this score, noting:

> Moving into a new area of research, especially an interdisciplinary area and from technical to social research data, can be daunting. (p. 1)

Borrego and Bernhard (2011) are clear that engineering training is not suitable for conducting education research:

> At present, the majority of scholars who identify with the emergent field of engineering education have been formally trained as engineers and have instructional responsibility for engineering students, or they work closely with engineering educators in a staff/faculty development role. Engineering educators understand the engineering content on a deep level, have strong pedagogical content knowledge regarding teaching and learning in their specialty, and are emotionally invested in engineering educational settings (as opposed to general education) (Borrego & Newswander, 2008). But they often find that research approaches suitable for their technical research are not as suitable for their educational studies. (p. 32)

In this overview of the US claims for legitimacy of EER, we can see that the social relations are strongly classified. This becomes more complex when researchers started trying to strengthen international links in the field, most especially through the initiative Advancing Global Capacity for Engineering Education Research (AGCEER). Borrego and Bernhard (2011) note that the establishment of departments of engineering education were likely to be of more significance in the US where such structures are important for legitimating research areas. Reflecting further on the AGCEER, Jesiek et al. (2011) note:

> Through a series of special sessions at engineering education conferences worldwide, one goal of the initiative was to cultivate a global network of engineering education scholars and practitioners, including to identify infrastructures needed to sustain such a community [8, 9].Yet as we report elsewhere, these sessions revealed that many advocates of engineering education research remain preoccupied with the field's sustainability in local contexts. (p. 77)

In our review of the literature we did not find many normative statements around who does EER from communities outside the US, and would therefore judge it as somewhat weakly classified in this domain.

Discussion

EER has taken quite a different shape in the US as compared to the rest of the world, with strong classification both in terms of its epistemic relations and its social relations. Referring back to Maton's (2014) four quadrants, this would place EER in the US as an 'elite' code (ER+, SR+), 'where legitimacy is based on both possessing specialist knowledge and being the right kind of knower' (p. 31). However, this characterization comes with an inherent tension, as the right kind of knower in EER is one with an engineering background, while the right kind of knowledge is rigorous by educational research standards and still recognizable by the rest of engineers. Lohmann and Froyd (2010) capture this well:

> Engineering education research has become an established field within the last decade, although its recognition and acceptance within the broader engineering community remains a challenge. (p. 11)

What explains the major difference between the US and the rest of the world? First, the stakes are higher: Differentiating *engineering* education research from simply educational research is important in order for researchers to gain access to earmarked funding from the NSF for this field. Second, there are organizational structures and professional identities in the US that are more explicit: departments of engineering education with explicit graduate programs for EER. These can be understood both as responses to the resource opportunity mentioned above, as well as reflections of the broader culture and institutions of American higher education (Abbott, 2002). As far as the relative absence of studies staking claims for EER in other countries, this can be partly explained by a lack of resources – the limited funding is available is mostly directed to conducting EER studies rather than internally focused questions about the state of the field itself. There are important exceptions analyzing, for example, the evolution of EER in Europe (Williams & Neto, 2018) and the recent special issue in EJEE on the coming of Age of EER in Europe (Bernhard, 2018), but these show more fragmentation and diversity compared with the field in the US.

What are the implications of this schism in the global field of EER? Looking at the US, there is a risk of EER becoming completely insulated from other disciplines if it continues to take on features of a 'singular' by constructing such strong boundaries. If the elite code dominates, then social scientists and education scholars alike may be blocked from contributing (and critiquing) EER. Also, the production of PhD graduates in engineering education introduces new dynamics, as these newly minted doctorates seek employment - both in EER departments and other disciplines, and in US and abroad. The opportunities presented to them, and the choices they make, could have an important influence on the strength of boundaries in the field. A recent paper by a group of Assistant Professors with PhDs in engineering education brings to life some of these identity dilemmas and disciplinary loyalties to life (Kirn, Huff, Godwin, Ross and Cass, 2019).

Countries outside the US might be tempted to follow the American model, but our analysis suggests caution and perspective: some of the elements are culturally embedded in the higher education system, and others can be problematic from a knowledge perspective.

Conclusion

Engineering education research exists in a dynamic tension with its parent regions of engineering and education. Proponents and early champions of the field have made particular claims about the type of knowledge produced by EER, and about who should legitimately be able to contribute. Numerous other studies have looked at this topic, often using bibliometric approaches that quantify the number of publications by different types of authors on different topics within EER. This paper has taken a different approach: a

sociologically framed discourse analysis. We have argued that the sociology of knowledge offers tools for analyzing the nature of the field, by examining the types of claims made. In particular, we use social relations and epistemic relations to map the historical trajectory of discourse. In doing so, we found major differences between the US and the rest of the world that have important implications for how researchers conduct research, present their findings, and represent themselves and their work in different arenas. This paper thus offers a first step in a new line of theoretical inquiry into the structures that underpin and constitute engineering education research. Some of the topics that could be explored comparatively include the ranging disciplinary emphases of EER in different countries; the links between resources and organizational structures; and the moral discourses underpinning different claims for legitimacy in different EER camps.

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