Evolution of engineering education research as a field of inquiry in the UK

Abel Nyamapfene
University College London, UK
a.nyamapfene@ucl.ac.uk

Bill Williams
Instituto Politécnico de Setubal, and CEG-IST, Universidade de Lisboa Portugal
bwbillwilliamsbw@gmail.com

Abstract*: We report on a preliminary investigation to determine the current state of Engineering Education Research (EER) within the UK, as well as its likely growth trajectory. The investigation involved the analysis and categorisation of articles published in the period 2000 -2017 by UK authors in the Journal of Engineering Education (JEE), the International Journal of Engineering Education (IJEE) and the European Journal of Engineering Education (EJEE). A similar analysis was also carried out on EER- focussed PhD theses published in the UK in the same period. Our study establishes that the level of engagement in EER in the UK is still relatively low, as evidenced by the small number of published articles. In addition, our study also finds that EER publications from the UK are predominantly single-authored, or from single institutions. This suggests low levels of internal and external collaboration amongst EER researchers in the UK.*

Introduction

Over the last decade there has been increasing interest in mapping the evolution of engineering education research (EER) as a field of inquiry. Lohman and Froyd (2010) looked at the process from a predominantly U.S. perspective, van Hattum-Janssen et al. (2015) studied EER evolution in Portugal while Edstrom et al. (2016) have characterised it in the Nordic context. This work-in-progress study aims to characterize the evolution of EER in the UK with a particular focus on the years from 2000 to the present.

Within the UK and other western countries it is now generally believed that technology is the bedrock for future economies, and that engineering education could contribute to this by ensuring that a sufficient number of young people acquire the necessary skills appropriate for a technology-based 21st century economy, and remain within engineering so that the economy can benefit from their acquired skills (EngineeringUK 2015). However, engineering education is still struggling with issues of underrepresentation, recruitment and retention, and some researchers now believe that these issues can only be resolved by resorting to well researched, and well-funded intervention strategies (Henderson et al. 2011). This therefore calls for well-resourced EER strategies to underpin engineering education.

However, a 2013 survey of EER researchers (Shawcross and Ridgman 2013) suggests that in the UK, EER remains under-resourced, especially when compared to mainstream discipline-specific science and technology research, with most of the EER research being carried out by individual academics without any supporting funding. Because of this, the time allocated by UK-based academics to EER is also small, to the extent that 65% of UK-based EER researchers spend no more than 20% of their time on EER (Shawcross and Ridgman 2013). The objective of the research reported in this paper is to map out the UK EER landscape, with a view to providing a concrete and accurate picture of the state of EER within the UK, and to provide evidence of how it measures up to EER in related Organisation for Economic Co-operation and Development (OECD) countries. We have used the following research question to guide our study:

What does an analysis of data on publications by UK-based researchers tell us about the evolution of EER in the UK?

Organisation and Structure of the Paper

The specific focus of the work reported in this paper is on the period beginning from 2000 to the present. However, EER has been taking place within the UK for a longer period than this. Therefore, to provide the context within which this work is situated, we will provide a brief overview of the history of EER in the UK. We will follow this with a discussion of our approach to mapping the current state of EER in the UK. Jesiek et al. (2011) developed a scheme for categorising EER journal papers which they used in their work on mapping global trends in EER over the period 2005-2008. We have used their categorisation scheme in the study reported in this paper. After this, we discuss the preliminary results that we have obtained to date, and this leads to a discussion of the potential implications of these preliminary findings.

Earlier UK-based EER

In contrast to many other European countries (see for example van Hattum-Janssen et al. (2015)), EER is not a recent development in the UK. Heywood (1970) describes how in the post-war period there was a national focus on the need to increase the qualified technological workforce. There were a number of Ministry of Education sponsored reports in those years: the Percy Report (Ministry of Education 1945), a White Paper(Ministry of Education 1956), the Crowther Report (Education 1959) and the report of the Bosworth Committee (Bosworth 1966).

These national initiatives were paralleled by a number of studies carried out by university faculty, often in collaboration with industry. Examples include the work of Heywood on graduate careers (Heywood 1969) and on engineering practice (Youngman 1978), Hutton and Gerstyl on engineers' attitudes to their education (1964) and Bosworth's study of engineering design (1963). The University of Lancaster made significant contributions to engineering education in this period and introduced "engineering analysis" to its engineering programs, an approach that today would be called problem based learning (PBL) (Heywood 1970). Heywood and his colleagues, firstly at Lancaster and later Salford University were particularly prolific from the 1960s through to the 1980s; see, for example, Heywood (1970), and Heywood and Monk (1977).

Meanwhile in Scotland John Cowan was carrying out research into self-managed learning and in 1982 Heriot-Watt University appointed him to be the first professor of engineering education in the UK.

Method

In this paper we report on preliminary research aimed at identifying and categorising the nature of engineering education research taking place within the UK. Our work follows similar studies that have been undertaken in the United States such as the work by Wankat (2004), Whitin and Sheppard (2004), and the more recent work by Jesiek et al. (2011). Like Wankat (2004), we restrict ourselves to the main EER journals, in our case the International Journal of Engineering Education (IJEE), the Journal for Engineering Education (JEE), and the European Journal for Engineering Education (EJEE). This is because, as Jesiek et al. (2011) observe, such publications have committed to publishing and disseminating high quality EER work.

We have also included in our dataset all the EER related PhD theses published in the UK between 2000 and 2017. Our reason for focussing on PhD theses is that the publication of a PhD thesis follows a sustained period of research on a substantive topic. A PhD thesis also strongly suggests the presence of expertise within an institution and faculty who are

committed to researching a particular field of interest. Hence PhD theses are likely to indicate areas deemed to be important and worth researching by academics with an interest in EER.

Jesiek et al. (2011) came up with a list of 38 categories for classifying the nature of EER research based on the keyword used by authors in their papers, as well as the key terms arising out of the paper contents. For the three journals, we identified all the papers authored by UK-based EER researchers and recorded the author keywords. Where keywords were not available, especially in the earlier journal issues, we scanned the abstracts of UK-authored papers to come up with appropriate keywords. Using this method, we identified for the period 2000-2017, 109 EJEE articles, 58 IJEE articles, and 5 JEE articles.

For the PhD theses we accessed the British Library E-Theses Online Service (EThOS), and used Boolean combinations of the terms “engineering”, “learning”, “education”, “practice”, “PBL” and “problem-based” to identify theses related to engineering education and practice. We then scanned the theses’ abstracts to establish their relevance. Using this method, we identified 93 PhD theses that had been submitted and published in the period 2000 – 2017.

Findings

As pointed out earlier, the research question guiding our study is: What does an analysis of data on publications by UK-based researchers tell us about the evolution of EER in the UK? To find answers to this question we broke it down into three sub-questions:

1. What are the specific categories, as defined by Jesiek et al. (2011), that characterise UK research publications?
2. What is the nature of research collaboration amongst UK EER researchers as evidenced by the categorised research publications?
3. What are the emerging trends in the evolution of UK EER as evidenced by changes in research categories over time?

Categorisation of UK EER publications

Table 1 shows the categorisation of UK EER research by journal ordered by the number of instances of occurrence. The table indicates that 6 categories feature in the top ten of both the EJEE and IJEE journal. These six are *edtech, assessment, design, collab, curriculum* and *profession*. The scope of each of these categories, as specified in Jesiek et al. (2011) is:

Edtech	Educational/Instructional Technology, inc. Online, Distance, Web-based Learning
Assessment	Assessment (of Student Performance), inc. Evaluation, Exams, Grading, Outcomes-Based
Design	Design, inc. Education, Methods, Practices, Processes, Projects, Skills, and Thinking
Collab	Collaborative/Group/Peer/Team Learning, Performance, Roles, and Skills
Curriculum	Design, Reform, and Development of Curricula and Courses (general/unspecified)
Profession	Studies of Alumni, Careers, Continuing Education, Employment, Postgrads, Professionals

Edtech ranked highest in both journals. This suggests that educational technology and its use in higher education is currently an active area of research. Curriculum and assessment also feature highly in EER research. Our findings also suggest that design based learning and collaborative learning are also active areas of investigation. Whilst the category “problem based learning” does not feature highly, the preoccupation of researchers with design and collaborative learning would however seem to indicate that activity-based, collaborative learning, of which problem–based learning is one, features highly in current UK EER.

Table 1: Categorisation of Journal articles

EJEE		IJEE		PhD Theses		JEE	
Category	**Count**	**Category**	**Count**	**Category**	**Count**	**Category**	**Count**
edtech	21	edtech	15	global	25	assessment	2
students	17	PBL	10	profession	15	mathsci	1
assessment	16	design	8	industry	12	curriculum	1
design	16	collab	7	socpolorg	11	learning	1
learning	12	curriculum	7	edtech	9	faculty	1
envsust	11	mathsci	4	learning	9	competencies	1
collab	10	assessment	4	diversity	8	students	1
curriculum	9	industry	4	envsust	7	global	1
progeval	9	labs	3	support	7	teaching	1
profession	7	profession	3	students	6	labs	1
diversity	7	teaching	3	graduate	5		
teaching	6	diversity	3	assessment	5		
industry	6	progeval	2	comm	4		
competencies	6	graduate	2	design	4		
PBL	5	genskills	2	engskills	4		
graduate	5	conceptual	2	faculty	4		
faculty	4	active learning	2	design	4		
conceptual	4	reflection	1	progeval	4		
graphics	3	learning	1	curriculum	4		
recruit retain	3	engskills	1	mathsci	3		
first year	3	students	1	competencies	3		
global	3			interdisciplinary	3		
mathsci	3			compskills	2		
active learning	2			collab	2		
reflection	2			conceptual	2		
labs	2			graphics	1		
compskills	2			PBL	1		
interdisciplinary	2			first year	1		
service learning	2			business	1		
comm	1			learning styles	1		
k12	1						
business	1						
learning styles	1						

There are however some significant differences between the rankings for categories for the two journals. For instance, the *students* category, which was second highest in the EJEE comes in at position 21 in the IJEE. Similarly, the *learning* category, which is 5th in the EJEE is 19th in the IJEE. Likewise, the *PBL* category, which is second in the IJEE ranks 15th in the EJEE; and the *mathsci* category, which is 6th in the IJEE is 24th in the EJEE. This may be due to differences in the focus of the two journals.

Six of the top ten categories in the EJEE are also in the top ten of the PhD Theses, with only 3 top ten IJEE categories making it into the PhD Theses top ten list. This suggests a closer alignment between PhD work and the EJEE compared to the IJEE. Given that EER is aimed at both practitioners and researchers, it may be that the EJEE and IJEE have a different research orientation on the researcher-practitioner continuum. We intend to explore this aspect in more detail as the research progresses.

The top category in the PhD theses is the *global* category. This category is 23rd on the EJEE ranking, and does not feature at all in the IJEE. Its frequency in PhD research may be a result of international PhD candidates coming to UK universities to do research on engineering education in their own national contexts.

Another category, *socpolorg*, is 6th on the PhD Theses list, and does not feature at all on both the EJEE and IJEE categories. Jesiek et al. (2011) define the *global* category as:

> Global Competence and Education, Intercultural Skills, Foreign Language, Mobility

and the *socpolorg* as:

> Social, Organizational, Philosophical, and Political Studies, inc. Ethics, Policy, STS.

It may be that PhD theses are going beyond researching classroom practice to considering global and societal issues related to engineering education. This may suggest that PhD theses are more oriented towards the researcher end of the researcher-practitioner spectrum.

When the individual category instances are summed up to come up with an overall ranking, *edtech* comes highest, with the most popular categories in the IJEE and EJEE generally making it into the top ten. However, the *global* category, which only features in the PhD Theses, comes second highest overall. This suggests a significant level of popularity for the category as an area of PhD research.

Collaboration

Our preliminary findings suggest that EER articles from the UK are predominantly single-authored, and in instances of multiple-authorship, the evidence suggests that typically all the authors belong to the same UK-based institution. For instance, over the period 2000 – 2017, of the 108 EJEE, 79 articles had either been single-authored, or authored by people from the same institution. 20 were the result of co-authorship with another institution. However, 7 of these co-authored articles comprised only UK-based institutions. Moreover when an article had 3 or more co-authors, it was more likely to be the result of collaboration with non-UK-based institutions. Similar trends are evident for the IJEE articles. Of the 58 IJEE articles over the same period, 42 articles were either single-authored or authored by people from the same institution. For those articles with two authors, five were by authors from the UK alone. Again, for the remaining 5 articles that had 3 or more co-authors, only one was by authors from the UK alone.

These data suggest that UK-based EER researchers are more likely to work and publish their work alone, suggesting rather low levels of collaboration with international researchers. Such low levels of collaboration may also point to low levels of engagement with the EER literature by UK engineering academics and researchers, and may suggest that both teaching practitioners and researchers may waste time and resources re-inventing work that has been discovered and evaluated elsewhere. Wankat (2004) suggests that increases in

co-authorship may be achieved by the formation of larger research teams, which can be achieved by access to EER funding.

With regard to the JEE, only two of the five identified articles were single authored. Of the three co-authored papers, only one was by UK-based authors alone. The other two were as a result of collaborations with at least a USA based author. This may point to a perception amongst UK-based EER researchers that the JEE is more focussed towards the USA, or it may indicate that the quality of UK-based EER falls short of the requirement of the JEE. Further investigations, using surveys and/or interviews would be needed to determine the correct position.

Category trend analysis

There is no definite trend signifying definite changes in the popularity of categories over the period 2000 – 2017 across all the three journals and the PhD Theses. This suggests that research within EER in the UK is not focussed to any particular institutional or national objective. This is a plausible suggestion given that EER research in the UK is generally not funded, and there is currently no national funding bodies directing EER research in any way (Shawcross and Ridgman 2013). Given such a scenario, individual researchers would probably only focus on EER areas in which they have an intrinsic interest. However, given the relatively low output of EER compared to other countries like Australia and the USA Jesiek et al. 2011), it may simply be that the small number of articles masks the presence of any trend. One possible way of establishing the existence or absence of research trends in EER would be to augment this analysis with survey instruments targeted at EER researchers in the UK. Findings from this preliminary study will be used to develop such a survey instrument. An advantage of such an approach would be the possibility of galvanising interest in EER within the UK.

Concluding Remarks

We have carried out a preliminary investigation into emerging trends in the evolution of EER in the UK. We have done this by categorising articles from the JEE, IJEE, and EJEE, as well as PhD theses in EER from UK–based institutions. Compared to countries like the USA or Australia, the level of EER in the UK is still relatively low. Whilst EER in the UK spans the entire range of available categories, there is no discernible trend to signify the direction of evolution. In addition, UK EER is predominantly single-authored. We suggest that this may be a result of lack of access to research-funding by EER researchers in the UK. Our preliminary conclusion is that UK EER is under-supported and this has led to a stunted development of the field, unlike in other countries where there is access to research funding.

However, our findings are based on a relatively small number of research articles, again a direct consequence of the low level of EER taking place in the UK. Hence more investigation, using surveys and interviews with UK EER researchers, are needed to enable us to reach fully-evidenced conclusions. Use of these instruments will now form the next stage of our investigation.

Copyright statement

References

Bosworth, G. (1963). "Towards creative activity in engineering." *Higher Education Quarterly*, 17(3), 286-297.

Bosworth, G. S. (1966). *The Education and Training requirements for the Electrical and Mechanical Manufacturing Industries Committee on Manpower Resources for Science and Technology*. HMSO, London.

Edström, K., Kolmos, A., Malmi, L., Bernhard, J., and Andersson, P. (2016). "A bottom-up strategy for establishment of EER in three Nordic countries – the role of networks." *European Journal of Engineering Education*, 1-16.

Education, M. o. (1959). *Report of the Central Advisory Council for Education (Crowther Report)*. HMSO, London.

EngineeringUK. (2015). *EngineeringUK, Engineering UK 2015: The state of engineering* London.

Henderson, C., Beach, A., and Finkelstein, N. (2011). "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature." *Journal of research in science teaching*, 48(8), 952-984.

Heywood, J. (1969). *An Evaluation of Certain Post-War Developments in Higher Technological Education*, Ph. D. thesis, University of Lancaster.

Heywood, J. (1970). "Qualities and their assessment in the education of technologists." *International Bulletin of Mechanical Engineering Education*, 9, 15-29.

Heywood, J., and Monk, J. (1977). "The education and career patterns of professional Mechanical Engineers in design and management." *The Vocational Aspect of Education*, 29(72), 5-16.

Hutton, S., and Gerstl, J. "Engineering education and careers." *Presented at Proceedings of a Symposium on Education and Careers. Proceedings of Institution of Mechanical Engineers*.

Jesiek, B. K., Borrego, M., Beddoes, K., Hurtado, M., Rajendran, P., and Sangam, D. (2011). "Mapping global trends in engineering education research, 2005–2008." *international Journal of engineering education*, 27(1), 77-90.

Lohmann, J., and Froyd, F. "Chronological and ontological development of engineering education as a field of scientific inquiry." *Presented at Second Meeting of the Committee on the Status, Contributions, and Future Directions of Discipline-Based Education Research, Washington, DC. Available: http://www7. nationalacademies. org/bose/DBER_Lohmann_Froyd_October_Paper. pdf*.

Ministry of Education. (1945). *Higher Technological Education (The Percy Report)*. HMSO, London.

Ministry of Education. (1956). *Technical Education (1956) Whitepaper. Cmnd 9703*. HMSO, London.

Shawcross, J. K., and Ridgman, T. W. (2013). *Publishing Engineering Education Research*. HEA Academy Working Paper. Higher Education Academy.

van Hattum-Janssen, N., Williams, B., and Nunes de Oliveira, J. M. (2015). "Engineering Education Research in Portugal, an Emerging Field." *International Journal of Engineering Education*, 31(2), 674-684.

Wankat, P. C. (2004). "Analysis of the first ten years of the Journal of Engineering Education." *Journal of Engineering Education*, 93(1), 13.

Whitin, K., and Sheppard, S. (2004). "Taking stock: An analysis of the publishing record as represented by the Journal of Engineering Education." *Journal of Engineering Education*, 93(1), 5.

Youngman, M., Oxtoby, R., Monk, J. D., Heywood, J. . . (1978). "Analysing Jobs". City: Gower Press: Farnborough, Hampshire, UK.