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Engineering Education Research in Portugal, an Emerging Field*

NATASCHA VAN HATTUM-JANSSEN
Academy of Creative Technology, Saxion University of Applied Sciences, Van Galenstraat 19, 7511 JL Enschede, The Netherlands. E-mail: n.vanhattum@saxion.nl

BILL WILLIAMS
ESTBarreiro/Instituto Politécnico de Setúbal and CEG-IST/Universidade de Lisboa, Rua Américo da Silva Marinho, 2839 001, Lavradio, Portugal. E-mail: bill.williams@estbarreiro.ips.pt

JOSÉ MANUEL NUNES DE OLIVEIRA
Escola Superior de Tecnologia e Gestão de Águeda—Universidade de Aveiro, Apartado 473, 3754-909 Águeda, Portugal, Centro de Investigação Didática e Tecnologia na Formação de Formadores—Universidade de Aveiro, Campus Universitário, 3810-193 Aveiro, Portugal. E-mail: jmo@ua.pt

Engineering Education Research (EER) has been increasingly recognised as an autonomous field of research with an important global role to play in preparing engineers to meet the technological and social challenges of tomorrow. In this article, the authors use Fensham's criteria for defining an emerging field of inquiry to characterize the evolution of EER in Portugal. They find that although there is as yet relatively little structural support for EER, data on research output suggests that the national and international contribution of Portuguese scholars to the field is on the increase in quantitative and qualitative terms. The authors identify challenges such as a perceived lack of legitimacy of the field and limited funding opportunities as factors limiting the development of this research field and hindering the diffusion and implementation of proven good practice at national level. They suggest that management support and availability of resources are key factors in meeting these challenges. They identify two important strategic goals for Portuguese EER scholars: research partnerships with international engineering education researchers and closer collaboration with researchers in learning science.

Keywords: Engineering education research; evolution of a field of inquiry; Fensham's framework

1. Introduction

Over the last decade, various authors in articles published in the American Society for Engineering Education's *Journal of Engineering Education*, have put forward claims for EER to be considered as an emerging field of research [1–3]. These scholars highlight the challenges facing engineering education, including the timely preparation of society for future technological developments and the evident need to prepare engineers to respond adequately to them. Reflection on the competencies to be acquired during the education process of future engineers has also been a focal point [4].

As the pace of technological change has accelerated in recent years, engineering faculty and students have had to face challenges that include not only the acquisition of technical skills but also the development of transversal competencies, such as communication, teamwork and continuous learning. As technology assumes an increasingly integral part of society in most parts of the world, the responsibilities of the engineering profession are heightened with regard to the impact on and interaction with society. At the same time, the tendency towards globalisation of science and technology has meant that future engineers are likely to need not just a local or national vision but also a global perspective. Here again, the challenges associated with playing a role in the economic and political relations between nations will call for engineering competencies beyond those traditionally emphasized in university engineering programmes. The path to achieve these goals has also been a subject of international debate [5, 6]. These developments have implications for decision makers in higher education as they consider how the existing paradigm for engineering education may need to be adapted to face new realities.

The UK study *Engineering in the 21st Century, the Industry View* carried out for the Royal Academy of Engineering, forecasts an increasing complexity of management tasks paralleled by growing technological complexity [7, p. 4]. In the US, the report *The Engineer of 2020: Visions of Engineering in the New Century*, published by the National Academy of Engineering, predicted that 'problems to be solved may require synthesis of a broader range of interdisciplinary knowledge' [8, p. 55]. In addition to the challenges of technological complexity it also high-

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lights the social context likely to be created as a result of world population growth, migration to cities and increased human lifespan, all of which will bring new pressures to bear on our health systems and our natural resources.

Given this context, EER is potentially a key element in providing the necessary innovation and continuous improvement, according to the report *Engineering for Changing World: A Roadmap for the Future of Engineering Practice, Research and Education* [9] prepared by the University of Michigan. In this report, Duderstadt suggests that 'the issue is not so much reforming engineering education within old paradigms but instead transforming it into new paradigms necessary to meet the new challenges such as globalisation, demographic change, and disruptive new technologies' [9, p. 5].

The current article sets out to characterize the evolution of EER in Portugal by applying national and international perspectives and to make appropriate recommendations.

2. Engineering education research as a field of inquiry

In order to consider claims for EER as an emergent field, the authors, following work by Borrego [10] and Lohmann and Froyd [11], chose to apply the criteria proposed by Fensham [12] as the hallmarks of a research field. Fensham, who was considering the emergence of science education research, put forward fourteen criteria grouped into structural, intra-research and outcome categories (see Fig. 1).

Structural criteria relate to infrastructural aspects, such as academic recognition, research journals, professional associations, specific conferences, and research postgraduate training. Intra-research criteria relate to the substance and methodology of the research itself. The final category focuses on the practical outcomes of research. In the next sections, these three types of criterion will be discussed in the context of EER in Portugal.

Category	Criteria	Exemplars of criteria
Structural	Academic recognition	Full faculty appointments in the area of research
	Research journals	Successful journals for reporting quality research
	Professional associations	Healthy national and international professional associations
	Research conferences	Regular conferences for the direct exchange of research that enable researchers to meet in person
Intra - research	Scientific knowledge	Knowledge of science content required to conduct the research
	Asking questions	Asking distinctive research questions not addressed by other fields
	Conceptual and theoretical development	Theoretical models with predictive or explanatory power
	Research	Invention, development, or at least adaptation of engineering education as a field of scientific inquiry
	Methodologies	Methodologies, techniques, or instruments
	Progression	Researchers are informed by previous studies and build upon or deepen understanding
	Model publications	Publications that other researchers hold up as models of conduct and presentation of research studies in the field
	Seminal publications	Publications recognised as important or definitive because they marked new directions or provided new insights
Outcome	Implications for practice	Outcomes from research that are applications to the practice of science education

Fig. 1. Fensham's criteria for defining a field of research (adapted from [11]).

2.1 Structural criteria

The structural criteria are essential to the establishment of a field of research. The existence of full professors in the area, centres or research groups that have the field as its primary focus, and reputable scientific journals, are criteria that characterize mature research fields. Although these criteria have been increasingly met for EER in some parts of the globe, in Portugal, as yet, there are relatively few signs of their being fulfilled.

2.1.1 Global context

Such criteria have been patent in the USA and Australia for more than twenty years and examples of academic recognition for EER have also begun to emerge in parts of Europe and in Asia, Malaysia being a notable example, in recent years. US universities such as Purdue, Virginia Tech and the University of Cincinnati have created departments or schools focusing on the field of EE over the past 10 years. A growing number of research centres are to be found around the world such as CELT, University of Washington in the US, the University of Linköping in Sweden, Swinburne University in Australia and UTM in Malaysia. In addition, several of these universities and centres offer masters' and doctoral programmes, which are generally, though not exclusively, geared towards engineering lecturers. In the case of masters' programmes, engineering educators can often include the area of teaching and learning in engineering within their engineering degree. Ph.D. programmes may have similar objectives but can also lead to a career in EER itself.

A further area of institutional growth has been the development of support centres for teaching and learning in engineering such as the Centre for Engineering Education, Colorado School of Mines (US), the Centre for Engineering and Design Education at Loughborough University (UK), and the Focus Centre for Expertise in Education of the Technical University of Delft (The Netherlands). Such centres typically deal with specific issues within engineering education by providing training sessions which can range from short one or two hour workshops devoted to a particular topic to more extended programs. The latter programs tend to focus on teaching practice and the implementation of approaches such as student-centred learning, curriculum development in engineering education and technology enhanced learning and aim to diffuse the findings of research on best practice into the everyday teaching of faculty members.

Workshops, seminars and other short courses, on the other hand, typically aim to support staff in resolving specific issues arising in their teaching, and simultaneously inform them about the most recent research developments in the area. These activities are very much in line with what Boyer [13], in a study for the Carnegie Foundation, described as the scholarship of teaching and learning (SoTL), which he sees as necessarily complementing the scholarships of discovery, application and integration. An example of a centre with a focus on SoTL is the Faculty Academy for the Scholarship of Education at the University of Western Australia, which aims to 'provide a scholarly framework for the development of new curricula and the constructive alignment of curricula with approaches to teaching and assessment' and at the same time 'build capacity in engineering, computing and mathematics education research' [14].

In parallel with the above national developments there has been a notable emergence of organised networks specifically devoted to EER. Examples include the Research in Engineering Education Network (REEN), which is global in scope, and the Working Group on Engineering Education Research ((WG-EER) of the European Society for Engineering Education (SEFI), which aims to create a European community of engineering education researchers in order to contribute with research evidence to the advancement of engineering education [15]. In Europe also, the Nordic Network for Research in Engineering Education focuses on developing EER in the Nordic and Baltic countries, while the Engineering Education Research Special Interest Group (EERSIG) has a similar mission in the UK. These networks have been increasingly involved in the organization of EER conferences and symposia, as is the case of REEN, which organizes the biennial Research in Engineering Education Symposium in various parts of the globe. Likewise, the SEFI working group has been responsible for the EER track introduced at the SEFI Annual Conference in 2009, which has seen increasing participation year by year.

With regard to the dissemination of the results of research, there are a number of journals, like the *Journal of Engineering Education* (*JEE*), the *IEEE Transactions on Education* (*IEEE ToE*) and the *European Journal of Engineering Education* (*EJEE*), which have been in existence in one form or another for 40 years or more, while others are of more recent genesis such as the *International Journal of Engineering Education* (*IJEE*), *Global Journal of Engineering Education* (*GJEE*), *Australasian Journal of Engineering Education*, *Advances in Engineering Education* and the *International Journal of Engineering Pedagogy* (*IJEP*). There are also a number of more discipline-specific journals such as the *Journal of Professional Issues in Engineering Education* (*JPIEE*) focusing on civil engineering, the *International Journal of Mechanical Engineering Education*, the *International Journal of Electrical Engineering Education* and *Chemical Engineering Education* (*CEE*). The majority of the journals are indexed on the international academic databases with *JEE* being the most cited with a five-year impact factor of 2.8 on the *ISI Web of Knowledge Journal Citation Report*, at the time of writing this article. However it does need to be said that this impact factor published by Thomson-Reuters has various limitations as a measuring instrument, not least being the fact that according to the formula used by the company, journals publishing fewer articles annually will tend to have higher impact factors [16].

2.1.2 Portuguese context

Although EER has been supported and funded in the US and Australia for around 20 years, it has only begun to achieve recognition in most other parts of the world more recently (if at all). In Portugal, the FCT (Fundação para a Ciência e Tecnologia) only received thirteen funding submissions for EER projects between the years 2000 and 2010 and funded three of these [17]. Even allowing for considerable differences of scale, this contrasts with the situation in the US during the same decade when there were 1375 projects funded [18]. Likewise there were notable differences in the funds allocated in the two countries as Table 1 illustrates.

Some structural indicators have begun to be visible in Portugal however. The year 2009 saw the founding of the Sociedade Portuguesa para a Educação em Engenharia (SPEE) whose statutory objectives include 'the promotion of engineering education by means of teacher training, diffusion of projects, exchange and cooperation between institutions and individuals and the analysis and resolution of problems within the scope of engineering education'. The society's first international conference CISPEE 2013 took place in late 2013. In 2011, another association with a focus on the PBL (Project and Problem-based Learning) community was founded, the Projetos para a Aprendizagem e Ensino em Engenharia (PAEE), whose objectives centre around investigating, applying, promoting and disseminating methodologies of learning in engineering based on projects, problems and other forms of active learning. It should also be mentioned that the IEEE Education Society—Portugal Section Chapter was created in 2005 for those in the field of electrical engineering and related disciplines.

Table 1. Comparison of EER project funding from 2000 to 2010 in Portugal (FCT funded [17]) and the US (National Science Foundation funded [18])

	Projects funded	**Total funding in Euros**	**Average project funding in Euros**
FCT	3	221,000	€74,000
NSF	1375	€257,000,000 ($321,000,000)	€208,276 ($260,528)

There are no research centres devoted to EER in Portugal. In the area of postgraduate programmes, no masters' or doctoral courses in the specific area of EER have been offered in Portugal to date. Nonetheless, there have been a number of doctoral theses in associated disciplinary areas where the research topic arguably falls within the domain of engineering education research. For example, the University of Minho has awarded two doctoral degrees for research in engineering education [19, 20], and two more are currently underway. Others in progress at other universities have already given rise to EER publications [21–25]. Comparing the evolution of EER in Portugal with that of Ireland, another of the so-called peripheral EU countries, we find similar overall contexts but it is notable that Ireland does have Ph.D. programmes that are established and there is a research centre at DIT focusing on EER [26].

When looking to events organized in Portugal or by Portuguese higher education institutions (HIEs) one can see a progressive increase over the last decade. In addition to the CISPEE 2013 conference, already mentioned, of note are the PAEE international symposia on Project Approaches on Engineering Education organized jointly by the University of Minho, SEFI and ASIBEI (Asociación Iberoamericana de Instituciones de Enseñanza de la Ingeniería), which began in 2009. They have been held in Guimarães (2009), Barcelona (2010), Lisbon (2011), Rio de Janeiro (2012) and Eindhoven (2013). The *ICEE* (*International Conference on Engineering Education*), took place in Coimbra in 2007 under the auspices of the International Network for Engineering Education and Research. The *First World Engineering Education Flash Week*, held in Lisbon in 2011 was an aggregation of events in the area of EER and involved the participation of a number of engineering education organisations including SEFI, ASIBEI, EUGENE, SPEE and IFEES. Also in 2011, the *Engineering Practice Roundtable* took EER community.

An important strand within the structural criteria concerns dissemination activites such as the holding of workshops, seminars and training sessions on aspects of engineering education or topics that are studied in EER. Over the last five years, for example, there have been workshops in Portugal by well-known international EER scholars such as Richard Felder, Susan Zvacek and John Cowan and other events led by specialists from international universities with a strong tradition in EER activity such as

Aalborg, Loughborough and the Dublin Institute of Technology. Likewise, members of the Portuguese EER community have been invited to present the results of their research at leading international HIEs, including the University of Western Australia, Universidad Politecnica de Madrid, Cornell, Purdue and Virginia Tech in the US, Universiti Tunn Hussein Onn and UKM in Malaysia, and the universities of Brasilia, São Paulo, Juiz de Fora and Caxias do Sul in Brazil. Research partnerships have also developed with scholars at the universities of Aalto, (Finland), Aston (UK), Purdue University and the University of Texas at Austin (US), University of Western Australia and University of Technology, Sydney (Australia) and DIT (Ireland), among others.

2.2 Intra-research criteria

2.2.1 Model or seminal research

With regard to model or seminal research from Portuguese EER scholars, the most notable candidate is arguably the model of engineering epistemology proposed by Antonio Dias Figueiredo in a review paper co-authored with Robin Adams and others in the hundredth anniversary issue of JEE [27]. Figueiredo describes the epistemology of engineering as being made up of four dimensions in a trans-disciplinary relationship: the basic sciences, the human sciences, design, and the crafts as shown in Fig. 2.

There have been a range of other EER publications and in the following sections we shall look broadly at EER journal article data and at on-going research in Portuguese higher education institutions.

2.2.2 Research publications

In a meta-study that looked at 885 empirical research articles published from 2005 to 2008 in the area of EER [28], and that aimed to include as broad a cross-section of journals as possible, the findings showed that more than 50% of the articles came from authors in the US and Australia and that the contribution from Portugal (eight papers) was less than 1%. Jesiek [29] also found that the degree of international cooperation between the authors was relatively low—indeed Portugal did not register in any international joint-authored articles. Nonetheless, the publication data that we have compiled from 2000 to 2012 does show some positive signs in this regard.

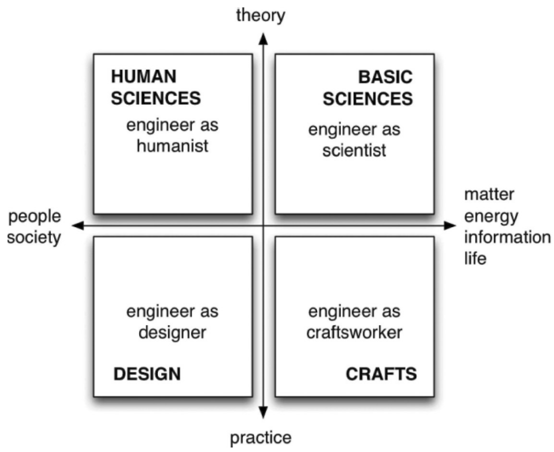

Fig. 2. Figueiredo's model of the epistemology of engineering [27].

Table 2 shows the data compiled by the authors for the number of articles from 2000 to 2012 with one or more author affiliated to a Portuguese HEI that were published in the leading journals in the field: *Journal of Engineering Education*, *European Journal of Engineering Education*, *International Journal of Engineering Education*, *Global Journal of Engineering Education*, *IEEE Transactions on Education*, *Journal of Professional Issues in Engineering Education and Practice* and the newly created *International Journal of Engineering Pedagogy*. The analysis was carried out on articles in the

Table 2. Number of articles with authors with Portuguese affiliation in international EER journals listed in SCOPUS and EBSCO between 2000 and 2012

	JEE	*EJEE*	*IJEE*	*GJEE*	*IEEE TEd*	*JPIEEP*	*IJEP*	**Total**
2000	0	0	0	0	0	0		0
2001	1	1	0	0	0	0		2
2002	0	0	1	0	2	0		3
2003	0	0	1	0	0	0		1
2004	0	5	1	0	1	0		7
2005	0	1	2	0	1	0		4
2006	0	2	2	0	0	0		4
2007	0	4	1	0	0	0		5
2008	0	0	2	0	0	1		3
2009	0	3	0	0	0	0		3
2010	0	0	1	0	0	0		1
2011	1	5	2	0	0	1	5	14
2012	0	3	2	1	1	0	5	12
Total	2	24	15	1	5	2	10	59

1. Learning	2. Assessment	3. Educational technology	4. Design
5. Collaboration	6. Students	7. PBL	8. Competencies
9. Maths and Science	10. Global aspects	11. Curriculum	12. Engineering skills
13. Diversity	14. Active learning	15. Environmental education	16. Teaching
17. Profession	18. Industry	19. Communication	20. Laboratories

Fig. 3. The twenty most common research areas in empirical EER articles according to Jesiek et al. [28].

SCOPUS and EBESCO databases, given that they include all the EER journals in question. The authors note some signs of an overall evolution in published output in recent years, with increased publication in EJEE and IJEP, the former being published by SEFI and the latter by IGIP.

To analyse the topics studied in these publications, we adapted a classification procedure presented in the Jesiek et al. article [28], where they listed the most common research areas encountered in the 885 papers analysed. The twenty most common of areas from that study, shown in Fig. 3 in order of occurrence, were used to categorize the 59 papers in Table 2 by following the category descriptions in that paper (Fig. 4).

In Fig. 3 we note that that the most frequent areas studied were educational technology, which includes IT tools in the classroom and online learning (see for example [29, 30, 31]), maths and science related topics, typically physics and chemistry teaching (see [32, 33]) and general teaching suggestions (see [34]).

Let us now consider this research output from the perspective of the typology presented in a special report in the *Journal of Engineering Education* [36] where it is proposed that the new discipline of Engineering Education could consist of one or more interrelated strands of research within five main research areas:

1. Engineering epistemologies
2. Engineering learning mechanisms
3. Engineering learning systems
4. Engineering diversity and inclusiveness
5. Engineering assessment.

We note that the majority of these papers are associated with an Engineering Learning Systems strand and the other strands were under-represented. This being said, there have been some recent examples of published research that does take a broader view of EER. In addition to the work on the epistemology of engineering by Dias Figueiredo [26] mentioned in Section 2.2.1, there have been significant contributions in the area of engineering practice beginning with a pioneering large scale study of Portuguese engineers, carried out by sociologist Maria de Lurdes Rodrigues in collaboration with the Ordem dos Engenheiros (the Portuguese professional board of engineers) and published as a book *Os Engenheiros em Portugal,* in 1999 [36]. More recently, another book co-edited by Williams and Figueiredo, *Engineering Practice in a Global Context, Understanding the Technical and the Social* [37], included a chapter on the history of

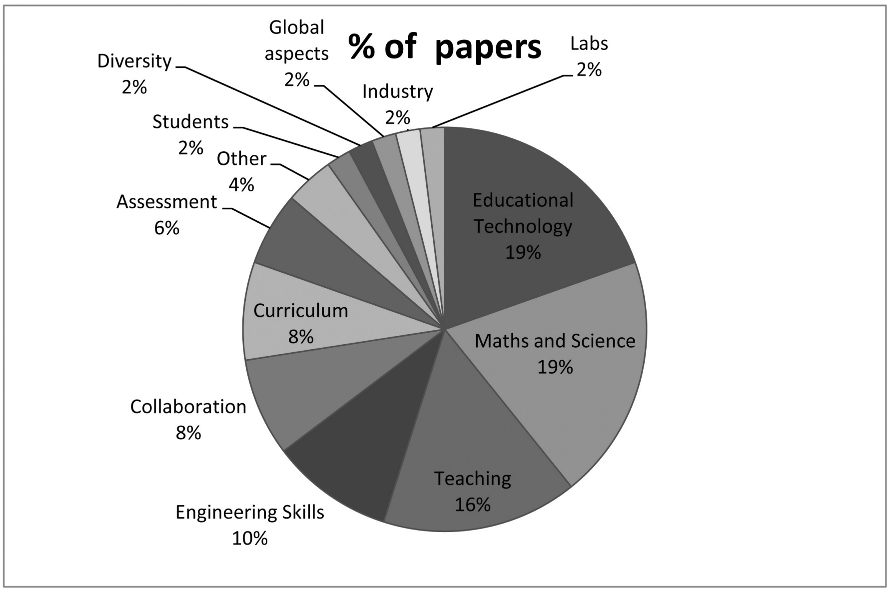

Fig. 4. Classification of research areas of the Portuguese authored journal articles listed in Table 2.

Table 3. Engineering education areas currently being researched in Portuguese higher education institutions

Institution	Research areas
Beja Polytechnic Institute	Course design
FEUP, University of Porto	Virtual Labs, IT tools in the classroom; Faculty peer observation; Serious games (game based learning); Project work ; E-training, Continuous education
ISEL, Lisbon Polytechnic Institute	Concept maps; Active learning
ISEP, Porto Polytechnic Institute	PBL, Remote labs, Game based learning; Learner autonomy
IST, University of Lisbon	Engineering education policy; IT tools in the classroom; Design education
Setubal Polytechnic Institute	Engineering practice and entrepreneurship; Bibliometric analysis; Technology stewardship; Faculty peer observation; IT tools in the classroom; Mobile learning
University of Aveiro	PBL; EER as emerging field
University of Coimbra	Engineering History and Epistemology; Engineering Design; IT tools in the classroom; Academic fraud
University of Minho	PBL, EER as emerging field, Social Responsibility; PBL, Assessment of Learning; Faculty Development; Serious Games; Project Management for student projects

engineering practice by Dias Figueiredo [38] and another chapter on engineering practice in Portugal by Williams and Figueiredo [39]. In addition there has been some research on the history of EER [40] and on its development as a field of study [41, 26].

2.2.3 Current research

To complement the data on journal publications, the authors compiled the topics presented in European engineering education conferences since 2010 (the annual IEEE EDUCON, SEFI and IGIP conferences and the inaugural CISPEE 2013 conference) and combined this with information on journal publications over the same period to provide the data on the main research areas underway in Portuguese universities and polytechnics shown in Table 3.

2.3 Outcome criteria

2.3.1 European context

Although Fensham [12] argues that the findings of research in a field would logically have an impact upon its practice, in the case of engineering education, actually detecting such an impact is not a simple matter. Due to the interdisciplinary nature of the field, other domains associated with higher education, such as the psychology of learning and pedagogy, for example, can also be influential. On the other hand, as the majority of studies carried out in the area can be characterized as scholarly teaching [13] there are some direct links between research and classroom practice. Such studies, in addition to their explicit objectives of dissemination of findings and theory construction, can often have the implicit objective of seeking support from the professional community.

The authors have not encountered any significant broad-ranging study into the diffusion and implementation of EER findings at the national or European level. Moreover, in spite of the large investment made in the US over the last three decades [18], a recent major study into the diffusion of innovative pedagogical approaches [42] found that the adoption of approaches like student-active pedagogies, service learning and design projects in US engineering departments was not as high as might have been expected, and its authors comment that 'despite decades of effort focused on improvement of engineering education, many recent advances have not resulted in systemic change' [42 p. 1]. A possible explanation for this situation in the US (and the authors believe the same may apply in the Portuguese national context) could be found in a study published in 2012 [43] that concludes that the implementation of innovative pedagogical approaches is dependent on a combination of nine factors, with the quality of the innovation being just one of these. The authors of that study recommend that new materials should be designed such that they demonstrate an obvious relative advantage over existing materials, are compatible with and adaptable to existing pedagogy, lack complexity, and are generally easy to use. Management support and availability of resources were found to be important environmental conditions that facilitate acceptance, while logistical issues and cultural differences were the chief impediments.

Nevertheless, despite the apparent inertia revealed in these studies, we do need to bear in mind that the vast majority of research in EER is devoted to the relatively small-scale implementation of pedagogical innovations and their evaluation. It is reasonable to expect that these do have an impact on their immediate teaching and learning setting at least. In the European context, it is important to mention the findings on Project and Problem-based Learning (PBL) in engineering (notably the work at Aalborg University in Denmark), which has clearly encouraged other European HIEs to implement, even if only in part, curriculum models in which PBL plays an important part. In Portugal, the School of Technology and Management at Águeda (University of Aveiro) and the School of Engineering at the University of Minho are examples of such an impact.

2.3.2 Portuguese context

Portuguese researchers have been notably involved in a number of international collaborations in recent years and have participated regularly in a range of initiatives, which have included international conferences, working groups and workshops aiming to further the development of EER at European level. The authors of this paper, for example, have contributed to SEFI-WGREE, NNER, BSIGREE, REEN and to Line B of the EUGENE Academic Network European whose Summit on Research in Engineering Education took place in Leuven, Belgium in 2011 and whose recommendations were submitted to the European Commission in 2012. Other examples of international cooperation include the work of Portuguese scholars as reviewers on journals such as *JEE*, *EJEE*, *IJEE* and *IEEE ToE*.

A further example involves the collaboration of researchers of the University of Western Australia with researchers of IST/University of Lisbon and the Polytechnic Institute of Setúbal on the project 'What Engineers Do', which is funded by the Portuguese FCT and which has involved collection and comparison of data on engineering workplace activity in Portugal and Australia. The study has benefited from the participation of engineers from national firms including PT, EDP, YDreams, STAP, AMAL and COBA, and the international companies Synopsis, Logica, Ford and CB Richard Ellis, as well as various SMEs in the Greater Lisbon area. This research has resulted in the book on engineering practice [38] mentioned earlier, which also includes chapters from researchers in Ireland, the UK, US and Switzerland.

Looking towards the future, it is worth noting that the American Society for Engineering Education (ASEE) decided to add EER to its list of recognised disciplines in 2006 based on the National Academy of Engineering report on the desired profile of the engineer of 2020 [8]. In Australia and the UK there have also been attempts to define the competences of future engineers [45, 7] and there is a growing consensus that engineering education needs transformational rather than incremental change. With this in mind, the authors see a clear need for the Portuguese system of engineering education to develop an approach based on systematic educational research, which is rigorous and displays the level of excellence demanded of traditional engineering disciplines, and the epistemological diversity characteristic of an interdisciplinary field as has been set out in this paper.

3. EER and other fields of study

The potential value of a strong articulation between EER and education science was mentioned earlier in this article and the authors would argue that this is has particular importance in clarifying the epistemology of engineering education, which John Heywood [39] defines as a crucial step in the evolution of EER as a field of research. Nevertheless, both internationally and in Portugal, the participation of education science scholars in EER has been relatively minor. The authors conjecture that one reason for this may arise from a perception that by being linked to engineering the field would be dominated by a post-positivist paradigm, which leaves little space for qualitative critical research. There has however been a notable emergence of broader perspectives and paradigms in the field, in recent years: the work of Baillie [46–48], for example, critically examines issues such as social justice, citizenship, ethics, gender and sustainability. Other examples include Beddoes and Borrego [49], Jonassen and Young [50], Trevelyan [6] and Zandvoort [51]. Nevertheless, these examples represent exceptions in the field as a whole, which is why education science can play an important part in the definition of the research field and broaden the debate to include issues such as these, which have been the subject of critical analysis in other areas of teaching and learning. By way of example, 6 questions posed by Aoki [52, p. 75] will now be included, which would appear particularly relevant to higher education, and especially to engineering education:

- What are the perspectives underlying a given curriculum?
- What vision of instructor and learner are implicit in curriculum planning?
- At root, the curriculum serves whose interests?
- What are the metaphors that guide those who plan, implement and assess the curriculum?
- What basic perspectives or prejudices do authors and publishers hold of course materials?
- What vision of the world is embedded in the curriculum?

Researchers in areas such as pedagogy, educational policy and philosophy have also had little contribution to EER up to now. The authors believe that all these trends should be the object of reflection, in order to allow for the establishment of solid connections between them and the field of EER.

4. Discussion

Assuming that Portugal needs to keep abreast of international developments in this field of inquiry, a national and international cooperation strategy would seem to be essential to achieve the critical mass needed to carry out projects that are more ambitious, better structured and with more impact than has been the case up to now.

Interviews with scholars who became active in EER in national contexts without a tradition in this field [53] suggest that the challenges they faced included the perceived lack of legitimacy of the field and subsequent scarce financial support. At national level, an important first step would be for the relatively small number of scholars who have been working in a somewhat isolated and sporadic fashion, to establish cooperation networks. This would help their projects gain sufficient dimension and recognition to achieve funding and to attract researchers from other areas, such as education science and social sciences, whose participation could be important to achieve a trans-disciplinary approach. Access to funding opportunities would also be beneficial to the evolution of EER at national level. The introduction in 2014 of the Innovative Didactics award program for higher education institutions [48] by the FCT may be positive in this respect [54] but the scale of the project and sums awarded (there is a ceiling of 5000 and, in the first year, seven grants were awarded to engineering and STEM proposals) suggests that the outcomes are likely to be modest.

A recent article by Aditya Johri of Virginia Tech and Barbara Olds of the US National Science Foundation [55] identifies significant potential for EER to build upon the knowledge accumulated by the learning science community and note that leading US universities in this area like Purdue and Virginia Tech already have specialists from such fields as part of the staff in their engineering schools. The authors believe that similar collaboration in Portugal could be beneficial to all concerned.

In the international sphere it is essential to take advantage of the opportunities presented by the embryonic partnerships alluded to in Section 3, so that Portuguese scholars come to participate in larger projects and play their part in international developments in the field. Building international partnerships that can win grant support by contributing to the EU Horizon 2020 initiatives would be an important step in this regard. Otherwise there is a danger of Portugal being left behind as more countries in Asia and Northern Europe join the ranks of the US and Australia in recognising the value of research in this area. Achieving this goal would also involve recognition that not only can EER contribute in terms of globalisation, economic growth and technological progress, but also that it has an important role to play in individual and social transformation [56] and in the sustainability of our environment [47]. Recognising the role of the engineers in society as a *mediator of the material environment* [56] and thus recognising the training of engineers as a process calling for constant research and reflection may contribute to the maturation of the field of EER in Portugal.

5. Limitations of this study

This study based on the available data on engineering education research in Portugal would benefit from being set in context by a comparison with data on the evolution of EER from other EU countries or in the EU as a whole. The fact that we have been able to find relatively little data may indicate that there is much to be done in demonstrating the contribution of such research to meeting the challenges of improving education and economic growth at national and European level. Future work is expected to involve gathering comparative data from other EU countries (see [26] for an initial approach) and from other international contexts (see [57] for an initial approach).

6. Concluding remarks

In this paper the authors present an evidence-based position paper that uses the Fensham Framework to show the extent of the emergence of EER as a field of inquiry in Portugal. The data presented demonstrates that there have been significant signs of a positive evolution over the past fifteen years. Nevertheless there is as yet little structural support and the financial support received for such research has been modest.

We show that the majority of published journal articles have been related to Engineering Learning Systems but there are signs of increasing attention being given to broader meta-aspects of engineering educational such as engineering practice and the epistemology of engineering (Section 2.2.2). With the continuing evolution of EER in Portugal it is to be hoped that critical mass can be achieved to produce research in all five of the critical areas set out in that section. This is likely to require a more active collaboration at individual and institutional levels between engineering educators and researchers and those in social and education sciences (Sections 3 and 4).

We mention the challenges such as a perceived lack of legitimacy of the field and limited funding opportunities and we propose that management support could play a valuable role in future evolution (Sections 2.31 and 4). We identify two important strategic goals for Portuguese EER scholars: research partnerships with international engineering education researchers and closer collaboration with researchers in learning science (Sections 3 and 4). We believe that the continuing evolution of EER in Portugal can play a valuable part in the diffusion and implementation of proven good practice at national level and also allow Portuguese scholars to make a valuable contribution to the development of the field internationally.

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Natascha van Hattum-Janssen holds a Ph.D. in Education and worked in Engineering Education and Project-Based Learning at the University of Minho in Portugal for almost 18 years. She now teaches at the Textile Engineering and Management course at Saxion University of Applied Sciences in Enschede, the Netherlands.

Bill Williams originally trained as a chemist at the National University of Ireland and went on to work in education in Ireland, the UK, Eritrea, Kenya, Mozambique and Portugal. He lectures on technical communication at the Instituto Politécnico de Setúbal and at the Instituto Superior Técnico, Universidade de Lisboa.

José Manuel Nunes de Oliveira is Adjunct Professor of Electrical Engineering (Electronics) at the Higher Education Polytechnic School of Águeda (ESTGA), University of Aveiro, Portugal. He has been deeply involved with the coordination of the move towards Project-Based Learning at his institution, and his research interests focus on Engineering Education, conceptual understanding in Electronics and Problem/Project-Based Learning. He is also a collaborator at the CIDTFF research unit (Research Center for Didactics and Technology in the Training of Teachers), at the University of Aveiro.