A History of Engineering Education Research in Portugal and Ireland

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The Emergence of Engineering Education Research in Portugal and Ireland

Abstract
The American Society for Engineering Education is the oldest professional society in the world that is solely dedicated to the betterment of engineering education. In its early days, ASEE was a gathering of faculty who wanted to improve the practice of engineering education through experimentation with new curricula, new teaching styles, or new gadgets. Presentations often consisted of "this is what I did" and "this is how the students reacted." Beginning in the 1990s, through the influx of federal dollars in the Coalitions, a new discipline began to emerge—Engineering Education—and along with this discipline a research area was born. At this point in time, the concept of rigorous Engineering Education Research (EER) is fairly well-established in the US, with dedicated programs for EER at the National Science Foundation, PhD degree programs in EER, and the reinvention of the Journal of Engineering Education to support this endeavour. Departments dedicated at least in part to Engineering Education Research are emerging on campuses across the country. There has also been an emergence of Engineering Education Research across the globe; however, efforts in other countries have often been slower due to many factors. This paper describes the emergenceof Engineering Education Research in two countries in the European Union—Portugal and Ireland. The evolution of EER in these two countries is set in a larger global context.

Background

According to Fensham[1], who defined the field of science education research, there are 12 criteria that should serve as the hallmarks of any education research field. These criteria are grouped into three major categories as outlined in Table 1.

Table 1. Fensham's (2004) Criteria for Defining the Field of Science Education Research Category

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
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 recognized 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

It has been demonstrated[2] that the field of Engineering Education Research (EER) in the US has met or has nearly met all of these criteria and therefore should be recognized as a field of study that is distinct from science education and distinct from the various disciplines in engineering. In fact, the ASEE added EER to its list of recognized fields in 2006 based on the NAE Engineer of 2020 report[3].

One category that Fensham[1] did not include in his criteria for "structural" hallmarks of a discipline, is that of availability of external funds for conducting high-quality, rigorous research. The authors of this paper believe that this is an important aspect in the establishment of the field and should have been included in Fensham[1]'s characterization because without adequate funding, high quality, rigorous research is unlikely to happen. In the U.S., the National Science Foundation (NSF) began funding STEM education-related projects beginning in the late 1980s-early 1990s. The current budget for the Education and Human Resources directorate in the NSF is nearly $1B per year (for all of STEM, not just engineering) and there are other funds available for EER within the NSF that are not included in this overall amount.

One could argue, that EER in the U.S. emerged primarily because there was a steady funding stream available to support people who wanted to do EER work, and in fact, the massive amount of money poured into the engineering education coalitions in the 1990s was probably the single most significant impetus to the establishment of EER within the U.S. This steady funding stream also contributed to the ability of EER faculty to be promoted for their educational research and to their recognition among their peers as true scholars.

Current Study

Arguably, the U.S. along with Australia have been international leaders in the development of EER as a recognized, distinct discipline. In the rest of the world, there are "pockets" of activity; however, in most countries EER has not yet emerged as a distinct discipline. The remainder of this paper will describe the status of EER, based on Fensham[1]'s criteria, in two countries within the European Union—Portugal and Ireland.

Structural

In 2007, The International Conference for Engineering Education was held in Coimbra, Portugal and was attended by engineering education researchers from around the world.

Portugal established a national society for engineering education (SPEE) in 2009 and this society recently hosted its first international conference in October 2013. At about the same time, an Irish society for engineering education was also developed; however, it is no longer active and has not been sustained. However, the European society for engineering education (SEFI), which recently celebrated its 40th anniversary, has participating members from Ireland and Portugal. In 2007, 2008 and 2010, Ireland hosted The International Symposium for Engineering Education conferences which attracted over 100 participants on each occasion primarily from the EU[4-7].This conference was held in the University of Sheffield in the UK in 2012 and is scheduled in the University of Manchester in September 2014, with Irish and UK participation remaining strong.

In 2003 the Irish University Quality Board (IUQB) Inaugural Conference was held in University College Cork. The development of engineering educational resources within Ireland was presented at this conference[8]. In 2007, the keynote presentation at the International Manufacturing Conference, held in Waterford was on the development of educational resources and the founding of the Engineering Community of Practice within Ireland in the same year[9]. The Engineering Community of Practice, emanated from the National Digital Learning Repository initiative. This Community presented funding through the Higher Education Authority in Ireland for the first time to aid broad collaboration amongst academics for the joint development, effectiveness assessment, collation, and sharing of educational resources. Over 500 digital learning resources and some on-going collaborative networks were established from this initiative [http://www.ndlr.ie/].

Although there are no specific Irish or Portuguese journals for publication of EER results, there are several other journals available to researchers in both countries, including ASEE's Journal of Engineering Education, SEFI's European Journal of Engineering Education, AAEE's Australasian Journal of Engineering Education, and several others. It is unlikely that countries the size of Ireland or Portugal could support separate journals for EER at this point in time.

The one structural area where both Ireland and Portugal are currently lacking is in the area of faculty appointments in EER. Although faculty appointments in EER are emerging within dedicated EER departments and within disciplinary departments in the U.S., there are currently no EER-specific faculty in either Portugal or Ireland at this time.

In addition to the lack of faculty appointments in EER within both Ireland and Portugal, there is a dearth of external funding opportunities available to faculty who wish to do EER work. Between 2000 and 2010, the FCT in Portugal (equivalent of the NSF) received 13 submissions for EER projects and funded three of those for a total of ~$300K. [By contrast, over the same time period, NSF funded 1375 projects in EER for a total of ~$300M[10].] In Ireland national funding for EER over the past decade has been limited to a few small-scale (typically in the region of $15,000) individual "teaching" projects. These small projects have primarily been in the form of curriculum development through pedagogical changes, adaptation of methodologies developed elsewhere, and a small number of more rigorous EER projects. The funding agency, Science Foundation Ireland, has begun to fund a limited number of projects for outreach, but these projects require a 50% cost-share, unlike the research projects funded by the Irish foundation.

The European Union has begun to fund EER projects, but this has only been a recent development and competition is high. In Ireland only about $120K in EU funding has been

obtained over the past few years; however, Dublin Institute of Technology was awarded a $330K grant in December of 2013 for an EU Marie Curie project in EER. It appears that the Horizon 2020 program in the EU will increase opportunities for EER funding in the future.

Research

In terms of Fensham[1]'s Research category, it is assumed that faculty who are graduating PhD students and who are publishing in peer-reviewed journals are satisfying the criteria in that category. Namely, they are drawing on their scientific knowledge, asking appropriate research questions, founding their research on a theoretical framework, conducting the research using the correct methodologies, building on the work of prior research and writing model or seminal publications. Therefore, for this part of the analysis, we will examine these factors in the context of the research category.

In the U.S. there are currently several departments or centers across the nation that have faculty devoted to EER, notably at University of Washington, Purdue, Virginia Tech, Pitt, Utah State, Clemson and others and there are several PhD programs in EER available. The establishment of these academic units devoted specifically to EER has served to elevate the discipline and to help it gain national recognition as an accepted field of study. In addition, there are 100s of engineering faculty across the U.S. who are engaged in rigorous EER work within their disciplinary homes. Most U.S. faculty engaged in EER have developed numerous collaborative relationships through the years with people at other institutions. Again, the coalitions, through their requirement for the involvement of multiple institutions, likely were a strong factor in the development of a community of scholars for EER in the U.S.

In both Portugal and Ireland, there are faculty dedicated to EER; however, they are largely scattered across their respective countries. Each institution of higher learning seems to have 1-2 EER researchers, many of whom do research in technical areas as well. However, there is an emergence of EER networks within institutions within these countries in recent times. For example, Portuguese researchers have been involved in a number of international collaborations in recent years and have participated regularly in a range of activities including international conferences, working groups and workshops aimed at furthering the development of EER at the European level. As further evidence of international collaboration, researchers at the IST/University of Lisbon and the Polytechnic Institute of Setubal in Portugal have teamed with researchers at the University of Western Australia funded by the Portuguese FCT to study engineers in the workplace.

In Ireland, Dr. Kevin Kelly of Trinity College Dublin collaborated on a European-wide project that looked at engineering recruitment, retention, and progression. In the fall of 2013, Dublin Institute of Technology established a research group specifically aimed at promoting EER across the college of Engineering and the Built Environment; leaders plan to convert this research group into an established center on campus in the near future. Several Irish faculty have also developed strong collaborations across the European Union for conducting EER work; however, there have been few instances of national collaboration to date. A very active research group in Ireland is found at the University of Limerick; however, this group is focused primarily on technology education and has been involved only tangentially in EER.

Both countries have graduated a handful of people with PhDs that have focused on EER; however, there are no specific programs in either country dedicated to producing graduates in this area. PhD graduates in both countries to date have been awarded through the disciplinary

departments. Discussions have been initiated at Dublin Institute of Technology to offer post-graduate degrees in EER; however, no firm plans have been established to date.

In a bibliometric study that looked at more than 800 empirical research articles published from 2005-2008 in the area of EER[11], Jesiek et al found that more than 50% of the articles came from authors in the U.S. and Australia and less than 1% came from Portugal. Unfortunately, in the Jesiek study, Ireland and the UK, although two different countries, were collapsed into one category, so it is impossible to gauge the impact of Ireland alone in this measure. The researchers also found that the degree of international cooperation between authors was low and in fact Portugal did not register in any international joint-authored articles during that time period. However, in looking across the leading journals in the field of EER, between 2000-2012, there were 59 total papers that included a Portuguese author with nearly half of these (26) published in the last two years. Thus, it appears that EER journal publications are increasing at a rapid pace in Portugal at this time.

Outcomes

Fensham[1] argues that the findings from the research should have an impact on its practice; however, in the case of EER, this data is particularly difficult to detect. Borrego et al[12]found that despite the large investment made by the U.S. over the past three decades that the adoption in U.S. engineering departments of approaches like student-centered pedagogies, service learning, and design projects was not as high as might have been expected and made the comment that "despite decades of effort focused on improvement of engineering education, many recent advances have not resulted in systemic change." One problem in the U.S. is the fragmented nature of higher education; another problem is likely the faculty reward system in place on many campuses. Hazen et al[13] concluded 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.

Although it is not entirely clear what the extent of the outcomes of the research into practice is occurring in both Portugal and Ireland at this time, there is some evidence that this is taking place. In Ireland, for example, the Higher Education Authority, provided small Teaching Fellowship grants to incentivize faculty to adopt modern pedagogies and to develop new curricula. Although these were open to faculty from any discipline, several were awarded to faculty who were teaching engineering courses or students across a variety of institutions in the country. In addition, Dublin Institute of Technology has continued this program after HEA funding ended and awards several each year to faculty in engineering.

In Portugal, one could argue that the increase in the number of faculty who are publishing results in either journals or conference proceedings is an indicator that research results are making their way into the classroom. The vast majority of EER research in Portugal to date has been in the conduct of relatively small-scale implementations of pedagogical innovations and their evaluation. Of the 59 EER journal publications attributed to Portuguese authors, nearly 20% (10) were in the International Journal of Engineering Pedagogy, a sure sign that new pedagogies are making their way into engineering education practice.

Conclusions

While EER has been firmly established as a viable, albeit small, discipline in the U.S., it has not reached the same level of prominence in other parts of the world. Differences in funding models may be a significant factor in these differences. Further, since engineering relies

heavily on the cultural context of the country in which it is practiced, it is likely also that engineering educational practices are culture-specific. There is however an international need for rigorous EER if we are to produce the best educational environment for engineers and to produce engineers who are capable of solving the significant global challenges of the future. Through application of Fensham[1]'s framework for defining a discipline, it appears that EER is well-underway in both Portugal and Ireland. Through this analysis we can also see where future efforts should be focused in order to move the field forward in these countries.

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