

# Training needs for a PhD programme in Engineering Education

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**Abstract**— The field of Engineering Education (EngEd) is a relatively new discipline that is attracting a growing interest all around the world. Despite this interest in research in EngEd, there are still only a few PhD programmes in the area, the oldest being that established in 2004 at Purdue University. Although some research groups exist in Europe, to our knowledge there are only three PhD programmes: those in Aalborg, Chalmers and Uppsala.

The Universitat Politècnica de Catalunya – Barcelona Tech is a technical University providing degrees only in engineering, sciences and architecture. We have a strong commitment to high-quality education and face the same problems as other technical universities, such as the need to increase student attraction and retention, the development of an engineering identity and the acquisition of the professional competencies required in a global world. While we have been developing research in all those subjects, our next goal is to create a new PhD programme in Engineering, Science and Technology Education, with the first cohort due to begin in September, 2020.

The structure of an EngEd PhD programme consists of a unique combination of engineering and education requirements. In order to design our program, we analysed the training courses offered by five programs (at Aalborg, Chalmers, Purdue, Uppsala, and Virginia Tech). This paper presents what we have learnt about the courses and learning objectives of those programmes.

**Keywords**— *Engineering Education, PhD Programs, Engineering Education Research*

## I. INTRODUCTION

The field of Engineering Education (EngEd) is a relatively new discipline that is attracting a growing interest all around the world. Maura Borrego [1] studied the conceptual difficulties for faculty to become EngEd researchers. Since then, some studies have shown the evolution and maturity of the discipline [2], despite the fact that there is a certain lack of definition about what constitutes quality research [3], how to become an EngEd researcher [4] or how to develop EngEd as an internationally connected field of inquiry [5][6]. Most researchers in EngEd have evolved from their own engineering fields of knowledge, with no EngEd communities in their universities, but in recent years EngEd departments and PhD programmes have emerged alongside the growing maturity of the field, so a new generation of EngEd researchers with both educational and engineering backgrounds is on the horizon.

According to the Engineering Education Wiki<sup>1</sup>, there are fewer than 40 PhD programmes in EngEd around the world, the oldest being that provided by Purdue University, which began in 2004. Benson et al [7] compared four of the first Programmes (those of Purdue University, Virginia Tech, Utah State University and Clemson University) highlighting common trends. Since then, more programmes have been created [8], most of them in the US.

In order to find the current EngEd PhD programmes in Europe, we consulted the Engineering Education Wiki, where we found only three European Universities which offer PhD programs in Engineering Education: Aalborg University (Denmark), Chalmers University of Technology (Sweden), and Uppsala University (Sweden). Other universities have research groups in

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<sup>1</sup> A resource created by the ASEE's Student Division and the Center for Engineering Learning and Teaching.  
<http://engineeringeducationlist.pbworks.com/w/page/27578912/Engineering%20Education%20Community%20Resource>

EngEd, such as the KTH Royal Institute of Technology<sup>2</sup> and Linköping University<sup>3</sup>, but according to their websites they have no explicit PhD programme in EngEd<sup>4</sup>.

## II. CURRENT SITUATION IN OUR ENVIRONMENT

### A. Enrolling in a PhD programme in Spain

Spain adapted its higher education programmes to the European Higher Education Area (EHEA) during the first decade of this century. Two types of master degrees have arisen: *Professional* and *Research* ones. While the second type puts a stress on research methodologies and provides students with the capacity to conduct accurate research as a learning outcome, the first type did not include this outcome. On the other hand, however, PhD programmes can accept students from both types of master degrees. To guarantee that students possess the appropriate background, every PhD programme may request students to enrol in some master degree subjects at their universities before enrolling in the PhD programme. There are no mandatory courses in the PhD programme, but every university has a Doctorate School which offer courses on research methodologies, statistics, how to develop a state-of-the-art study, etcetera. The programme admission committee can recommend students to enrol in some of these courses, depending on their background.

Every PhD programme must pass an audit conducted by the quality agency of our country and which is held every four years. One of the conditions of this audit is that every thesis must be aligned with the research lines of the programme.

In such an environment, in which no programmes in Engineering Education currently exist in our country, students who wish to do a PhD Thesis in Engineering Education must ask themselves the following question: Are their theses about education or about engineering? Should they wish to join a programme in education, they are required to hold a master in education, psychology or related studies. Furthermore, these programmes are usually focused on education without any particular specialization, and the only programmes which focus on engineering and sciences education are limited to K12 studies, without the inclusion of higher education studies. On the other hand, engineering programmes usually include only technical research lines, without the mutual inclusion of education, mainly because Engineering Education is a transversal issue that is not related with any particular programme but to all of them across the board. Thus, PhD proposals are usually rejected because they do not conform to their lines of research and the programmes are fearful of failing to pass the national audit.

### B. Engineering Education situation in Spain

In Spain most of the universities are public, so lecturers are public servants and their salary is regulated by the government. Salaries depend on category, seniority and the quality evaluations obtained. Every lecturer undergoes two quality processes, one at a national level and the other conducted by his/her university. For many years, the university has prioritized the scientific training of professors and research capacity over the ability to train good professionals. The reason for this inertia derives from the century-old primacy of research and the publication of scholarly work over teaching, despite research showing that there is no association between excellence as a researcher and excellence as a teacher [9]. Thus, in our country lecturers find that only published papers and grants obtained are taken into account for recruitment and promotion.

Despite this situation, a study developed by Lima and Mesquita [10] shows that in our country there is a high number of lecturers involved in engineering education research. The authors studied the number of papers published in EngEd in European countries between 1970 and 2017 and Spain is in second position on this list.

### C. Our University situation

The Universitat Politècnica de Catalunya – Barcelona Tech (UPC) only offers degrees in engineering, sciences and architecture. We have neither schools nor departments of psychology or education, nor a tradition of social science methods among our faculty. In our environment, as in the rest of the country, recruitment and promotion are based on research. Nevertheless, our University is the 4th Higher Education Institution in number of papers published in EngEd, according to the previously mentioned study by Lima and Mesquita.

There is a unit at our University called the Institute of Education Sciences, the mission of which is three-fold: 1) To provide tools and training in educational methods for new and senior lecturers at our university; 2) To provide training and advice on

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<sup>2</sup> KTH has two EngEd research groups related with this work: Engineering Education in Society (<https://www.kth.se/en/larande/forskningsomraden/ingenjorsutbildning-1.805896>) and Learning in Technology and Science Education (<https://www.kth.se/en/larande/forskningsomraden/tn-didaktik-1.805899>)

<sup>3</sup> Engineering Education Research Group <http://www.didaktik.itn.liu.se>

<sup>4</sup> KTH Doctoral programmes: <https://www.kth.se/student/kurser/dr?l=en>. Linköping University PhD programmes at the Faculty of Science and Engineering: <https://liu.se/en/article/forskarutbildning-vid-tekniska-fakulteten>

STEM issues to K-12 teachers, as well as stimulating STEM vocation among young people; and 3) To promote Engineering Education Innovation and Research among our academic staff. The authors of this paper belong to this Institute.

Five years ago, we started a project to promote EngEd research among our lecturers. The first step was to create a lecturer training programme [11]. This programme stresses the idea that good teaching requires innovation, and this innovation must be based on EngEd research. Innovative activities must be linked with education theories and a scientific analysis of the results (mainly learning outcomes), which go beyond merely anecdotic reports based mainly on grades or student satisfaction.

In order to help our lecturers to develop good EngEd innovation and research, we found that it is necessary to build a type of “ecosystem” in which our lecturers could publish papers, apply for grants and conduct a high-quality research activity. We initially created the Barcelona Science and Engineering Research group (BCN-SEER) the first EngEd Research group recognized by the quality agency of our country. The idea of creating a PhD programme in EngEd (the first in our country) then naturally arose, despite the fact that many engineering schools (all around the world) opposed the idea of such programmes. We got in touch with EngEd researchers at conferences such as SEFI and FIE and asked them about their own experience, and in May 2018 we paid a visit to the universities of VirginiaTech, Purdue and the MIT to talk with the people in charge of EngEd research<sup>5</sup>. Also, in 2019 we got in touch with the groups at Uppsala University and KTH. With the experience thus gained, we draw up a proposal for a PhD programme in *Engineering, Science and Technology Education*, which was submitted to our University for approval. The programme was accepted in December 2018 and is now undergoing the process of evaluation by our National Quality Agency, with the first cohort due to begin in September, 2020.

In the light of the advice received from our colleagues, one of the most important factors in a PhD programme such as this are the training courses, which define the expected learning outcomes. The structure of an EngEd PhD programme consists of a unique combination of engineering and educational requirements and, as pointed out above, although our University has little experience in education it does have expertise in engineering research methodologies and in social sciences research methods. In order to design our program, we analysed the programmes of the two US Universities we visited (Virginia Tech and Purdue) and the three programmes that, to our knowledge, currently exist in Europe (those at Aalborg, Chalmers and Uppsala).

### III. TRAINING COURSES OF THE STUDIED PROGRAMMES

The information given here is based on the papers by Benson et al [7] and Murzi, Shekhar and McNair [12]; on the information collected during our visit to Virginia Tech and Purdue; and on the websites of the five programmes. This study has the limitation that no confirmation is available about the validity of some information (especially from those European Universities where information exists in English, but some information is available only in their own languages, about which the authors cannot speak). Nevertheless, this work is not conceived as a research paper comparing these five programmes, but rather as a search for common ideas on learning outcomes and courses to guide the design of our own programme.

#### A. Aalborg University

Programme: PhD in PBL in Engineering Education.

This programme is oriented towards Problem and Project Based Learning (PBL), because since Aalborg University was first established in 1974, all university degrees have been based on PBL. The PhD training consists of two main elements: working on a research project supervised by one or two members of the academic staff, and following a number of PhD courses according to the Doctoral Programme with the aim of acquiring the necessary competences (up to 30 ECTS). Different courses exist, but those most closely related with EngEd are as follows: *PBL in Engineering and Sciences – Development of Supervisor Skills; History of Engineering Education; Curriculum Models and Learning Theories*, and *Educational innovation – Theories and Strategies of Change*. In addition, the following courses concern Research Methodologies: *Mixed Methods and Research Design; Design-Based Research; Construction of Questionnaires and Interviewing Guides*, and *Quantitative Methods*. Finally, there are two general courses: *Writing and Reviewing Research Papers*, and *Professional Communication*, some of which are offered as online courses. The time expected for the completion of the PhD by full-time student is three years.

#### B. Chalmers University of Technology

Programme: PhD in Engineering Education Research

The PhD programme comprises 240 ECTS, which correspond to 4 years of full-time study. The programme includes compulsory courses; optional courses based on the needs of the research project; participation in seminars and guest lectures,

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<sup>5</sup> Purdue and Virginia Tech have the two oldest PhD programmes in EngEd. The MIT has no an EngEd PhD programme, but we visited people from the NEET – New Engineering Education Transformation – programme (<https://neet.mit.edu>)

and research work leading to a scientific dissertation. The mandatory courses include: *Theory of Science* (7.5 ECTS); *Engineering Education Research* (7.5 ECTS) and up to 15 ECTS of the so-called Generic and Transferable Skills, including five mandatory courses (*General Introduction for Doctoral Students*; *Career Planning - your personal leadership*; *Teaching, Learning and Evaluation*; *Sustainable Development: Values, Technology in Society, and the Researcher*; and *Popular Science Presentation*). The doctoral examiner and the main supervisor draw up a course pack that is individually designed; these courses could be from Chalmers or from other universities such as the University of Gothenburg. Examples of these optional courses are: *Theoretical Perspectives on Engineering Education* (7.5 ECTS) and *Methodological Aspects of Engineering Education Research* (7.5 ECTS).

#### C. Purdue University

Programme: PhD in Engineering Education

Students typically graduate in 4-6 years. There are 32 credits courses in research preparation and 9 credits in the area of specialization. Research preparation courses are divided into: 1) EngEd foundation courses (oriented to integrating engineering and education concepts), 2) Secondary Engineering Expertise (oriented to providing depth of understanding of engineering concepts, consisting of a coherent sequence of graduate courses in an engineering field other than engineering education), and 3) Research Preparation (approaches to EngEd research and guidance on developing methods). The mandatory courses of EngEd foundations are: *Foundations of Engineering Education*; *History and Philosophy of Engineering Education*; *Content, Assessment and Pedagogy*; *Research Seminar in Engineering Education*; *Theories of Development and Engineering Thinking*; and *Leadership, Policy and Change in STEM Education*. The research preparation courses are: *Engineering Education Inquiry*; *Social Science Statistical Methods*; and an elective course from the College of Education.

#### D. Uppsala University

Programme: PhD in Computer Science with specialization in Computer Science Education Research

As may be deduced from the name of the programme, it is focused on Computer Sciences, so acquiring a pass in the CS examination is recommended. There are five specializations in the CS PhD programme, CS education research being one of them. The PhD includes courses corresponding to 60-90 out of 240 higher education credits (four years for full-time students). Students enrolled in this programme follow three mandatory courses for the Graduate School in Subject Didactics. Each doctoral student and his/her supervisor draw up an individual study plan that must be approved by the head of department. Courses may be of different kinds, such as lectures, literature studies, practical exercises, field studies, etc.

#### E. Virginia Tech

Programme: PhD in Engineering Education

The length of the programme is not defined, but is based on the student's progress, with the expectation that the dissertation defence should take place between semesters 6 and 10. The courses includes some core courses (*Foundations of Engineering Education*; *Assessment Techniques in Engineering Education*; *Engineering Education Research Methods*; and a Practicum) plus 15 credits in an Engineering Concentration course (in an engineering field other than education) and 9 credits in courses from the School of Education. In addition, students must enrol in Engineering Communication and Research Preparation (which include Statistical Methods and Research Methods). Nevertheless, there is a high degree of flexibility.

### IV. DISCUSSION

The five programmes are consistent in terms of the training needs they seek to cover.

All the programmes are congruent in terms of the importance of Foundations of Engineering Education, with courses devoted to those foundations that include relevant theoretical frameworks, assessment and evaluation techniques, future trends, etc. Furthermore, emphasis is also placed on the ability to conduct effective and rigorous research in the field of EngEd. In particular, all of them stress the importance of EngEd research methods, such as statistics, mixed methods, qualitative and qualitative research, construction of questionnaires, and so on. The number of credits required in well-articulated courses varies considerably, with the minimum number of credits in courses ranging between 30 and 60.

Purdue and Virginia Tech provide a secondary engineering expertise with courses in an engineering field other than EngEd. These courses may not be necessary in other programmes such as that provided by Uppsala, where an examination in Computer Science is recommended before joining the programme.

All programmes include courses on generic skills, such as writing and reviewing research papers, the history and philosophy of EngEd or values in society and research. All of them have links with their respective Education Schools (or other universities, as in the Chalmers' programme), it being mandatory to take courses from the Education School in Purdue and Virginia Tech.

Another common trend is flexibility: programmes offer a tailored organization for each student, according to his/her own interests, a high number of elective courses being available. All of them include seminars that count towards training credits. Moreover, Virginia Tech includes a Practicum among the core courses.

#### V. CONCLUSIONS: WHAT MUST WE DO?

The programmes under study differ slightly: Chalmers, Purdue and Virginia Tech are oriented towards engineering education, while Aalborg is oriented towards PBL (in EngEd) and Uppsala towards Computer Sciences. Our programme is more general in the sense that it includes Engineering but also Science and Technology Education.

It seems clear that the training provision of a PhD in EngEd must include some core courses related to foundations of the field as well as courses in research methodologies. Our Doctorate School offers courses in statistics, quantitative methods, and generic issues such as reading and writing research papers, although there are no courses on foundations of engineering and science education. Since we have a postgraduate programme in education innovation oriented to our academic staff [11], we will use these courses for the training of our future students in education foundations. Unfortunately, this postgraduate programme is more focused on learning the basics of EngEd and the application of innovative methodologies than on basic research, so we are currently designing a course on social sciences research methods, including methods not commonly found in engineering research such as phenomenology, grounded theory, ethnography, and mixed methods, or tools such as the design and validation of interviews, questionnaires or focus groups.

In our programme, students are expected to hold a degree or a master in engineering or in sciences, so it does not seem necessary to set up secondary engineering concentration courses such as those that exist at Purdue and Virginia Tech.

We have no school of Education, so we are unable to recommend that our students enrol in some of those courses. Nevertheless, our university has a Master Degree course in Education for Secondary School and Vet Studies. In our country, it is mandatory to hold this degree to be hired as a secondary or Vet teacher. Some courses of this Master can be recommended to our PhD students as elective courses.

According to our philosophy, it is mandatory to run a research seminar, and we like the Virginia Tech idea of holding a practicum, which would be mandatory for those students who have no previous teaching experience.

Finally, we agree with the studies programmes about the idea of flexibility, adapting the training pack to each student according to his/her background and research and career interests.

So, our final programme will consist of three general courses (available for all PhD students): Ethics for researchers (2 ECTS), Information resources and services (2 ECTS), Experiment design and analysis (3 ECTS). Also, five activities specifically designed for our PhD students: Educational learning theories (7 ECTS), Introduction to research and innovation in education (8 ECTS), Advanced research methods and methodologies in education (2.5 ECTS), Specific workshops in EngEd – these workshops can change from one year to the following, depending on visiting professors (1.5 ECTS) and Planning your personal research (4 ECTS). The basic bibliography chose is [13, 14, 15, 16, 17].

#### VI. SUMMARY

Creating a new PhD programme in a subject like EngEd is not an easy task. Several challenges arise, one of which is the design of the training courses. The analysis of other programmes has helped us to identify the principle lines of such courses, but deeper research into the training courses and their impact on the learning outcomes of the doctorates is necessary to assist in the emergence of new programmes in the future.

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