Collaborative PhD Tracks: Working Together for Sustainability

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ABSTRACT

This paper elaborates on a form of university–industry cooperation called 'collaborative PhDs'. Engineers working at companies or governmental organisations get the opportunity to do a PhD at the university. The aim of these science-based collaborations between academia and industry is to increase the impact of research on sustainable development. However, to fulfil this promise, how should doctoral engineering education for collaborative PhD tracks look like? A literature search, a benchmark on successful doctoral education programmes, in-depth interviews with 10 PhD candidates and their supervisors, as well as observations of meetings, revealed the requirements for a track that is consistent with the relationship and everyone's interest in it, as well as the needs and talents of the PhD candidate. The conclusion of the research is that collaborative PhD candidates come to the university to conduct research, but do not intuitively fit into the academic world. Some feel squeezed between their jobs as, for instance, project managers on the one hand and doctoral candidates at the university on the other hand. This research led to 10 recommendations for setting up a track within the graduate school.

Conference Key Areas: Continuing Engineering Education and Lifelong Learning / University-Business cooperation

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INTRODUCTION

Many institutes for higher education maintain good contacts with business and governmental organisations. It is from these contacts that professors regularly recruit talented candidates for PhD projects. These PhD candidates remain stationed elsewhere and their companies granted them part-time leave to follow a PhD programme. The added value of this PhD research can be significant. Knowledge and insights developed by PhD candidates can be applied in practice immediately – which is in line with the 'Europe 2020' goals and the need to speed up the process of sustainable development.

The Deltas Infrastructures & Mobility Initiative (DIMI) and Delft Energy Initiative (DEI) at Delft University of Technology (TU Delft) have launched a pilot for this group of PhD candidates who are employed not by the university, but by companies or governmental organisations interested in the same research themes. They are called ‘contract PhDs’ and their trajectories ‘collaborative PhD tracks’. These PhD candidates defend their dissertations at TU Delft. Their theses must meet the same requirements as the fulltime employed PhD candidates at TU Delft.

The goal of these collaborative PhD tracks is to jointly develop knowledge that is useful for transforming practice and at a sufficient level for a PhD defence. These PhD tracks strengthen the cooperation between the university and industry and this interaction increases the potential for innovation. Especially for research with a link with practice, these PhDs have an advantage over regular PhDs in understanding the context and having access to practical data. However, what sounds appealing in theory is not so easy in practice. Not only is the time available for research a problem for externally based candidates, but they spend a relatively large amount of time learning to do research (searching for literature, formulating research questions, selecting research methods, etc.). It is sometimes years since they last attended university, which means that they possess a great deal of practical experience but need to be trained as scientific researchers. Furthermore, former research shows that implementing innovations generated by PhD projects is not a matter of course. Moreover, the competences needed for a future career in industry and the competences needed in a PhD project do not always correspond [1]. An important condition to fulfil the promise of sustainable development is that these collaborative PhD trajectories run smoothly. The research question therefore is: *What does doctoral engineering education for collaborative PhDs look like?*

We will discuss doctoral education from the broader perspective of the knowledge triangle, the interplay between research, education and innovation (chapter 1). In chapter 2, the interests of all parties involved will be discussed. In the third chapter a need analysis will be described. A series of interviews were held with supervisors, PhD candidates and companies in order to identify the specific needs of each party and be able to co-design a tailor-made track within the graduate school. In chapter 4, the outline of the track will be revealed. Finally, the conclusion describes in 10 recommendations how these pathways can be made more efficient and more effective.

1 COLLABORATIVE PHD TRACKS IN THE PERSPECTIVE OF THE KNOWLEDGE TRIANGLE

Joint PhD projects are a promising form of research collaboration, connecting universities to firms or governmental organisations. One organisation alone cannot

achieve the goal of developing critical knowledge for sustainability challenges. For example, to accomplish integrated design and management for resilient, durable infrastructures or system integration in the energy sector, universities, companies and other institutions need to collaborate for a longer period of time. Technological change and economic success no longer depend solely on capital and labour; they require knowledge and other intangible entities like the interaction between public and private organisations and their ability to refresh: 'renewal capital' is an equally important driver of national growth [2]. A PhD project in this context therefore entails not only the training of an individual to become a scientific researcher, but also a collaborative project in which new knowledge is developed that should lead to innovation. These collaborative PhD projects are a way to implement the knowledge triangle.

The Lisbon Agenda introduced the knowledge triangle at the dawn of this century in order to enhance Europe's competitiveness. As shown in figure 1, the knowledge triangle links together research, education and innovation, with special platforms and processes on its three sides. It replaces the traditional one-way flow of information, from research to education and from educators to students, with a circular flow between the three corners of the triangle.

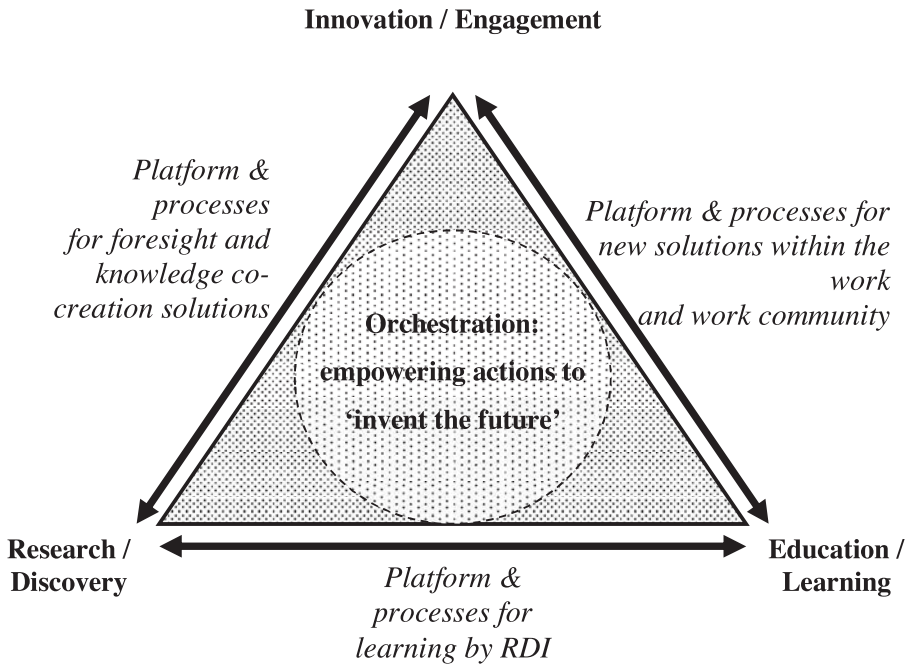

Fig. 1. The Knowledge Triangle [3]

The concept of collaborative PhDs covers all corners of the knowledge triangle. First of all, these PhD candidates are lifelong learners, educated to be scientific researchers. Doctoral education is therefore a form of continuing engineering education. Moreover, these PhD candidates can be involved in ordinary education. Second, the learning process of PhD candidates is strongly linked to research. The aim of the PhD study is to contribute to science, therefore delivering new knowledge. At the same time, these PhD candidates are incorporating the third corner of the

triangle in ensuring sustainable economic or societal innovation. So this PhD concept offers tremendous opportunities for education, research and innovation, provided that these processes are well designed.

2 NEED ANALYSIS: THE INTERESTS OF ALL PARTIES INVOLVED

2.1 Introduction

As Pronk et al. [4] showed, one of the success factors of a collaborative research project is clarity regarding everyone's objectives, benefits and risks. This paper briefly discusses the interests of the parties as described in the introduction.

2.2 University

The benefits for the university can be found in various policy documents. Contract PhD candidates and their employers address research themes that are relevant to business and society. By initiating these joint projects the university satisfies both their research and knowledge valorisation efforts in developing, implementing and commercialising their knowledge [5]. The Dutch government also encourages cooperation between universities and industry. The government wants to increase the number of PhDs in business since they contribute to increasing the competitiveness of the country [6].

The interests of academic staff regarding contract PhDs differ. We interviewed four TU Delft professors who are supervising several contract PhDs for approximately one hour each. The semi-structured interviews were conducted using an interview template, and were recorded and transcribed. All transcripts were then analysed. Furthermore, in the past two years, we spoke with many researchers and professors about their experiences during and after various meetings: from informal one-to-one meetings with PhD candidates to official go/no-go meetings. In this paper, we focus on why the professors are interested in starting with a contract PhD and the problems they encounter during the various phases of the PhD project. We leave out of consideration the various ways they supervise these PhDs.

The manner in which university supervisors get involved in these collaborative PhD projects differs. A professor and PhD candidate may know each other for a longer time: 'It's someone from my network' or ‘It’s a former student’. It also happens that an organisation, for example the tax authorities, asks a university professor to conduct joint research on innovative ICT applications. The university professor may then select one or more PhD candidates from this organisation.

Although there are several reasons to collaborate, university professors tend to be mainly interested in PhD candidates who will contribute to their own research. The goal is to publish jointly in the scientific journals in which they themselves publish. The greatest advantage of contract PhD candidates is that they have direct access to cases and data. For more context-related research, the experience of the PhD candidates has been viewed as very important: 'The contract PhD candidate understands much better what is going on at major complex infrastructure projects than a recently graduated PhD candidate who has been at the university only.' The other side of the coin according to some scientists is that contract PhD candidates, due to their experience, do not always want to contribute to the core of their research. Furthermore, the supervision of a contract PhD can take a great deal of time. That also has to do with the fact that the quality of the PhD candidates – and thus the quality of the dissertations – varies significantly.

Contract PhD candidates may also contribute to education. They can give guest lectures in order to link theory and practice or supervise graduate students. In

addition to these well-known forms of education, contract PhD candidates can be enablers of innovative teaching methods, for example through participation in living labs, MOOCs, sustainable business idea competitions and so on. This collaboration increases awareness of sustainable development among the next generation of students.

2.3 Private and public organisations

The best chance for success is when the parties already collaborate [7]. Pilots with collaborative PhD tracks could therefore be set up with companies and organisations already involved with the university. Public and private organisations participate in collaborative PhD projects for different reasons, since they have different goals and responsibilities. In this section, we concentrate on companies. It was possible to provide an overview of the benefits for some companies by consulting several representatives (mostly managers) from companies in various consortia.

Companies are currently experimenting with how they can shape and maintain their intellectual capital. It is important for companies to offer individual employees interesting opportunities in their career development. The company gets more motivated and better trained employees in return. A partnership with a university also means access to the academic world. The development of cutting-edge technology and the foresight knowledge of universities will make these companies able to strategically respond to future developments or, in other words, 'co-create the future'. They can take advantage of the good name and reputation of the university, thus increasing the market value of the company. Furthermore, by participating in a PhD project, several regular students can also become involved (e.g. for their Master's thesis), which can help to attract young talent. Managers, however, differ in expectations of the applicability of the results. They mainly appreciate three or four related studies with intermediate results instead of one large-scale study.

2.4 PhD candidates

We also studied the needs of PhD candidates employed elsewhere. Because their talents and expectations are at stake the most, we decided to elaborate in more detail on the needs of the PhD candidates.

Ten PhD candidates were interviewed for approximately 90 minutes each (see table 1). The semi-structured interviews were conducted using an interview template with seven blocks of questions. Each interview started with general questions about the motivation for, background to and subject of the PhD study. The second block contained questions concerning the educational programme. This was followed by blocks of questions about the problems they encountered during the first year, during the next phase and during the final phase of the PhD project. Finally, there were questions relating to external partners: what kind of support do you receive from your company? There were also questions about the future: what do you want to do with the end result, both in terms of career development and implementation of the results? The interviews were recorded and transcribed. All transcripts were then analysed using the seven blocks of questions. Respondents 7 to 10 were followed and interviewed several times during their first year. In this paper, we focus on the motivation to start a PhD project and the problems encountered during the various phases of the PhD project.

Table 1. Background of the respondents and their motivation to start a PhD

	Background (study)	Background (work)	Motivation
1	Information science, MBA	Employed at energy company	- Value for the enterprise - Personal development
2	Mechanical engineering, process technology in chemical engineering, executive MBA	Self-employed (formerly employed at [different] energy company)	- Academic career
3	MTS, HTS	Teacher at university of applied sciences	- Achievement of highest level on this topic
4	Electrical engineering	Teacher at university of applied sciences	- Interest in the topic
5	School for business administration and economics (in Dutch: HEAO), Master's in Information management, register accountant	Registered accountant at Dutch tax and customs administration, and trainer at a university	- Tax administration has opted for ICT research - Own motivation: more freedom and appreciation, higher level of teaching
6	Civil engineering	Staff/policy-making position at a water supply company	- Expert training, possibly to find a new job
7	Civil engineering	Project manager	- Achievement of highest level on this topic
8	Civil engineering and MBA	Self-employed (senior consultant)	- Intellectual challenge - Develop own ideas - Useful for company
9	Bachelor's in mechanical engineering, Master's in business administration	Project manager at design and engineering firm	- Validate scientifically what works of current activities
10	Internal relations (political science)	Innovation manager (energy company)	- Real contribution to discussion in society - Personal driver/ intellectual challenge

The motivation to do a PhD varies significantly, as table 1 depicts. All PhD candidates showed an interest in the topic and made an effort to change something essential in the current situation through their research. However, their ultimate goals vary, from a future academic career to innovation in their company or public

organisation. In the case of two teachers at two different universities of applied sciences, it was less clear what they want to do with their PhDs; it might be self-evident that they use them in their teaching, but it could also be that too little attention is paid to the career prospects of teachers at universities of applied sciences with PhDs.

Success factors identified by the five first-year PhD candidates were: 1. quality of the supervisor; 2. flexibility to organise work; 3. substantive linkage PhD topic with work. What they described as difficult in their first year was: 1. finding the right scientific frameworks and getting it on paper; 2. continuous balance: work and PhD, practice and science; 3. administration around it.

A large part of the interviews was designed to create an overview of the problems encountered by PhDs or what they feel is lacking in the process. Some of these problems can be easily solved. Administrative problems and IT-related problems, for instance, can be solved through a proper intake process and by appointing someone who is responsible for organising an effective infrastructure.

This study, however, revealed other problems that are less easy to solve since they arise from differences between the domain of practice and that of scientific research. These PhD candidates work in a company (domain of practice), often for many years, and are motivated to solve a practical problem. They want to make a difference in practice through their research, which is another starting point that differs from an internal PhD candidate carrying out a subsidised project with a proposal written by a scientist. The translation of a practical problem into a scientifically interesting research question is a difficult issue for most contract PhD candidates. They use their own reference scheme to solve this issue, but that approach falls short. Some supervisors also speak a language different from what the PhD candidates are used to. In terms of the Model–Activity–Utility (MAU) framework, developed by Sjoer, Nørgaard and Goossens, universities and companies operate on the basis of different models, carrying out different activities. What is more, the incongruity regarding the production of satisfactory results poses problems for contract PhD candidates and universities [8].

3 OUTLINE FOR A COLLABORATIVE PHD TRACK

Collaborative PhD tracks that overcome these problems should be designed in such a way that they are consistent with the relationship and everyone's interest in it, as well as the needs and talents of the PhD candidate. This approach should lead to more successful doctoral education programmes. Based on the results of this study and the existing literature, a tailor-made track within the graduate school of the university was defined. We consider the first year of the PhD study in this paper.

There are several ways to get in touch with the university to arrange a PhD trajectory, and there are different paths to success. Candidates differ in backgrounds, motivation and skills. The route outlined below is therefore not a fixed but a flexible way to better support contract PhD candidates.

Preparatory phase

Every PhD candidate starts with an on-boarding module: ‘From Practice to Science’. The goal is for the candidate to discover what a PhD trajectory requires, what the differences are between the world of practice and that of science, and the language that goes with it, and to combine practical and scientific relevance towards an initial research proposition. Meeting other contract PhDs and exchanging experiences are

also part of this module. This module can be done online or blended, and results in a F2F presentation of a (written) research proposition. At this meeting, there are important points on which agreement should be sought:

a. Are all parties sufficiently interested and is the theme of sufficient strategic and scientific interest? The subject of the research should be interesting for all parties involved. This sounds obvious, but all parties (PhD candidate, organisation and university) should be committed to a topic for a longer period of time. So the topic should be the core business, or sufficiently related to the future core business, of the organisations involved.
b. Are all those concerned committed to carrying out or supervising this PhD research for a longer period, namely towards the go/no-go decision (after approximately 1–1.5 years and then after approximately a further 3–4 years)? All parties should be able to work together for a longer period of time. Continuity in the guidance team is a well-known success factor. A recommendation for all parties involved is to invest in the relationship and to pay attention to the selection criteria for all supervisors. For instance, selection criteria for the company supervisor might be the ability to contribute to the implementation of the results and a knowledge level on the specific topic that is roughly in the same range as that of the allocated university supervisor (cognitive proximity) [9]. On the side of the university, we observed that many PhD candidates prefer to be supervised by professors they already know; however, other professors might be more appropriate.
c. Are the expectations, wishes and conditions of the company supervisor, the university supervisors and the candidate discussed satisfactorily? Topics such as time allocation, funding, guidance, intellectual property rights, and publications need to be agreed upon. As stated by Salimi [10], the success of a collaborative PhD project is more likely if there is joint decision-making, which is more often the case when there are mutual dependencies. That means that no one party controls all critical resources.

As a result of this meeting an agreement should be signed and the candidate should be registered at the graduate school as a PhD candidate.

First year

At the start of a doctoral education programme, a short introduction module will be assembled in consultation with the PhD candidate. Many compulsory start-up modules at graduate schools are designed for a different target group and are done at times that are not suitable for part-time PhDs. Further, a workplace with ICT facilities, a library card, etc. is provided by the faculty of the PhD candidate. Moreover, the candidate will be invited to join the scientific community related to his/her topic. It is recommended to see whether several collaborative PhD projects can reinforce each other. The projects contribute to the same body of knowledge and, although PhD candidates run their own projects, they could meet, share insights and stimulate each other.

The graduate school of TU Delft has an extended doctoral education (DE) programme. The DE skills training programme offers a range of courses and activities that help candidates to acquire transferable skills, increase their disciplinary competences and obtain research skills. In the guidance team of the contract PhD candidate, training needs should be discussed. Nearly all PhDs examined are especially in need of research-related skills. They follow courses such as The informed researcher (at the library), Research design and, if relevant ‘How to make a

questionnaire and conduct an interview' and 'Discovering statistics using SPSS'. Additionally, 'Scientific writing in English' courses are popular. The knowledge acquired in the courses should be applied immediately in their own research, which is often part of the course design; however, it also requires on-the-job coaching afterwards. For the courses to teach discipline-related skills or transferable skills, customisation is needed since the offerings are not tailored to this target group. Therefore, the process of getting a PhD and the needs and talents of the candidate should be discussed regularly. HRM plays a role in this.

Many graduate schools and doctoral education programmes have a form of performance assessment in place. At TU Delft, the products for the go/no-go decision point after 12–15 months usually consist of a research proposal and/or a first article. It seems best to structure a collaborative PhD track according to a set number of scientific articles. In this way, progress is made visible and there is always something to celebrate. In addition, it fits the rhythm of engineers, who often work in successive projects. Further, the extent to which the cooperation runs smoothly can be assessed. Most contract PhDs are goal oriented. They want to know the precise requirements for the deliverables for the go/no-go meeting and they make a detailed plan of how to get there.

Not all PhD candidates, however, survive their first year. As literature shows, there are several reasons why doctoral candidates drop out: they either do not come up with a concrete research question or they receive inadequate guidance [11]. Yet, for contract PhDs there are some other pitfalls such as their unrealistic expectations (over- or underestimation), not being taken seriously as PhD candidates, little physical presence so that they become 'invisible' and socially isolated. In all cases, guiding a contract PhD is guiding a 'transition' in identity development [12]. We believe that the aforementioned ingredients of a collaborative PhD track strongly support contract PhDs and their companies in overcoming these problems.

4 CONCLUSION AND RECOMMENDATIONS

This paper answers the question what does doctoral engineering education for contract PhDs look like in order to run smoothly and fulfil the promise of sustainable development. By interviewing stakeholders (PhD candidates, university supervisors and company supervisors), observing several collaborations, consulting literature and performing a benchmark with other university programmes, we identified requirements for a collaborative PhD track within a graduate school. We identified 10 recommendations to better train an experienced engineer in becoming a scientific researcher while at the same time facilitating a collaborative project in which new knowledge is developed that should lead to innovation.

1. Set up the collaborative PhD track as a multi-year collaboration between the PhD candidate, the employer of the PhD candidate and the university.
2. Introduce a preparatory phase. One of the most difficult issues for contract PhDs is the transformation of the world of practice into the world of science. Important questions for an engineer who has been away from university for quite some time are: what are the scientific frameworks, which language fits with it and what makes a topic scientifically interesting? This phase ends with the presentation of a written research proposition that is interesting for all parties involved.
3. Discuss expectations and formalise commitment with the employer of the PhD candidate before starting a PhD trajectory.

4. Offer an introductory programme in consultation with the candidate instead of a compulsory programme at inconvenient times. This approach is critical to setting a tone of flexibility and enabling rather than standardisation and bureaucratising.
5. Create a tailor-made educational programme. The actual educational needs should be defined. The focus should be on what is really necessary for this PhD candidate to become a good scientist, not on obtaining all kinds of exemptions. It appears that mainly research-related skills are important. Time, attention and credits should be based on what is needed.
6. Ensure that administrative and ICT-related issues are well organised and not time consuming. Many candidates from industry are used to a well-organised infrastructure in which they receive good support.
7. Facilitate relationships between contract PhDs themselves and between contract PhDs and their scientific peers. It is important to ensure that this PhD trajectory is not a lonely journey, but a joint effort in a learning community that pays off for all parties.
8. Better prepare academic staff, since adult learners' needs differ from those of regular students. Furthermore, collaborating in a multidisciplinary PhD track is not always easy. It requires specific training expertise and 21st-century skills that cannot be transferred through an information meeting, but requires forms of coaching and peer review, or more unusual arrangements such as job rotation. For example, a daily supervisor can work for a certain period of time in a company, and the PhD candidate can provide regular education.
9. Assign a dedicated person for collaborative PhD candidates within the graduate school.
10. Ensure a link between the subject of the PhD candidate and the strategic needs of the company of the PhD candidate; It increases the chance of success substantially.

A collaborative PhD track can be valued as a multi-year collaboration between PhD candidate, employer and university, with an explicit commitment for a longer period of time. In these tracks, the flow of academic expertise into practical application is accelerated and the promise of sustainable development can be realised. The focus is not only on the best practice, but also on 'the next practice'. And above all, collaborative PhD tracks ensure an interesting learning process for all parties involved.

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