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Supervision of engineering doctorates in Australian universities: a review of key issues

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ABSTRACT: The changing environment in doctoral education in Australian universities has led to the emergence of new challenges, which need to be identified, researched and perhaps mitigated. These changes, mostly associated with the increasingly diversified student cohort and the focus on developing Australia's knowledge economy, have spread across the different disciplines, including engineering. This article deals with significant issues affecting doctoral supervision in engineering covering various aspects. The presentation is divided conceptually into four distinct but interrelating elements, based on a meta-level approach: the student profile (cohort); the programme options (framework); the educational process and the educational output. Particular emphasis is given to the interaction between industry and engineering education, as industry is considered to have a substantial impact as a source of research funding and employment prospects for doctoral programme graduates.

INTRODUCTION

Doctoral degrees in Australia are rather new, as they were first introduced in 1948 [1][2]. During this relatively short period, the supervisory practice in this area of higher education has faced various challenges attributed mainly to the increasing number and diversity of doctoral students, particularly in terms of their age, background and origin [3-5]. Significant statistical and qualitative research has been undertaken to identify the various aspects affecting, negatively or positively, the operation of doctoral programmes in Australia [6-11]. Nevertheless, limited emphasis has been given to the engineering programmes. Most of the studies examine student populations coming from various disciplines (science and non science-based), including engineering. Engineering education, at the level of doctoral studies, is of paramount importance to the national economy. Therefore, a question is whether the educational practices are appropriate to achieve the desired educational outcomes and, if this is in line with the current and future students' cohort.

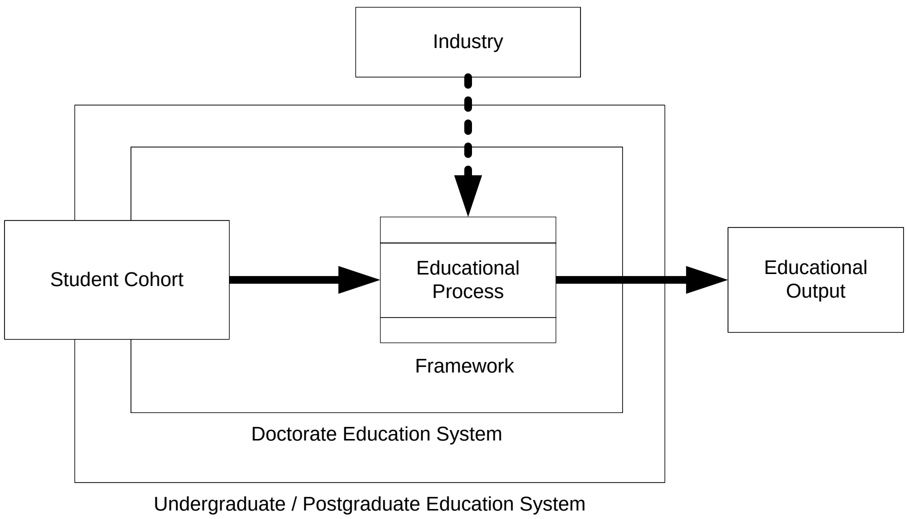

Figure 1: Meta-level approach model of engineering doctoral education.

A meta-level approach has been developed to conceptualise, present and discuss the various aspects involved in engineering doctoral education, which reflect the key themes that are evident in the literature. The parts and functions of this system (conceptual model), represented in Figure 1, include the mixed student cohort (recent undergraduate/

postgraduate students and experienced professionals); the supporting framework (doctoral programme types) with its core part being the educational process (policies, regulations, supervisor practice, pedagogical methods, etc); and the educational output (aims and actual results of the system). In addition, industry has both a direct and indirect impact on the doctoral education system, since it interacts with the framework (e.g. professional doctorates) and the educational process itself (e.g. requirements, research funding, etc). The literature review and critique in the following sections follow this structure.

THE STUDENT COHORT: STUDENT PROFILE AND DEMOGRAPHICS

Various surveys and statistical analyses have shown that the profile of research students in Australian universities varies greatly by discipline; with respect to age, mode of study (full time/part time) and gender [12][13]. In particular, the typical profile of the doctorate candidate in engineering is a 25-29 year old, full-time male student. Interestingly, the engineering student's age lies in the lower band, compared to the rest of the disciplines examined (e.g. arts, health, management, etc). This observation is related to the fact that international students, generally younger than Australian students, make up the majority in the engineering cohort [14]. Nevertheless, engineering schools tend to be more selective with international students to minimise risk associated with English language proficiency and educational background skills, in order to recruit students requiring minimal supervision and direction [15].

One other important feature of the internationalisation of doctorate programmes is the potential alienation of international students, which has its roots in the underlying cultural differences between the student and the supervisor [16]. Of course, this filtering of the prospective doctorate candidates is of concern since a number of qualified students may not be admitted to the programmes because they deviate significantly from the typical *ideal* student profile and consequently are unacceptable to the engineering schools.

The effectiveness of engineering doctorate programmes, compared to other disciplines, has been researched using indices such as completion rate and average time to complete. In particular, large-scale studies (during 1988-1999 and 2001-2003) have revealed that engineering PhD students had completion rates higher than other disciplines, but at the expense of prolonged candidacy time [17][18]. As an additional observation, engineering disciplines have one of the highest ratios of full-time to part-time students, which may act as a positive contributing factor for the reduced completion times/increased completion rates taken in conjunction with the impact of the higher percentage of international students on whom time restrictions are imposed, due to visa requirements.

FRAMEWORK: THE PHD AND PROFESSIONAL DOCTORATE

A significant development in doctorate education is the introduction of professional doctorate programmes in various disciplines, including, more recently, engineering [19]. This has complemented the PhD degree and is aimed at professional engineers and other experienced practitioners, while having lower admission standards [20]. This in turn leads to a different student profile, compared to that of the PhD candidate. The benefits of the professional doctorate programmes include the development of students for the knowledge economy, increased universities' revenues and networking with industry. However, quality concerns have been expressed indirectly by the industry regarding engineering, as the PhD is still considered to be most suitable for science-based professions, e.g. engineering [19]. Nevertheless, it has been recognised that it is the applied nature of professional doctorates which can provide the necessary knowledge and solutions to practical problems and issues that industry faces through the active involvement of the part-time research student employee of the company [21].

EDUCATIONAL PROCESS: OBJECTIVES AND CHALLENGES

There is a difficulty in setting distinct boundaries between education and research in doctoral engineering programmes. This is because the student evolves gradually to become an independent researcher through guidance (teaching, mentoring, etc), as well as testing and exercising in practice the acquired knowledge (research, experimentation, analysis, etc) [16]. Particular characteristics, methods and techniques of supervisory practice can be identified with reference to a doctoral programme in a science-based discipline. The scope of this article is to address issues affecting doctoral supervision in engineering, which is reflected in the literature search.

As with every graduate educational programme, the aims and challenges of engineering doctorate programmes are to develop a set of skills (e.g. problem formulation and solving) appropriate to the advanced level of study, while remaining in line with both the specific requirements of the programmes and ultimate career goals [15][22][23]. In this context, a project management approach to the development of research students' attributes has been developed by Manathunga and Lant [22], namely the Research Student Virtual Portfolio (RSVP). The application of this methodology to engineering doctoral candidates has proved to be beneficial in enhancing their learning and career development, as well as improving the overall supervisory practice.

The use of threshold concepts (discipline-specific core concepts) in undergraduate education has been widely examined in the past, but most recently has attracted the attention of researchers working in doctoral education [24-26]. A generic study defined a set of possible threshold terms, while for the case of engineering students major supervisory challenges have been identified in the field of theorising and theoretical modelling as an outcome of the research [26].

An integral part of doctoral level research education is writing, from the early stages of the studies to the completion of the PhD thesis and further on to scientific publications. Doctoral candidates are expected to be able to produce a higher quality and quantity of written work. This should be an emphasis in the teaching and learning practices of supervisors and students [27]. With respect to engineering sciences, it has been recognised that supervisors expect students to quickly approach their supervisor's level of writing skill, as well as adopt the underlying culture of the discipline [27]. Also, there are particular challenges in enhancing the writing skills of international non-native English-speaking students [14][28]. This issue has gained increased significance, as the engineering doctorate programmes are more heavily internationalised than in the past.

THE INDUSTRY CONNECTION: CAREER PREPARATION AND EDUCATIONAL OUTPUT

Recent expansion has taken place in the enrolments of PhD students and the production of research graduates. A relatively high proportion of these graduates are attracted to, and consequently absorbed by, industry [29]. This trend has been reinforced by industry, through funding and by support for engineering doctorate programmes (research grants, scholarships, partnership schemes, etc). These allow a closer connection with universities in industry-driven research projects [15]. Nevertheless, this may eventually lead to industry-driven research, which is a core part of industrialisation, becoming less substantive (based on originality, contribution to knowledge, etc) by comparison with the past and with research conducted in other science-based disciplines. In terms of graduates' attributes, transferable skills are highly regarded in engineering. This can be defined as the ability to transfer smoothly the problem-solving skills to the workplace, which were developed during the candidate's course [30]. Engagement of doctoral students in industry collaborative environments is a rewarding process (experience, career prospects, etc), though new challenges occur when working within interdisciplinary and multidisciplinary mixed (industry/university) teams [31].

Engineering is a university discipline requiring autonomy, but which also needs to be capable of ensuring the responsiveness of the marketplace to its research. This requires a weaker boundary between the university and industry [32]. Supervisors need to address these challenges by adopting the role not only of mentor, but also of negotiator and translator in complicated research relationships [23]. Supplementary to the formal doctorate education, attendance at conferences, seminars, workshops, etc, is considered an effective means of developing links between students and their future employers in the industry, as well as increasing their awareness of the importance of networking [33].

CONCLUSIONS

The proposed meta-level approach to modelling the doctorate education system can be supplemented and enhanced through a more detailed representation, based on the above analysis. In particular, the conceptualisation of the various contributing parameters, factors, system constituents, findings, etc, is facilitated by the construction of the concept map presented in Figure 2. The three different elements of the educational system can be distinguished (student cohort, framework, educational process), which contribute to the final (educational) output. Further, these are divided into subcategories, corresponding to the findings from the literature: study options (framework), student profile characteristics (student cohort) and form of education (educational process).

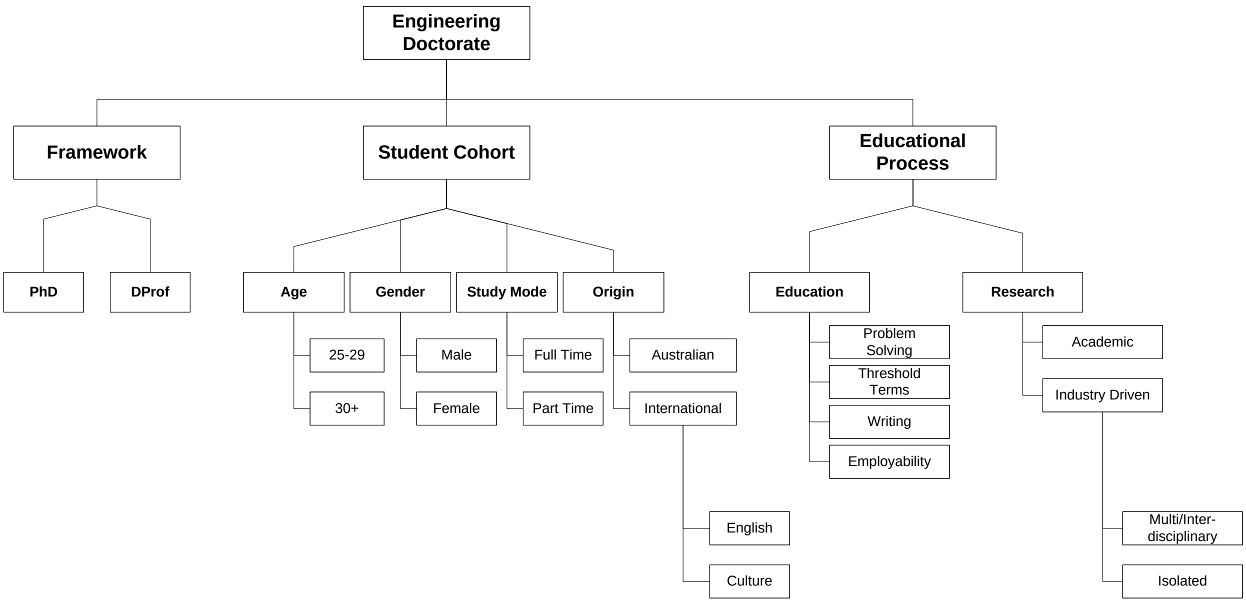

Figure 2: Concept map of the engineering doctoral educational system, based on the meta-level model.

The examination (mapping) of the engineering doctoral student cohort reveals very useful information about the typical student profile and demographics; provides indirect performance indices of the programmes; gives insight into the current status and future trends, etc. This is important as the first step toward a systematic analysis that identifies the problem. Most notably, the reviewed literature reveals the existence of a significant gap, which needs to be filled, with respect to specialised surveys and statistical studies of engineering doctoral programmes (PhD and professional doctorates) delivered in Australian universities. Based on the statistical studies, particular emphasis needs to be given to the international students' population in engineering programmes due to its large proportional size and; hence, impact on the overall performance of the programmes.

This brief overview of the doctoral education framework in engineering indicates that it mainly relies on the PhD programme, with the professional doctorate programmes as an alternative option available to experienced engineers and other practitioners. Despite the fact that the professional doctorate was partly an industry-originated programme, the industry deems that, in engineering, the PhD is still preferred. This interesting finding needs to be validated by the universities (those that are currently running or intending to introduce such programmes) with more extensive and targeted feedback from the engineering industry.

In an examination of the educational process, it was apparent that the aim should be the development of a set of graduate attributes, capable of addressing current and future challenges. In particular, the literature relevant to the engineering discipline has identified four primary fields for attention: problem-solving in industry, threshold terms, doctoral writing and employability. In this regard, supervisory practice (policy, methods, techniques, etc) should adapt in order to address these new challenges.

The increased level of interdisciplinarity and multidisciplinarity in doctorate research is considered to be not just *nice to have* but rather a demand for engineering programmes, emerging from industry. This requirement is evident in the reviewed literature and is justified on the basis of the increased interconnection between universities and industry through funded projects and other collaborative schemes. Nevertheless, besides the apparent advantages of engaging the engineering students in real-life practical, focused research projects, questions arise whether the produced outcome (research) is of the expected (PhD) standard, in terms of substantiality and originality.

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