What do Engineering postgraduate research students know about industry work?

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Abstract: *This paper explores the views of two groups of stakeholders in the Engineering research education process. The findings of two studies are compared and contrasted, one exploring the views of research candidates and the other the views of employers about the preparedness and perceived value to industry of the Masters and PhD experience. The employer data revealed two types of research-related engineering work, which we term 'niche innovator' and 'innovative adapter' roles. We conclude that providing clearer information about the nature of these roles and their associated attributes would help reduce the uncertainty research candidates express about their future professional roles. It would also confirm for them the value placed on their Masters or PhD experience.*

Introduction

The relationship between industry and higher education is complex, interdependent and often invisible in the day to day work of the people involved in each sector. As in industrialised nations elsewhere, Australian policy rhetoric promotes knowledge and innovation-intensive industry activity as a means of increasing economic competitiveness, with considerable focus on developments in science, engineering and technology (DEST, 2005). However, much of the innovation that occurs in Australian businesses involves adapting products developed in other countries; less than 10% of all innovative developments in Australian businesses contribute new knowledge in an international context (DITR, 2007). Only a fraction of this 'new knowledge' innovation occurs in engineering-related activity.

In contrast, research in universities is most often focused on generating new knowledge, and an important role of postgraduate research education is to prepare discipline scholars for future roles within and beyond the university research environment. American and European research indicates that, in the discipline of Engineering, most Masters by research and PhD candidates intend to work outside of academia (Enders, 2002; LaPidus, 1997) and this is likely to be so for Australian research students. However, little is known about the professional goals of these students or their beliefs about the ways postgraduate candidature prepares them for their future professional work. The knowledge

we have about the professional development of postgraduate research students in general focuses on their preparation for academia (Austin, 2002; Bieber & Worley, 2006; Weidman & Stein, 2003). Furthermore, the voices of industry employers are rarely heard beyond the level of policy rhetoric, and little is known of their perceptions of the roles and aptitudes of engineering researchers in their organisations. The lack of student and employer perspectives highlights the gap, mentioned by McAlpine and Norton (2006), between the broad-ranging conversation promoting government, industry and university collaboration (Etzkowitz et al., 2000; Fairweather, 1989; Keating et al., 2000) and the lived experiences of students, academics and, we suggest, industry employers.

This paper contrasts the views of Engineering postgraduate research candidates in an Australian university with those of employers of engineers with postgraduate research degrees. It is based on the findings of two studies that form part of a larger investigation into the professional socialisation of Engineering postgraduate research students: study 1 explored the views and beliefs of two groups of Engineering research candidates (Adams et al., 2006) and study 2 focussed on the views and beliefs of employers of Engineering Masters by research and PhD graduates. Key assumptions underlying the large study are that Engineering disciplines in universities value the practical and industrial relevance of much of their research activity and research education, and that successful commercial innovation in industry is dependent, in part, on the research knowledge and capabilities of its professional engineering workforce. However little has been documented about the relevance and value of the Engineering Masters and PhD experience to the non-academic engineering workplace. By contrasting the beliefs of students with those of employers, this paper sheds some light on the ways candidature prepares students for professional engineering work.

The methodological approach

In our two studies, qualitative data in the form of group discussion and individual interview transcripts were studied using Grounded Theory methodology. This approach employs a series of rigorous, analytical coding procedures for qualitative data to build a theoretical framework (Strauss and Corbin, 1990), with the aim of providing insights into the beliefs, expectations and experiences and perspectives of participants. One benefit of this methodology is its potential to illuminate under-researched or poorly understood personal beliefs in particular social contexts (Miles & Huberman, 1994; Stern, 1984 in Strauss & Corbin, 1990), such as those that influence the professional work practices of Engineering researchers. In such situations, a deductive approach, such as a theory-based survey, carries considerable risk of 'confirmation bias' by forcing existing theory to explain a social phenomenon regardless of its adequacy to do so (Johnson & Onwuegbuzie, 2004). In this paper, students' views were used to gain greater insight into their beliefs about and expectations and experiences of candidature; the employers' views were analysed to reveal a theoretical framework of the roles and attributes expected of postgraduate educated research engineers in industry.

Study 1: Students' views

Fifteen self-selected research students, 2 Masters and 13 PhD candidates, in the Schools of Mechanical Engineering and Chemical Engineering at the University of Adelaide participated in 2 focus group discussions, 6 participants in the first focus group and 15 in the second, centred on their beliefs and understandings about the ways candidature prepares them for their anticipated professional roles. The students were at various stages of candidature, ranging from 6 months to 5 years. Key questions that prompted the open discussion included the following:

- What do you plan to do after completion of your postgraduate candidature?
- What have you learned from candidature that you believe is of value to prospective employers?
- What, if anything, has interfered with your professional socialisation during candidature?

Participants' comments were thematically analysed to identify key concepts and themes that emerged from the transcribed data (Creswell, 2003; Strauss & Corbin, 1990).

Results

Most candidates viewed the research degree as a means to greater career opportunities in the form of faster progression on the career ladder, interesting and challenging work, and a way to avoid ending up in a management position (Table 1).

Table 1: Reasons for pursuing postgraduate research

Concept	No. of comments
Belief that PhD would open up opportunities	10
Graduate engineering work seen as boring/seek challenging work	6
Offered scholarship/seen as temporary job	4
Enjoy research	4
Wish to pursue a field of interest	3
Seek status and recognition of ability	1
Total comments	**28**

The desires to avoid boredom and engage in novel, innovative and challenging work were recurrent themes throughout these discussions. Most participants had commenced candidature before graduate engineering work became plentiful in association with growth in the resources sector and the subsequent high demand for Engineering graduates; they viewed a research degree as a pathway to more and better work. None mentioned availability of a definite job prospect, and all seemed quite unsure about their post-candidature futures.

For me it was a bit of a disappointment with actually being in the industry to begin with. Didn't meet sort of my expectations and realisations. I think some of it can be boring… (B1)

'[My friends had] *gone out to do graduate work…I didn't like the sound of anything they were doing. They find it boring.'* (B3).

Only five students had prior industry or research organisation experience, and fewer than half had been involved in consulting work at university. Most intended to work in industry or research organisations. These findings concur with findings of doctorate student destination studies conducted overseas (e.g. LaPidus, 1997; Enders, 2002). None of the students in this study were interested in academia, although some considered part-time teaching attractive. Student B10 made the point that he did not consider it necessary for his PhD activities to meet the professional aims of academia.

My job is to get a PhD. An academic's job is to publish and present and find new research. … it's a case of academics' aims not always being aligned with the aims of PhD students, which is purely to get a PhD. (B10)

The students' perceptions of impediments to their professional development centred on factors that they believed hindered completion (Table 2). For example, several complained about supervisors' requests for additional research not relevant to their thesis topic, and university administrative demands. A number related instances of inadequate resources.

Table 2: Beliefs about impediments to professional socialisation

Concept	No. of comments
Supervisor/supervision	12
The PhD	8
Irrelevant compulsory activities	7
Opportunity for poor time management	6
Lack of resources	3

Lack of adequate remuneration during candidature	3
Total comments	**39**

Perhaps the most interesting finding of this study was that many participants believed that a PhD itself interfered with their professional opportunities. Their pessimism related to the time they spent out of the workforce, their perception that employers did not value PhDs in Engineering, and a belief that some companies view PhD holders in a negative light.

I went to a job interview about two months ago…they let me know that the PhD was of no value to them whatsoever. They said, "We hire your learning capacity and previous experience". (B1)

Study 2: Employers' views

This study aimed to provide insights into the beliefs, expectations and experiences of employers of postgraduate research educated Mechanical and Chemical engineers. Snowball sampling, where social contacts and interviewees are asked to recommend other potential interviewees, was used to recruit participants. This technique is non-probabilistic, meaning it is not an attempt to create a representative sample from which the researcher can generalise to the wider population, as is the case with random sampling for deductive research. Snowball sampling is particularly suited to inductive, theory generating analysis of populations (Miles and Huberman, 1994), for populations made up of members of small, informal networks or networked organisations, and populations who are difficult to access without using social networks (Bernard, 2002; Cohen et al., 2000; Neuman, 1991). In this study of employers, all three of these criteria applied.

Eight employers were interviewed: seven professional engineers and one scientist. Six were directly responsible for hiring postgraduate research trained engineers, one had been responsible until recently for doing so, and one held a position on a national body that entailed the accreditation and employment of professional engineers. The interviews were semi-structured around guiding questions which included the following:

- Why do you decide to employ a postgraduate engineer for some positions?
- What attributes do you believe postgraduate engineers should bring to a position?
- What attributes do you believe postgraduate engineers bring to a position?
- Are you ever surprised by what a postgraduate is or is not able to do?

Transcripts were thematically analysed using a constant comparative method of rigorous, analytical coding procedures for qualitative data (Charmaz 2006; Strauss and Corbin 1990),

Results

No employer specifically sought engineers with postgraduate research degrees. Rather, their responses indicated that they sought 'advanced knowledge workers' (Alvesson, 2004) who displayed the knowledge, skills and attributes to perform well in positions where they would use their knowledge and experience to make judgments, in the process of problem solving and decision making, that impact on the viability of an organisation.

We don't necessarily need to employ people that have a research degree but we need certain people characteristics and certain people knowledge and certain people abilities… (Emp 6)

Alvesson (2004) defines 'professional role' as a set of externally created expectations of a professional person, often determined by a group such as an employee's work organisation, whereby professional role defines that person's position in relation to others in the group context. The employers identified the roles generally performed by engineers with postgraduate qualifications in their organisations, and described desired attributes, or personal characteristics, of these workers. With varying emphases, all the employers identified all the roles and attributes outlined in Table 3.

Table 3: Roles and attributes required in advanced engineering work.

Roles	Attributes
Technical leader	Deep, broad ranging technical and theoretical knowledge
Problem solver	Ability to transfer knowledge quickly
Product creator / developer / maintainer	Intelligence for problem solving
Client consultant	Commercial awareness / Financial rigour
Business opportunity seeker	Interpersonal intelligence
Document writer/checker	Initiative / Results driven
Technical mentor	Practicality
Team worker	Intellectual curiosity
	Responsiveness to product development lifecycle
	Commitment to task

However, further analysis revealed that these employers placed differing emphases on different roles and attributes, and that their preferences tended to cluster around two distinct role categories, which we define as 'niche innovator' and 'innovative adapter' (Table 4). Key differences between these two roles reflected a company's need for either individualised, unique product development in response to customer requirements, or for monitoring of products or innovations that can be applied to existing practices to create a market advantage for a company. Such differences are reflective of the general pattern of innovation in Australian businesses, with most innovation in Australia carried out by large firms of more than 200 employees (DITR, 2007). In the current study there was a tendency for niche innovators to be employed by smaller firms, and innovative adapters by large organisations.

Table 4: Key roles and attributes (in italics) of niche innovators and innovative adapters.

Niche Innovators	Innovative adapters
Knowledge creator for product development	Technical knowledge 'gap filler' for product development
Product developer / maintainer	Field scanner (assessing readymade products)
Client consultant	Team leader (technical, financial, people manager)
*Deep, broad ranging, **relevant** technical and theoretical knowledge*	Document writer/checker
Practicality (technical focus)	Technical mentor
Responsiveness to product development lifecycle	*Deep, broad ranging technical and theoretical knowledge*
Intellectual curiosity	*Practicality (commercial focus)*

Niche innovators create knowledge that can add novelty to products and services, thus providing the company with a commercial advantage in a specialised marketplace. This strategy was described by employer 6, the CEO of a specialised engineering company:

...we do have a stated objective to be a leading edge company in the fields that we work in…. And that to us is a survival strategy. We kind of see that manufacturing is under pressure as such because of cheaper labour countries becoming more prevalent, so anything that doesn't have some degree of difficulty incorporated in it isn't going to survive very long. So education and knowledge are things that are not easily copied and so we base our business on knowing how to do things and developing new and better products and services. (Emp 6)

Innovative adapters used their advanced knowledge, acquired in candidature, to identify and adapt existing knowledge products, created elsewhere, to create useful improved company products and

services. Employer 7, an engineering executive in a large organisation, refers to this 'off the shelf' approach:

If we decided to focus on an area then we'd want someone who is capable of research into who the parties might be that we could collaborate with - other businesses - or who has technologies that are available off the shelf that could be factored onto some other technology that we can buy, perhaps off the shelf. (Emp 7)

Employer 4, another employer of innovative adapters, identifies their role as engineering knowledge 'gap fillers':

,,,we have a post grad engineer working amongst that team and he's been working on filling in the gaps in missing data we've got so that he's able to actually create an engineering baseline that the others can then work from. (Emp 4)

As well as the difference associated with knowledge creation and adaptation, two additional differences were found between the employers of niche innovators and innovative adapters: the importance they placed on relevance of engineering knowledge gained in candidature, and the character of desired commercial acumen. Employer 2 introduced the expression 'niche' to this study, and placed great value on the depth of knowledge acquired through postgraduate research experience:

… post graduate experience gives you a much greater depth in particular niche areas and hopefully greater breadth as well by virtue of having to deal with a whole range of issues in getting deeper and deeper into one particular niche area. (Emp 2)

Companies seek innovative adapters, not for the knowledge they gained in their relatively narrow postgraduate research, but for their general skills and attitude.

We're employing those people because of the skills that they bring, their knowledge generally that they've acquired through their degree and how well they've done their course, the type of person they are, their personality and so forth, those sort of attributes would be worth more to us, or judged more highly I would say. The PhD is sort of nice to have but we won't then directly use it. (Emp 7)

The non-technical roles expected of advanced engineers differed for niche innovators and innovative adapters. In niche market firms, due to lower staff numbers and the uniqueness and specialisation of products, an advanced engineer is expected to play an integral role in product conception, production, maintenance and ongoing development (the product development lifecycle). Technical practicality is valued in this role, as described by employer 3.

In all the stuff we do, you've got to get in there and you've got to be able to know [how to use] *a screwdriver bolting something up… it's not really anything too technical, it's not something like welding or anything like that where you have to be a bit more specialised but just the commonsense of we've got to plumb something up so we've got to get some hose…the ultimate post grad for us would be someone who was qualified as a plumber and as an engineer.* (Emp 3)

In innovative adapter firms, involvement in physical production and maintenance processes may be more limited, and commercial practicality, including management ability, is viewed as essential to the advanced engineering role.

We tend to employ the post graduate people in the design area as opposed to the sustainment area. …you're executing if you like, applied work and if they are going to help to do that then they have to be aligned with those goals which includes those things…such as you know, liaising with people, cost and schedule, all those things as well. (Emp 4)

Commercial acumen was strongly emphasised by employer 7.

When I mean commercial I mean having the smarts to go and negotiate contracts and large contracts and negotiate deals if you like and understand discounted cash flow and profit and loss accounts and you know, income statements and all that sort of stuff, it's all part of doing business deals and putting projects forward and so forth, or running a business… (Emp 7)

Discussion and Conclusion

Focus group studies involving research students indicated that many intended to pursue engineering careers in industry, but were uncertain about the value of postgraduate research study to industry employers. A number of the students believed they had received disaffirming messages from employers about their postgraduate experience. In contrast, interviews with employers confirmed that engineers with Masters and PhD experience play important technical and management leadership roles in their organisations, but also revealed that, when selecting engineering employees, these employers placed importance on the knowledge, skills and capabilities of the engineers for particular advanced roles, rather than on formal qualifications.

This paper clarifies ways in which the employers interviewed believe postgraduate research experience prepares candidates for advanced engineering roles in industry, through knowledge, skills and attribute development. However, it also highlights differences in the way these qualities are valued in different workplace contexts. Interviews with employers revealed two types of industry workplace roles for professional research engineers: 'niche innovators' and 'innovative adapters'. These roles were distinguished from each other by differences in the following: relevance of prior specific research topic knowledge, uniqueness of innovative aims, amount and type of adaptability required, and need for management skills and attributes. Interestingly, these advanced engineering roles reflect the two types of business innovation, product adaptation and new knowledge innovation, described by DITR (2007).

The findings of this study indicate that, far from considering postgraduate research experience as detrimental to engineering career prospects, most of the employers interviewed valued highly the depth of knowledge and skills developed and commitment displayed by research postgraduates. Candidates seeking employment or careers in a field of research interest that requires technical challenge, responsiveness to product development, and opportunities for creativity might best be positioned in niche innovator roles. Those interested in broad application of their knowledge and skills, who are less concerned about remaining in their postgraduate research area, and who are interested in financial and people management might find an innovative adapter role more interesting. Informing candidates of the range of attributes valued for differing professional roles in industry might help to reduce their uncertainty about their professional futures, and might assist those interested in industry-based careers to tailor their postgraduate experiences to their professional goals.

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