Entrepreneurship and UK doctoral graduates

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Abstract: *This paper discusses the experience of UK doctoral graduates in pursuing entrepreneurial careers: there is evidence that this applies to a substantial number – about 10% – of doctoral graduates. The nature of their experience was explored using 37 interviews with doctoral entrepreneurs. The research was funded by Vitae (www.vitae.ac.uk), an organization championing the personal, professional and career development of doctoral researchers and research staff in UK higher education. The stories that the participants tell suggest that doctoral entrepreneurship develops out of a complex interaction between the personality and skills of the entrepreneurs and the environment in which they operate. In particular, the authors argue that the participants have mobilized a mix of financial, social and educational capital in order to create and sustain their enterprises successfully.*

Keywords: *doctoral graduates; graduate entrepreneurship; Roberts Agenda; knowledge transfer; UK*

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Over 14,000 people qualify with a UK doctorate every year (Vitae, 2009a). These doctoral graduates go on to work in a wide variety of roles including academic and commercial research, teaching and lecturing, management, finance and IT (Vitae, 2009a; Vitae, 2009b). There has been extensive discussion about the value added to an individual's skills and employability by a doctoral degree (see, for example, Roberts, 2002; Thrift, 2008) and the relative value of doctoral graduates to employers (McCarthy and Simm, 2006; Vitae, 2010a). Recent research has suggested that across Europe one in ten doctoral graduates go on to become self-employed (Auriol, 2010). It is likely that this figure matches or exceeds that of first degree graduates who are self-employed (Mora and Vila, 2009); but there has been little academic discussion to date of the role of entrepreneurship amongst doctoral graduates. This study suggests that the skills acquired and capital accumulated during doctoral study can be put to good use during the pursuit of an entrepreneurial career.

The study is based on 37 interviews with doctoral graduates who went on to set up their own business or enterprise. The study was funded by Vitae (www.vitae.ac.uk), an organization which champions the personal, professional and career development of doctoral researchers and research staff in UK higher education. A publication based on initial findings was produced for use in the enterprise and career education of researchers (Vitae, 2010b) and stories are available from the Vitae Database of career stories (www.vitae.ac.uk/docs).

This research was conducted as part of a broader initiative in UK higher education on the development of researchers' skills and careers (commonly known as the Roberts Agenda). An overview of the development of this policy initiative can be found on the Vitae website

(www.vitae.ac.uk/policy). The impact of these policies on doctoral graduates and how these developments have related to the parallel agenda to support the development of entrepreneurship (BERR, 2008) are discussed below.

Interest in the skills, abilities and corresponding economic impact of doctoral graduates has been growing over the last ten years. *SET for Success* (Roberts, 2002) argued that there needed to be a substantial investment in the human capital that underpins the UK's research base. A key recommendation was that the higher education sector should invest in the training and development of doctoral students. The report prompted a response from the sector which led to new training and career development programmes for doctoral researchers designed to increase skills and support the transition from academia to industry.

Roberts (2002) argued that a key selling point of doctoral graduates was their ability to contribute to 'making discoveries and creating new products, services and processes'. The Warry report (Warry, 2006) also stressed the need for a focus on knowledge transfer between HEIs and business, arguing that all doctoral researchers should receive enterprise training. Wellings (2008) reported a strong correlation between the number of doctoral students registered at an institution and that institution's creation of patents. As these reports show, doctoral research is frequently understood by policy makers as being creative and innovative by nature and doctoral researchers have correspondingly been asked to explore ways to commercialize their research.

While policy recognises that doctoral training has the potential to increase an individual's capacity to develop intellectual property, the process of innovation and commercialization is usually regarded as involving a range of stakeholders; the doctoral researcher is not necessarily expected to drive their idea all the way to the establishment of an enterprise. However, parallel to the doctoral skills agenda has been a move to increase the number of spin-out companies (Minshall and Wickstead, 2005). These spin-outs, as demonstrated in the case studies presented here, frequently provide a vehicle for those with doctoral qualifications to pursue an entrepreneurial career path.

This paper will examine how entrepreneurialism develops in the case of doctoral researchers as both an output of their skills, attributes and aspirations and as a response to challenges that are faced within the labour market.

Literature review

There is a considerable body of literature that examines the nature of entrepreneurship, what predicts entrepreneurial activity and how to foster the growth of entrepreneurship. This section of the paper will briefly review some of this literature in the context of understanding doctoral entrepreneurship. One argument that will be made is that there is almost nothing known about how entrepreneurship relates to the skill set of doctoral graduates or about how doctoral graduates progress towards and within entrepreneurial careers.

The main characteristics of entrepreneurs/self-employed individuals identified from previous studies has been summarized by Delmar and Davidsson (2000). They characterize entrepreneurs using five variables: parental occupation; gender; ethnicity/race; education and work experience; and psychological profile. The self-employed were typically male and had parents who were self-employed. Ethnic minorities were well represented and in the UK this was particularly true of the Indian, Pakistani and Bangladeshi communities. Entrepreneurs were more likely than average to have a graduate level of education and this higher level of education was especially prevalent in entrepreneurs in the knowledge intensive industries.

In terms of work experience, research found that two groups were particularly well represented: people who had been previously self-employed and the unemployed. Martinez *et al* (2007) also summarize the typical entrepreneur as being a man, aged between 25 and 40, having self-employed parents, a higher education degree, a need for achievement, a propensity for risk-taking and a preference for innovation.

For graduate entrepreneurs, Lüthje and Franke (2003) conclude that many attributes align with those required of entrepreneurs on the whole: independence, challenge and self-realization. Mora and Vila (2009) found that, generally, graduate entrepreneurs tend to be male, with high grades in secondary education, but who took longer to complete their degrees and preferred gaining practical experience to attending lectures. In relation to competencies upon graduation, entrepreneurs scored higher than other graduates on leadership skills and were particularly strong in negotiating, working independently, taking responsibilities and decisions and critical thinking.

Whilst there has been very limited work on the role of doctoral entrepreneurs, a study by Klofsten and Jones-Evans (2000) looked at the entrepreneurial experiences of academic researchers (employed by universities) in technology based industries in Sweden and Ireland. They found that the typical academic who was involved in entrepreneurial activity was male, middle-aged, with experience of working outside the university sector and sometimes with experience of running a business. Klofsten and Jones-Evans also noted that the entrepreneurial activity tends to emerge from

academics who have contact with industry and who feel that their institution is supportive of their knowledge transfer activity.

There is considerable debate about the way in which personality impacts on entrepreneurial intentions and performance (see, for example, Carsrud and Johnson,1989; Scherer *et al*, 1991; Rauch and Frese, 2007). A recent meta-analysis by Zhao *et al* (2010) suggests that personality plays a role in both the emergence and success of entrepreneurs. Simon *et al* (2000) indicate that optimism, enthusiasm, passion and energy are key personality traits of entrepreneurs when setting up a business. It is notable that a number of these personality traits and behaviours seem to be common to many of the doctoral entrepreneurs in this study.

While this evidence suggests that personality is likely to be a factor in entrepreneurship there is clearly a process of interaction between the individual, their environment and the opportunities and challenges with which they are presented. The importance of educational achievement has already been discussed (Delmar and Davidsson, 2000; Lüthje and Franke; 2003; Martinez *et al*, 2007): however it will be argued that the use of educational and intellectual capital constitutes a key element of the way that entrepreneurship is manifested in relation to doctoral graduates. It will also be demonstrated that access to financial resources and social capital are powerful influences on entrepreneurial success.

Blanchflower and Oswald (1998) note that while childhood personality type is a poor predictor of entrepreneurship, access to financial resources is a very good predictor. While this does not dismiss personality as a factor, there is clearly validity in Aldrich and Martinez's (2007) use of the phrase 'many are called, but few are chosen' and that an entrepreneurial personality does not necessarily lead to an entrepreneurial career. The pursuit of a successful entrepreneurial career is likely to be considerably influenced by access to financial resources (Cooper *et al*, 1994; Montgomery *et al*, 2005; Hussain *et al*, 2007) as well as other kinds of resources. Although there is no research that examines this directly in the context of doctoral graduates, Colapinto's (2011) work on academic entrepreneurship suggests that financial capital is crucial in supporting revenue growth in academic spin-outs.

There is good evidence to suggest that well developed social skills and access to social capital have a strong influence on entrepreneurs' success (Baron and Markman, 2003; Davidsson and Honig, 2003; Liao and Welsch, 2003). For example, Davidsson and Honig (2003), following an eighteen month study of nascent entrepreneurs, argued that social skills supported some entrepreneurs in the development of more social capital and that this in turn helped them to acquire other resources. The socially skilled entrepreneur who was well enmeshed in relevant networks and able to draw in wider resources was therefore more likely to experience a successful entrepreneurial career.

Methodology and sample

The study consisted of 40 interviews conducted with doctoral graduates from the UK who had undertaken entrepreneurial ventures. This paper is based on 37 of these interviews: three were not included because the participant withdrew from the study. Contacts were identified through Vitae's network of higher education professionals and through the authors' own networks. A word-of-mouth approach was then adopted to extend the sample. The sample was constructed with the deliberate aim of including a variety of doctoral disciplines and a wide range of different types of enterprise from a number of sectors.

Semi-structured interviews were used to explore the career stories of the entrepreneurs. Interviews were mainly conducted using the telephone (Stephens, 2007; Holt, 2010) although a small number were collected using asynchronous online methods (O'Connor *et al*, 2008; James and Busher, 2010). Each interview was transcribed and coded and then developed into a case study which was approved by the interviewee before publication.

The use of career stories as the main data for this research obviously offers some interpretative challenges. Participants were allowed to tell, and if they chose, to mis-tell their stories as they wanted. Researchers did not attempt to cross-check their stories with alternative sources such as their business records or accounts. The advantages and challenges of working with autobiographical material especially through the medium of oral testimony have been well-documented (Hoffman, 1974; Perks and Thompson, 2006; Merrill and West, 2009). However, for the purpose of an initial investigation into the subject of doctoral entrepreneurship the methodology seems appropriate. Finding out how doctoral entrepreneurs understood and rendered their own experience provided valuable insights into how doctoral entrepreneurship should be investigated and analysed.

Research methods designed to capture the narratives of individuals have been used effectively to investigate the issue of career development. Cohen *et al* (2004) argue that attending to how individuals and groups construct their own realities can help us to 'access the parts that other approaches cannot reach' when studying career planning. There is also considerable discussion

about the value of career stories in entrepreneurship research and entrepreneurial learning (Foss, 2004; Johansson, 2004; Hjorth and Steyaert, 2005; Rae, 2005).

Findings

Appendix 1 provides an overview of the respondents. In general, the demographics of the respondents in this study match the profiles suggested by the literature in terms of gender, age, education and knowledge of industry. Most studies indicate that there is a predominance of male over female entrepreneurs. Participants in this study fitted this pattern (25 males, 12 females). Various studies also emphasize that entrepreneurs are likely to be middle-aged: on average, the sample in this study had completed their doctorate some 17 years before they were interviewed, meaning that – again – they broadly follow this pattern. The role of education in entrepreneurship is also emphasized and by definition all of the participants in this study have a strong educational background, with most of them likely to have been academic high achievers throughout much of their lives. Finally, the literature emphasizes that entrepreneurs are likely to have had work experience in and acquired knowledge of industry that they could draw on in the establishment of their enterprise. 32 of the 37 participants in this study gained work experience following their doctorate, before establishing their businesses.

Discussion

The literature review above suggested that there are patterns in the demography, life experiences and personality types of entrepreneurs. This section will explore how these patterns relate to the specific case of doctoral entrepreneurs and examine the factors that enable venture creation by doctoral entrepreneurs.

Klofsten and Jones-Evans (2000) argue that experience and contacts in the wider labour market underpin academics' success in knowledge transfer and this applied to the participants in this study in their venture creation. While the doctoral experience itself and the associated skill set was key to many of the businesses that were established, the experience of the broader labour market seemed equally important. Before starting their businesses, participants had worked in a wide range of roles (see Table 1). It is also worth noting that a significant sub-set of interviewees (8/37) had at some point in their career been involved with the process of commercialization of research or knowledge transfer as part or all of their job. It seems likely that this enhanced their ability to develop entrepreneurial skills.

Table 1. Pre-entrepreneurial occupations (showing the occupations reported by individuals after completion of their doctoral studies before they established their enterprise).

Occupations following doctoral completion	Number
Higher education lecturer/professor	21
University researcher	9
No occupation	5
Other	4
Project manager	3
Trainer	3
Business analyst	2
Research and development manager	2
Market/social researcher	2
Investment/ merchant banker	1
Management consultant	1
Civil engineer	1
Patent examiner/agent/officers	1
Broadcasting professional	1

Note: The total number of occupations is displayed in the table. Some individuals reported more than one. Therefore the total number (56) exceeds the total number of entrepreneurs interviewed.

The literature review raised a number of interesting questions in relation to personality type of entrepreneurs. The methodology used in this study makes it difficult to draw any definitive conclusions in this area, however. Participants were interviewed in a manner that allowed them to present their perspective on their life history and to disclose as much or as little of their personality as they chose. Nevertheless, semi-structured life history interviewing is a process that can encourage personal reflection (Sturges and Hanrahan, 2004) and participants in this study revealed aspects of their personality in ways that raised questions. These questions could be explored in subsequent work, perhaps using a quantitative instrument as part of the methodology.

Despite the caveats about inferring personality type from qualitative interviewing it is useful to set down some observations about the behaviours of participants. Simon *et al*'s (2000) key personality traits of optimism, enthusiasm, passion, and energy were in evidence among many of the entrepreneurs. For some, this passion was manifested as a political or moral commitment; for instance, Neil Jennings, whose main reason for enterprise creation was to raise awareness about climate change. For others the passion was for the work itself as much as its outcomes. Rebecca Steinitz notes, 'I love the flexibility of running my own business, being able to choose my own work and working with lots of different people. I am also doing

completely fascinating work! I don't do anything that doesn't interest me'.

Many of the doctoral entrepreneurs talk about the energy required to bring their ideas to fruition. Emma Heathcote-James, who runs two companies (a soap manufacturing company and a production company), talks about the need to develop a strong work ethic for both doctoral study and business. She had to learn '. . . marketing, branding, packaging, sales and the like. You do need to have a certain work ethic to drive through the completion of a doctorate and four books, and I think this has served me well in my working life as well'. This commitment and willingness to work beyond the standard work pattern was reflected in several of the interviews, including that of Barrie Hopson, a serial entrepreneur and author who, after launching and ultimately selling a number of businesses and being past the normal retirement age, stated, 'I am still writing, presenting, consulting and doing some non-executive director work. I never want to retire'.

For graduates, Martinez *et al* (2007) identified the desire to participate in the labour market without losing their sense of independence as a key driver which led people to become entrepreneurs. The desire to perceive themselves as independent players in the labour market came through strongly in a number of the interviews. Krista Scott-Dixon discussed her frustration with the limitations that were placed on her autonomy whilst she was employed. Caron King also describes her decision to pursue an entrepreneurial career as being about putting herself into a position where she could exercise 'choices over who I was working with'. Some doctoral entrepreneurs complained that they did not fit very well into conventional organizations and that the hierarchies within academia or other sectors were too constraining. Mark Hughes did not want to be 'a small cog in a big machine'. Dave Fillopovich-Carter states that he still looks at jobs, but has '. . . never yet found one that appeals enough to take the risk of sticking on a suit and going to work for someone else'.

It is important to recognise that while independence and autonomy were strong values for most of the doctoral entrepreneurs it is not the case that conventional employment was necessarily seen as compromising these values. Many of the doctoral entrepreneurs had found a way to spend much of their careers within organizations, sometimes combining entrepreneurial activity with employment. For example, David Goulson created the Bumble Bee Conservation Trust alongside his work as an academic. Similarly, Brian Tanner and Steven Howdle both managed to combine their academic careers with developing spin-out companies.

Although personality is an important aspect in understanding the development of entrepreneurial careers, it is clear that it does not explain entrepreneurship in any straightforward manner. Some of the doctoral entrepreneurs were driven to actively pursue an entrepreneurial career, but most only became entrepreneurs in response to circumstances. Reynolds *et al* (2002) argue that entrepreneurship actually emerges in response to a range of circumstances. On one hand there are those for whom opportunities catalyse the development of an entrepreneurial career (opportunity entrepreneurship); on the other, there are those for whom it is the presence of an obstacle which leads to the establishment of a business (necessity entrepreneurship). The majority (27/37) of the participants in this study created their venture in response to a perceived opportunity.

A minority of participants (10/37) described the move to an entrepreneurial career as being in response to necessity or a career blockage of some kind. For example, Joanne Whitaker, who developed the underwear company Favio, felt that there were considerable barriers to career progression in higher education for women: 'I had become a bit disillusioned with academia on noticing that career progression was more limited for women'. The spark for venture creation clearly emerges from an interaction between the personality of the individual and factors in the environment within which the individual is pursuing their career. However, the phrase 'many are called, but few are chosen', as used by Aldrich and Martinez (2007), suggests that while many researchers may experience an 'entrepreneurial moment' there is a need to examine when and how the initial spark of interest develops into the creation of successful ventures.

The participants in this study all had attributes, skills and knowledge that supported their entrepreneurial careers. However, most also found other places in the labour market to use their skills before they established a business (see Table 1). Most often the entrepreneurs remained within higher education as lecturers or researchers. Only five participants started a business immediately after their doctorate (see Table 2). Most doctoral entrepreneurs only founded their enterprises after a considerable period in employment and many combined their entrepreneurial activity with other forms of work.

Regardless of the precise journey, the doctoral experience played a very important role in many of the doctoral entrepreneur's careers. The specific knowledge and expertise gained was especially important where the business was closely related to the area of doctoral study: 15 of the 37 doctoral entrepreneurs developed their business idea from the subject of their doctorate.

Table 2. Immediate start-ups (showing those individuals who started up their businesses immediately after completing their doctorate).

Name	Enterprise	How it got started
Neil Jennings	Student Switch Off campaign	His personal drive to address climate change combined with a strong business idea which built quickly.
Kate Ho	Interface3	A university business competition provided her with the platform and opportunity to create her first application and gain visibility.
Alexander Griekspoor	Mementos	His interest in computer programming combined with a strong idea to create a new kind of storage system for academic articles. He was able to develop the business with the aid of both formal partners and the informal help of family and friends.
Tim Willis	Flexpansion	Developed a text prediction system for the disabled people during his doctorate and secured development money from the University and NESTA.
Trudi Deakin	Xperthealth	Used her doctorate as an opportunity to get proof of concept and to develop her business idea (a programme of diabetic education).

For example, Nick Gostick created '. . . a small start-up, commercializing the knowledge that I gained as part of my doctorate'. Similarly, John Okyere used his expertise in molecular genetics to create Crossgen, a company which makes tools for gene expression.

Some participants (8/37) developed their enterprises out of their experiences of being in higher education, perhaps by training and supporting future generations of researchers. Equally, a smaller group (5/37) of the entrepreneurs had gone on to work in areas that are allied to their doctorates but which did not evolve directly from them. For example, Steve Jones built on his experience of research and now runs an intellectual property and patent company. Other participants (9/37) set up businesses that have less clear relationships with the subject of their doctoral study. Joanne Whitaker moved from biomedical sciences to the design and manufacture of underwear, Caron King moved from pharmacy to change management and Emma Heathcote James moved from theology to setting up a soap making business and production company.

Regardless of the focus of their businesses, in nearly all cases the doctorate was useful as a place where intellectual, organizational and analytical skills were established. Dave Filopovich-Carter illustrated how his doctorate had developed his organizational skills in particular: 'The PhD gave me a huge amount of confidence and the process of finishing something so challenging, navigating supervisors, managing myself and my time taught me a lot about how I now manage my work'. Understanding the process of venture creation is about tracing the relationships between a range of intersecting factors. For the participants in this study doctoral education played a part, as did personality and broader labour market experience. The final section of this article proposes a framework within which it is possible to organize the kinds of resources that are typically used by doctoral researchers as they establish entrepreneurial careers. It is suggested that these resources can be effectively organized under the headings of social, financial and educational capital and that entrepreneurs are likely to be individuals who are good at combining these elements and mobilizing resources in response to an opportunity.

The role of financial capital

Access to financial capital is an important element in successful venture creation. Table 3 lists the various methods entrepreneurs used to capitalize their businesses. Just under half (17/37) of the participants managed to establish their ventures with little formal financial help, relying instead upon their own resources either to secure new, or use existing, capital: most of these ventures were relatively small and often only employed the participant, at least initially. The second largest group (7/37) secured funding through the universities where they worked. These ventures tended to be larger and required both extra people and plant or equipment. Other ventures were initially capitalized using a variety of other sources, including other public

Table 3. Capitalization of ventures (sources of funding used by the doctoral entrepreneurs).

Venture capital typology	Number
Bootstrapping	17
University funding	7
Not clear	5
Other public sector funding	3
Other	2
Competition funding	2
Venture capital	1

sector funders, competition funding and the use of venture capital. None of the entrepreneurs mentioned help from friends or family or access to substantial amounts of existing capital in relation to the initial capitalization of their ventures.

A lack of financial capital may go some way to explaining why relatively few of the doctoral entrepreneurs established their business immediately after completing their degree. Doctoral study may be a good way to generate ideas but it rarely provides its graduates with a stock of available financial capital which can be used to support the activities of a start-up. Some of those who were able to capitalize their ideas at this early stage in their career were able to do so through the provision of some kind of university or sector backed scheme. For example, Steve Howdle won the UK Research Council business plan competition in 2002 and used the prize money of £25,000 to capitalize his start-up. Tim Willis was another competition beneficiary and used product development money and advice from a NESTA (National Endowment for Science, Technology and the Arts) competition to help to establish his business.

An unusual but instructive case is that of Trudi Deakin (health sciences) who used her doctorate as an opportunity to secure funding to undertake her proof of concept work. Obtaining funding for her doctorate enabled her to pursue a randomized controlled trial leading to the creation of the X-PERT Programme, a six week diabetes self-management programme. As she said, 'I didn't actually want to do a doctorate, but in the end it was the only way I could get the funding to further develop the programme and undertake a randomised controlled trial'.

The establishment of a spin-out company was a more common mechanism for the capitalization of research ideas. Barrie Hayes Gill established Monica Healthcare as the culmination of 15 years of research. It is likely that universities feel far more able to provide financial capital to mid-career academics such as Barrie than to early career researchers and this may explain the age profile of the doctoral entrepreneurs.

There was also evidence of substantial support from organizations such as Business Link and Regional Development Agencies.[1] While these organizations rarely provided capital they frequently provided valuable access to training, advice and support which all fed into the establishment of the enterprises. Madhuri Warren noted the role of the Eastern Region Biotechnology Initiative (ERBI) and the East of England Development Agency (EEDA) which were '. . . extremely important in helping us get established'. Similarly, Jenny Koenig, now an education consultant, benefited from '. . . a couple of very good training courses around developing consultancy skills which were based at the development agency'. For Kate Ho, an IT developer with a background in computer science, it was a university competition which proved critical to her being able to get her project started: 'Things really kicked off with a competition which was run at Edinburgh University in partnership with two industry partners. It was a great platform and opportunity to create my first software application and gain awareness and visibility'.

Financial capital was vital to all – but mentioned more often by entrepreneurs involved in bringing high-tech products to market. As Max Robinson noted, 'Hi-tech products demand lots of investment up front, and the search for funding is a business in itself'. Having set up Critical Pharmaceuticals, Steven Howdle was responsible for '. . . going to pitches and presentations and we convinced a number of people to put money up' and he noted that this need to continue to raise capital has not gone away as the business has grown: 'Challenging aspects have included the raising of finance and keeping it sustainable'.

Many doctoral researchers found that seeking financial capital required the use of skills developed during their doctoral studies such as attention to detail and making presentations. For others, the overlap with social capital was clear as they relied on their networking skills to provide them with openings for the financial support they needed. The importance of financial capital cannot be ignored: it is a key element in enabling larger-scale doctoral entrepreneurship.

The role of social capital

For participants in this study it was often the experience gained in the higher education sector and the wider labour market that provided contacts which later served as a platform for venture creation and business development. Barrie Hayes Gill supervised a number of doctoral students who went on to help him to commercialize his idea and to work for his spin-out company. The ability to access this pool of highly skilled and trusted human resource was clearly an important factor in the establishment of the business. Arnab Basu also reflected on the importance of others to entrepreneurial endeavour, saying that new entrepreneurs should 'surround yourself with people better than you. Human capital is most important'.

Drawing on their existing social capital was therefore essential for the development of many of the ventures. However, they were also generally very aware of the need to amass new social capital as part of the entrepreneurial endeavour. Nathan Ryder reflected that 'it's really important to build your reputation and get

yourself known' and a similar point was made by Steve Howdle who noted that '. . . developing contacts has been extremely important in developing the business'. Krista Scott-Dixon's experience of setting up a new business in a different sector led her to conclude that building social capital and the business were inexorably linked: 'Establishing a steady stream of income and a whole new network took a lot of time'. Many of the entrepreneurs had developed active and deliberate strategies to bolster their social capital. For example, Emma Heathcote-James invested time in the development of a support network, for those in similar situations to her, called Women in Rural Enterprise (WIRE).

The role of educational capital

Also essential to the success of the entrepreneurs was their educational capital. This consisted of their doctoral qualifications and certain 'soft skills' developed throughout their studies Often these skills were supplemented and developed by others gathered during post-doctoral working life. However, regardless of the type of business they established the participants drew on their doctoral skills. As Mary Chadwick says, 'My doctorate taught analytical skills – I can read a legal document quite easily now!' Nathan Ryder emphasized how the project management skills he developed during his doctorate were highly applicable to a business environment. Other participants discussed how their doctoral experience supported their ability to present to a range of audiences, clarify their thinking, sharpen their personal branding and develop their confidence.

Participants noted the value of both the hard and soft skills that they had developed during their doctorates. Some emphasized communication skills, such as explaining difficult concepts in layman's terms. Max Robinson stressed the importance of this: 'My background of doctoral completion provided me with skills and experience in writing technically demanding concepts clearly and succinctly. This part of doctoral study is so important, because it is about selling your ideas and convincing people that there is a gap for your research'.

However, others emphasized the value of 'hard' or technical skills that they had acquired in doctoral study. John Okyere's grip of gene expression techniques was the basis of his business, while Andrew Sutton felt that technical skills developed in his doctorate enabled him to have control over his ideas and direction: 'My doctorate was excellent at ensuring I developed the skills of independent thought, to design my own experiments and dictate the way my research went'. For Trudi Deakin the technical skills were vitally important, enabling her to evidence, develop and apply the X-PERT programme.

Many of the doctoral entrepreneurs emphasized that what they had learnt since their doctorate was at least as important as what they had learnt during their doctorate. Some talked about the way in which the establishment of their business had driven their learning. Joanne Whitaker acknowledged that her learning was still ongoing: 'Inventing and launching a new product requires a broad range of skills: financial, business, technical, IP, funding, research, development, people management, customer service and many more. All my little jobs during college, my degrees and full time work prepared me for the experience of running a company'. Caron King also highlighted the discrepancy between her highly developed technical skills and her initial deficit of business skills: 'While I am a good operator (and this is what I sell to other people!) it is the up-front selling of that which is very important, and also the pure administration and finance stuff which you don't get taught that is the challenge'. This led to some, such as Andy Phillipps, accessing specific education and training to meet these needs: 'I did an MBA to enable me to get the full picture and marry this with the engineering that I already knew'.

Educational capital in the form of skills and qualifications were undoubtedly essential to the career progression of those interviewed. The 'hard' and 'soft' knowledge and skills developed throughout doctoral study and beyond were often intertwined. For most of the doctoral entrepreneurs it was this synthesis of high level knowledge, technical skills and broader 'soft skills' that enabled their businesses to be born and then to thrive.

Conclusions

The translation of skills and knowledge into economic value is clearly of considerable concern both at national government level and for HEIs seeking to develop their knowledge transfer activity. One way in which the transfer of value happens is through the commercialization of research and innovation. Entrepreneurship provides an important channel through which research ideas can be commercialized and the economic value of research investment realized.

Following this paper, there would be considerable value in a larger scale study of doctoral entrepreneurs. The very high skills possessed by this group, their training in research and innovation and their value to the high skill and high yield elements of the economy should help to focus the interest of policy makers and researchers on them. Whilst this study is no more than an initial exploration of some of the issues relating to

doctoral entrepreneurship, it has nevertheless identified a number of key questions that may inform future studies. In particular there is a need for a study of labour market data to establish more clearly how common a phenomenon doctoral entrepreneurship is and the demographic patterns of doctoral entrepreneurs.

This study also briefly explored how the personalities of the participants interacted with the environment within which they pursued their careers. The stories that the participants tell suggest that both who they are and what they experience contribute to the establishment of successful ventures. The distinction made by Reynolds *et al* (2002) between opportunity entrepreneurship and necessity entrepreneurship seems useful in helping to explain the different environmental factors that can lead to the establishment of a successful venture. Deeper research around how personality intersects with entrepreneurial activity in the case of doctoral entrepreneurs would be useful.

Finally the resources that doctoral entrepreneurs drew on in the establishment of their enterprises have been explored. The stories told by the participants suggested that financial, social and educational capital were all critical to their success as entrepreneurs. This typology may be useful in guiding further examinations of what factors contribute to entrepreneurial success and, in particular, in exploring whether doctoral entrepreneurs require a particular blend of these kinds of resources which makes them distinctive from other entrepreneurs. Further exploration of how these factors interact and how the context within which the business is developed (sector, region, relationship to higher education, etc) may have an effect on the success rate will also be important.

The aim of studying doctoral entrepreneurship is clearly to further our understanding of the process so that entrepreneurship can be supported more effectively in the doctoral community. This study has identified some areas in which further thinking would certainly be valuable. It is of course important to recognize that the secret of doctoral entrepreneurship is not something that is likely to be resolved with one investigation. The so-called 'x-factor' clearly plays an important role and analyses of chaos and complexity would undoubtedly have something to contribute to this endeavour. Nonetheless, from this initial study there do seem to be some patterns that are worthy of further exploration. It is hoped that, if nothing else, this study can at least put the idea of doctoral entrepreneurship more firmly on the map.

Notes

[1] Regional Development Agencies in England, RDAs, were abolished in 2011 by the UK coalition government. They are to be replaced by Local Enterprise Partnerships, LEPs, which will provide different services, and will deal with smaller geographic areas of the country, to those of the RDAs.

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Appendix 1.Overview of participants in the study.

Name	Subject	Gender	Year of completion	Career Summary
Alex Linley	Psychology	Male	2004	Spent a number of years in academia before starting up his consultancy Capp.
Alexander Griekspoor	Biological Science	Male	2006	Became a software developer after discovery of computer programming leading to creation of Flexpansion.
Alexandra Samuel	Politics	Female	2004	Researched the Internet as a tool for community-building and used this expertise to set up the social media consultancy Social Signal.
Andy Sutton	Biochemistry, Molecular Biology and Biophysics	Male	1984	Was involved in a several business start-ups, and is now CEO of Compandia Ltd.
Arnab Basu	Physics	Male	?	Currently CEO of Kromek, an IP-rich company producing products for x-ray detection.
Atul Shah	Business and management	Male	1993	Had a lengthy career in academia before setting up a social enterprise, Diverse Ethics.
Barrie Hopson	Psychology	Male	1969	Worked in a variety of roles throughout his career, spanning teaching, research and writing.
Barrie R Hayes-Gill	Electronic Engineering	Male	1978	Combined a background in industry with his academic subject knowledge to create the spin-out Monica Healthcare.
Bill Law	Education	Male	1976	Worked for several years as a lecturer before embarking on full-time education and guidance consultancy.
Brian Tanner	Materials Science	Male	1972	Worked as a researcher, lecturer and now Professor in higher education. Established his company in 1978 alongside his academic career.
Caron King	Biomedical Science	Female	1991	Worked in the pharmaceutical industry in technical and management roles before founding a change management consultancy.
Dave Filopovich-Carter	Law	Male	2000	Experiences of teaching and project management during and since doctorate led to the establishment of his own training consultancy.
David Goulson	Biology	Male	1991	Remained in academia in the biological and environmental sciences and set up the Bumble Bee Conservation trust.
Emma Heathcote-James	Theology	Female	2001	Followed up a theology doctorate with a book, and now combines soap making with running a production company.
Jo VanEvery	Sociology	Female	1994	Runs a coaching and academic development consultancy that draws on her experience as an academic and working for a research funder.
Joanne Whitaker	Biomedical Science	Female	2002	Worked as a researcher and intellectual property specialist before launching a lingerie company.
John Okyere	Biochemistry, Molecular Biology and Biophysics	Male	2001	Developed ideas for a business during postdoctoral studies, and now runs Crossgen which makes tools for gene expression.
Kate Ho	Computer Science	Female	2010	Following a doctorate in Computer Science, brought a software application to market through the start-up Interface3.
Kenneth Mostern	English	Male	1995	Followed up an academic career with creation of election company, TrueBallot – running elections on behalf of labour unions.
Krista Scott-Dixon	Women's studies	Female	2002	Worked as a researcher and editor before starting a fitness website.

Appendix 1.*Continued*

Name	Subject	Gender	Year of completion	Career Summary
Mark Hughes	Chemistry	Male	2001	Continued to study following his doctorate before becoming a management consultant and then setting up his own consultancy.
Mary Chadwick	History	Female	1977	Followed a career as an investment banker with the development of a social enterprise.
Max Robinson	Electrical and Electronic Engineering	Male	1972	Combined academic work with running a number of spin-outs and consultancies.
Nathan Ryder	Mathematics	Male	2008	Worked on career skills workshops during doctorate and used this experience to set up as a training consultant following graduation.
Neil Jennings	Geography	Male	2008	Followed his doctorate by setting up a social enterprise focused on climate change.
Nick Gostick	Microbiology	Male	1989	Joined a scientific company as a Technical Manager following his doctorate. He then established his own start-up in the area of wastewater treatment. He is now an Incubation Manager and advises new start-ups.
Rebecca Steinitz	English	Female	1997	Decided against having a traditional 'job' and now describes herself as a writer-editor-consultant.
Robin Henderson	Mechanical Engineering	Male	1997	Worked as a researcher and lecturer before establishing his own training consultancy.
Steve Howdle	Chemistry	Male	1989	Has combined academic work with running a spin-out company.
Steve Jones	Chemistry	Male	1982	Following his doctorate he worked in industry. He then retrained as a patent attorney before creating an intellectual property company.
Tim Hart	Microbiology	Male	1997	Worked as a researcher before setting up two spin-out companies.
Tim Willis	Computer Science	Male	2008	Developed a text prediction system for disabled people during his doctorate and developed the idea into a business towards the end of the doctorate.
Trudi Deakin	Healthcare	Female	2004	Undertook doctorate to test a programme for diabetic education and then developed a business out of the programme that she had tested.
Andy Phillipps	Materials Science	Male	1993	Has set up a variety of businesses since his doctorate in Materials Science.
Madhuri Warren	Clinical medicine and Biomedical science	Female	2002	A long career in clinical medicine prior to retraining as a research scientist and completing as a research scientist and completing doctorate. Academic and commercial experience of discovery research and clinical medicine led to creation of diagnostics company, Pathology Diagnostics Ltd.
Anon*	Geology	Male	?	Has combined a successful academic career with long stints as a consultant to both companies and governments.
Jenny Koenig	Pharmacology, toxicology and pharmacy	Female	1989	Enjoyed a highly successful academic career, before becoming a science education consultant.

*One individual wished not to be named in the published paper.