Article

Recognising scientific entrepreneurship in New Zealand

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Introduction

A widely-held view is that if New Zealand wants to get wealthier, it needs increased productivity. A way of achieving higher productivity is to innovate, and research, science and technology (RS&T) and entrepreneurship are two means (among others) of contributing to innovation (Knuckey *et al*. 2002; Workplace Productivity Working Group 2004; Hall & Scobie 2006; Smith 2006; Mason & Osborne 2007; Earle 2010). It might be assumed that these two separate factors – science and entrepreneurship – would make an even greater contribution were they combined in some way, and indeed much public policy is aimed at achieving such a combination (Ministry of Research, Science and Technology, MoRST 2007).

Yet scientific entrepreneurship is a phenomenon that has not received a great deal of consideration either in New Zealand or internationally (Oliver 2004). This is largely because, although science and entrepreneurship are both recognised as being important contributors to innovation, there is a prevalent mental model (Johnson-Laird 1983) of these two sets of activities belonging to quite separate, albeit linked realms and requiring distinct sets of competencies. This conventional model underpins a linear view – of research producing academic knowledge, which is then turned into intellectual property (IP) and transferred into the commercial market (Slaughter & Leslie 1997; Evans *et al*. 2004). That is to say, ideas are generated, codified and passed along a chain from one person, or agency, to another.

However, it is increasingly recognised that it is tacit knowledge and other attributes that are of critical importance in the commercialisation of scientific research (Buenstorf 2009), and tacit knowledge can be transferred only through the movement of people who have it. This implies a different model of commercialisation wherein individual scientists take their ideas with them as they progress, through various stages, towards the market (Etzkowitz 1998; Graversen & Friis-Jensen 2001; Nås *et al*. 2001; Corolleur *et al*. 2004; Murray 2004). Scientists capable of operating in this fashion are rare, particularly when entrepreneurship is also involved, but not so rare as policy makers may think.

The classical linear technology transfer model does not reflect the way science actually works, and it is much discredited (Ziman 1984; Kline & Rosenberg 1986; Stokes 1997; Etzkowitz 1998), but policies and structures are still often based upon it, as with the design of the New Zealand science system. A consequence of such design can be suppression of both creativity (Charlton 2009) and the potential for scientific entrepreneurship.

It may be the case that conventional processes of transfer will work in the presence of already-existing sectors with 'absorptive capacity' which are capable of delivering very good returns on investment (Hall & Scobie 2006). Where there is no absorptive capacity, however, for example in nascent industries, the transfer model breaks down completely, both conceptually and in practical terms.

Scientific entrepreneurship offers another approach to creating radical, technology-push innovations and underpinning the development of new economic sectors (Schumpeter 1987; Workplace Productivity Working Group 2004). But study of this phenomenon faces a number of challenges, and, given the complexity involved, traditional research methods such as surveys and statistical analysis are inappropriate, both philosophically and in terms of scale, for building understanding of scientific entrepreneurship. New perspectives are needed. The research project summarised in this paper used an alternative approach to the topic of study, including a novel research framework and methodology, in an attempt to throw new light on the process of innovation and to inform public policy development.

Summary of methodology

Available space precludes a full description of the methodology, but this can be found at http://researcharchive.vuw.ac.nz/handle/10063/810. In brief, interviews were held with 46 respondents who either met working criteria for being a scientific entrepreneur, or worked with scientific entrepreneurs, or developed policy for science-based innovation. As well, an analysis was carried out of New Zealand science policy documents and reports produced from the 1980s until the middle of

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the first decade of the 21st Century. Some of the conclusions of that documentary analysis have been fed back into this introduction, and are described more fully elsewhere (Menzies 2008). A selection of overall findings, and a discussion of implications for policy and management, are provided in the rest of this paper.

What the literature says

Entrepreneurship

There is no such thing as an average entrepreneur, let alone an average scientific entrepreneur. Nevertheless, it is possible to identify *a priori* indicators of entrepreneurial success and contextual factors or individual attributes that contribute to entrepreneurship. Several studies have shown a cluster of personality traits common among all successful entrepreneurs, including the need for achievement (McLelland 1961) as well as persistence, innovative outlook, low need for conformity, high energy level, risk taking, and efficiency (Belt 1990). The factors which empirical evidence most strongly links to entrepreneurial success are: high self-efficacy; ability to spot and recognise opportunities; high personal perseverance; high human and social capital; and superior social skills (Markman & Baron 2003). Meta-analysis by Zhao & Seibert (2006) indicates significant differences between entrepreneurs and managers on four personality dimensions: entrepreneurs score higher on conscientiousness and openness to experience and lower on neuroticism and agreeableness. No difference is found for extraversion. Hansemark (1998) claims that only two psychological attributes (of all those that have been extensively studied) have shown any significant relation to entrepreneurship: need for achievement and *locus of control*. Many other researchers suggest that these are simply artefacts of cultural conditioning, with the latter comprising a mix of other dimensions of personality and cognition (Llewellyn & Wilson 2003).

Risk is a major recurring theme in the literature about entrepreneurship, and numerous attempts have been made to measure the risk-taking attribute of entrepreneurs, but this is not just a function of personality. It also seems to reflect organisational context and history (McCarthy 2000).

Opportunity recognition is also seen by many as a key behaviour of entrepreneurs (Smart & Conant 1994; Baum *et al*. 2001: 293) although opportunity recognition might also be seen to be driven more by the distinctive knowledge possessed by individuals than by their personality traits (Shane 2000). Entrepreneurs often challenge existing wisdom and reconcile opposing forces, moulding external information with their individual decision-making processes. Nevertheless entrepreneurs need a considerable amount of social and interpersonal skill to build and cultivate networks and other social capital that will enable them to glean the information and resources they need (Cromie 1994; Baron & Markman 2000). They have to be able to organise and lead others if their endeavours are to be successful. At the earliest stages, most entrepreneurs tend to be more or less creative, visionary, opportunistic, intentional, and controlling (Smart & Conant 1994).

The literature reveals that most entrepreneurs seek and experience personal autonomy, a sense of achievement and enhanced job satisfaction from proprietorship. While not the prime motivator, the potential to earn substantial sums of money acts as a powerful reinforcer of behaviour. Most business proprietors are keen to be in control of their own lives rather than accept the subordination frequently encountered in bureaucratic organisations. Putting a venture together and making a success of it requires a good deal of independent action on the part of the entrepreneur but it also affords a strong sense of accomplishment to those individuals who manage to do so (Cromie 1994).

Science and entrepreneurship

Science differs from entrepreneurship in that it is often regarded as being based on a particular set of norms and it has a sociology which creates a difference from the world of business in general (Merton 1973; Ziman 1984; Ziman 1994). But many of the traits required by scientists are not inherently different from those required by people working in many other realms – for example imagination, self-criticism, diligence and curiosity. Scientists are considered to have a devotion to truth and respect for the public literature, and to be motivated by the science itself rather than by external rewards (*ibid*). In this respect they are quite similar to many entrepreneurs. However, the traits of scientists have been so idealised and eulogised that some that are less desirable but are inseparable from the role, such as narrowness of view and egoism, have been ignored (Ziman 1984).

Like entrepreneurs, scientists spot opportunities and take risks, albeit these are less likely to be of a financial nature. They also at times challenge conventional wisdom (Kuhn 1996). But science is a collective activity (as is business) and its output belongs to a world of public knowledge (Ziman 1984; Callaghan 2004). Recognition tends to come from extreme specialisation (*ibid*) and in the form of credentials, awards and measures such as citation rates for publications although these suffer from a number of limitations (Whitehead 2003). Scientists are rewarded by these non-economic returns for sharing knowledge – in effect the bargain that is struck for making knowledge freely available.

Oliver (2004) identifies an inherent conflict between entrepreneurship as an individualised behaviour and research as a collaborative process. This would seem to misunderstand the mostly collaborative nature of true entrepreneurship as described in other literature but there may also be a values conflict, for example between the information sharing of science and the secrecy of business. Finding the right balance between the two is a delicate challenge that not all can negotiate (Janson & McQueen 2003). It is possible that scientists who are 'insiders' may have to become 'outsiders' if they are to become entrepreneurial, and this comes with a personal cost (Ziman 1984; Morris *et al*. 2002).

Etzkowitz (1998) does not see a divide between scientific entrepreneurship and other kinds, but acknowledges that:

> *As long as the traditional disjuncture between theory and invention is accepted, the emergence of entrepreneurial science is an anomaly, even a deviance from the shared normative role model of scientific behavior* (p. 826)

There is also still a popular view that scientists cannot be entrepreneurs (Heeringa 2003; MoRST 2007) and the increase of entrepreneurial activity within academia has raised concerns that the research orientation of universities might become 'contaminated' by the application-oriented needs of industry. In reality no trade-off seems to have occurred between entrepreneurial and scientific activities and it is concluded that it is indeed feasible to organise both scientific and entrepreneurial activities, without one jeopardising the other (Van Looy *et al*. 2004). Slaughter & Leslie (1997) found that faculty members did not simply replace altruism with a concern for profit:

> *Rather, they elided altruism and profit, viewing profit making as a means to serve their unit, do science, and serve the common good* (p. 179)

Rubinstein *et al*. (2002) report that industry seeks *T-shaped* people, in whom the down-stroke represents depth and specialist knowledge in a discipline and the cross-stroke represents breadth and flexibility. The authors note that many science students learn such skills, but typically only in departments of social sciences and in business and management schools. They therefore make recommendations for changes in teaching to build requisite knowledge and skills such as teamwork. Wright *et al*. (2007) also extol the virtues of university programmes which combine science and technology with business management but there exists a tension to be managed. On the one hand, interdisciplinary efforts seldom work if the participants are not fully competent in their own fields, but on the other, disciplinary competence is sometimes at odds with broad interests and imaginative speculation (Davies & Devlin 2007).

Human capital

The fields of science and entrepreneurship may have differences, but they are both human activities which may be employed for the purposes of economic innovation. In order to understand the overlapping phenomenon of scientific entrepreneurship therefore, it seems sensible to draw on the knowledge base related to human capital – a subset of the economics literature which originated with Becker (1964) and Schultz (1971). There is, however, a view which regards human capital as an almost pejorative term and a manifestation of the worst excesses of neoclassical economic theory (treating people as mere commodities to be invested in, bought and sold). Ellstrom (1997), for example, criticises human capital theory on the grounds that it is wrongly informed by a rationalistic perspective which does not readily lend itself to the study of learning processes within firms and their role in the promotion of social innovation. The criticisms of Ellstrom and others may have some merit (*see also* Benade 2007), but human capital theory does seem to have evolved past pure rationalism and neoclassicism and it provides useful insights which are complemented by other literature. For example it is useful to note that there are higher rates of return from earlier stages of education, and the cost of later training increases due to higher rates of income foregone (Schultz 1971; Nerdrum & Erikson 2001). Much human capital development, particularly in the sciences, is also cumulative, i.e. each new element builds on what has gone before (Ziman 1984) and tends to move incrementally rather than in leaps and bounds. The implication is that it is expensive to add on human capital later in life to people who are highly trained in another field. In purely investment terms, is better to embed desired attributes as early as possible in the life cycle (Durbin 2004; Keeley 2007).

Understanding of the role of human capital has been incorporated in considerations of the so-called ‘knowledge economy’ (Keeley 2007). However, policy work on science and technology human capital (STHC) has tended to focus more on quantitative measures of stocks and flows which have been represented by traditional indicators such as qualifications or codified knowledge such as patents. While undoubtedly important, these measures are not adequate for recognising the increasingly important tacit knowledge (Polanyi 1967) and other attributes which are coming to assume greater significance within RS&T-based innovation. The focus on traditional, quantitative measurement has tended to be reprised at the operational level in research organisations (Menzies 2008). The *quality* of human capital is measured only indirectly.

There are, however, trends towards measuring the quality of national human capital by assessing what people are actually capable of doing and the degree of matching of those abilities with future needs. A competence ‘movement’ has arisen out of controversy over the validity of measures and insufficient correlation between measured intelligence and life outcomes (Brophy & Kiely 2002), and there is a logic which suggests that identification and direct measurement of observed behaviours and their underlying composition and effects in particular situations (together comprising competencies) are key elements in building understanding of the role of human capital in a modern innovation system (OECD 2008).

Competencies

Despite their ubiquity, the concepts of competence and qualification are often poorly defined in the literature, and a general consensus on their meaning seems to be lacking. There is, though, a persistent element of hierarchy among terms (Ellstrom 1997; Oates 2001), albeit once again the terms used in different parts of the hierarchy may differ.

What is common among definitions is that competencies are seen as comprising more than simply knowledge and skills, and they always have an aspect of application within a context. But the context is not simply a passive background. Hipkins (2006) describes views of learning which distinguish between situated knowledge and distributed knowledge, where competence emerges in the context rather than being seen as the property of an individual. Rychen & Salganik (2002) go further, to say that it is the demand, task or activity which defines the internal structure of a competency.

In National Innovation Systems (NIS), emphasis is beginning to shift to take on board not only the R&D system and the interactive learning processes between firms and other institutions, but also what might be called ‘competence-building systems’ (Tomlinson 2001). There has been relatively little work on studying these systems, yet one of the major reasons why NIS differ is connected to the people they contain and the building of competencies. Indeed:

> *While it may be argued that the science part of National Innovation Systems has become increasingly globalised, education systems and labour markets remain more closed and labour specific* (Tomlinson 2001: p. 33)

For managers, a model of effective job performance based on fit between the individual, the job’s demands, and the organisational environment has been developed by Boyatzis (1982). Specific actions or behaviours are in the overlap between these three domains, all of which are represented in the model shown in Figure 1.

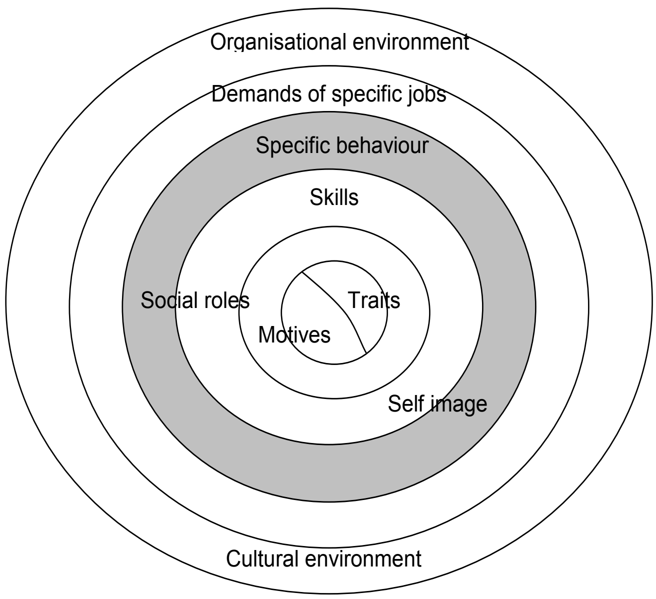

Figure 1. Boyatzis' competency model.

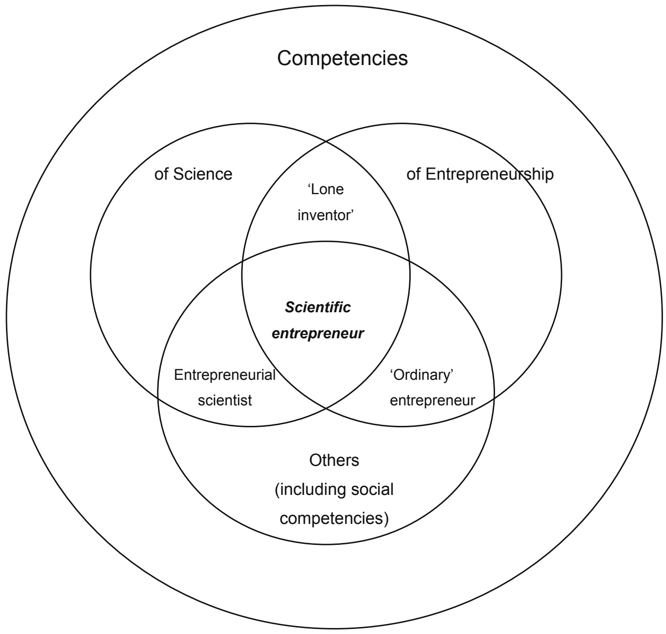

Figure 2. Conceptual location of the competencies of scientific entrepreneurship.

A job competency is defined as:

> *An underlying characteristic of a person which results in effective and/or superior performance in a job* (Boyatzis 1982)

In Boyatzis' own terms, an underlying characteristic (attribute) of a person may be a motive, trait, skill, aspect of one's self-image or social role, or a body of knowledge which he or she uses. The existence and possession of the above characteristics may or may not be known by the person who has them – an idea that owes much to Polanyi (1967).

Given different schools of thought as to whether competencies are characteristics of an organisation, a job (or role) or an individual (Hamel & Pralahad 1991; Ellstrom 1997; Brophy & Kiely 2002; Lawson 2004), the value of the Boyatzis model is in its recognition of all these and their interaction within a context, thus enabling holistic thinking and research. The threads of the various literatures can be encompassed within this model, which, while presented in circular form, can be seen to occupy a 'vertical' dimension (from the 'outside' to the 'inside'). Thinking 'horizontally' we can see how the competencies of scientific entrepreneurship might be located in the zone of overlap between those of other realms (Figure 2).

These concepts are of little more than passing research interest unless they can be employed as part of an applied methodology, with results such as those described in the following section.

Results

The quotations provided here from participants are drawn from a much larger selection (Menzies 2008) to provide an illustrative narrative on similarities and differences between scientists and entrepreneurs. The 'grounded' analysis produced themes which at a high level were able to be organised within the framework provided by the Boyatzis competency model, thereby validating its usefulness.

Similarities: scientists and entrepreneurs

Although they might be applied differently in each realm, some attributes enable people to work in both science and business. The ability to communicate in each is a key example:

> *Whether people believe it or not, if you're not a good communicator you're never going to be an effective scientist. And the people who ultimately make it in science and distinguish them from those who don't but show promise, is that they can write well and they can speak well and clearly about their work, and speak simply about their work.*

Alternatively, the same or similar attributes, such as creativity or perseverance, might be applied out of one realm into another in much the same way:

> *Of course the attributes of a good scientific researcher are a person who is patient, and perseverant, and very organised and very creative. And the two there that are in common with entrepreneurship is persistence or, perseverance and creativity.*

Differences: scientists and entrepreneurs

Many respondents are of the firm view that the attributes of scientists and entrepreneurs are totally different, but allow that there is some overlap. The most significant difference is that scientists are less likely to be 'ready for market' or willing to let a product go:

> *An entrepreneur needs to be, if you like, very broadly looking and not see problems. So, if they come across a problem they'll either solve it or ignore it and then somebody needs to pick up the pieces after them. But a science person, or a university-trained person, will tend to identify a project and risk and analyse it and all that sort of thing.*

Scientists and business people/entrepreneurs are seen as having quite different modes of communicating and there may be different attitudes to problems:

> *There's an incredible level of discipline required I think to do research and an incredibly ordered and methodical approach. And that seems to me to be somewhat inconsistent with the highly creative paradigm - the paradigm that doesn't see the problems. It just sees that there must be an answer.*

This does not sit with the view of scientific problem solving held by other respondents – all prominent, successful scientists, who see science as being highly creative. But in general it is clear there are areas of difference, similarity and overlap between scientists and entrepreneurs. The challenge is to find a model that incorporates these similarities and differences and allows for connecting the two realms across any boundaries that may exist. One respondent describes a model of an entrepreneur as a 'broker' who can cross boundaries between science and business in order to help them come together:

> *I've spent a lot of time in .... with people who are like, operating across the boundary, and some, some were quite good at it, but they ended up becoming managers in operations that meant that they had to leave the science bench behind....Entrepreneurs are a different kettle of fish, they are people who operate in this case, if we're focusing around science and business, then they are people who operate between science and business, and they might not be the scientists themselves. They're most likely not the scientists themselves.*

Other respondents are of the view that entrepreneurs work on or across boundaries easily because they are either not aware of them or see them as being of no significance at all. Scientific entrepreneurs are different again. They are seen by respondents as rare individuals, but those that do exist are seen to have a cluster of similar attributes, headed by the 'ability to see the big picture'. However, equal numbers of respondents note the need for a *broad* 'big picture' as do the need for a *deep* one. One respondent refers to research (Roberts 1991) which shows that successful intrapreneurs and entrepreneurs need:

> *A deep conceptual understanding of the basic science or engineering behind the idea, the product or the service if it is a scientific based one. So we have little evidence of generalists producing real innovations.*

Breadth can come from life experience or the application of particular problem solving techniques:

> *I think entrepreneurs have to be people driven by curiosity and inventiveness, I think they are people who think outside the square. I think often it can be due to life experiences or it could be due to extensive training in particular disciplines, which because these people think outside the square, they can take advantage of the knowledge they have in one area and translate it in a very imaginative way into another area. So it's all about opportunism and it's all about extending your mindset beyond your conventional boundaries.*

The remarks in the above paragraph repeat a recurring theme, as does the following quote about the importance of an orientation towards the *application* of science and technology:

> *You will find brilliant fundamental scientists who are also scientific entrepreneurs, so the two can overlap, but generally with scientific entrepreneurs in my experience, they're more likely to be guys who are, or girls who are, more at the applied end of the spectrum, possibly a bit more towards, yes, applied, so applied science and engineering .... They're someone who's going to be more connected to the market at the practical applications of the idea, they'll be scanning the environment for, 'hey, if I take that I can use it there', and then maybe have more of the skills in terms of pulling the interest in and getting a group together to drive the thing forward.*

> *What we want, is someone who can develop a product with the commercial goal in the forefront of their mind and not the scientific goal.*

Only two respondents state that in the context of scientific entrepreneurship they consciously 'switch' the way they operate from one realm to the other, despite this type of strategy being probed for. Most respondents who comment on their own behaviour in this regard speak of the 'seamlessness' of science and business, or of themselves 'being the same person' in both realms. This reinforces the presence of core attributes that enable some individuals to be both scientists and entrepreneurs.

Discussion

There is a high level of consistency between the key themes in the literature and the findings of the field research, but the latter make some things clearer. The competencies of entrepreneurs, scientists and scientific entrepreneurs emerge as being different from one another, but the component sets of attributes are not mutually exclusive. Some attributes *are* unique to one particular group, but others are similar or shared.

One way to characterise scientific entrepreneurs would be as entrepreneurs who happen to operate between science and business rather than in some other realm – i.e. it's their entrepreneurial attributes that are key and so entrepreneurs should be directed towards science to act in brokering ways.

However, without having a *whole of picture insight* based in deep knowledge it is difficult for an entrepreneur to understand what is scientifically possible and to fully exploit related opportunities. And since some of the attributes of scientists and entrepreneurs are effectively opposites, scientific entrepreneurs must have an ability to reconcile contradictions in attributes such as motivation, propensity to perfectionism and attitudes to financial risk.

They also have other higher order attributes which allow them to relate to opportunities, to communicate within and between the realms of science and business and to lead others towards the realisation of an entrepreneurial vision. These attributes, along with those that are shared by scientists and entrepreneurs, are the underpinnings of *metacompetencies*.

The term metacompetency is not a new one, but it has been used in different senses, for example to describe the management of tension between innovation and continuity (Rychen & Salganik 2000: citing Haste (1999)) or in the sense of knowledge about the availability and use of one's own competencies to optimise learning and solve problems. In this view, metacompetencies operate at a different level from either separate or shared competencies. Metacompetencies have also been used in selecting and developing executives (Briscoe & Hall 1999).

From a much larger set of results than the illustrative set presented in this paper, a range of attributes of scientific entrepreneurs have been identified and sorted as identified in Figure 3. This metacompetency model is limited in that it excludes contextual factors, but respondents' comments confirm the importance of context and the likelihood that the apparent

Attributes of scientific entrepreneurs

Ability to reconcile differences in respective competencies
High-level communication skills within and between realms
High-level leadership and teambuilding abilities
High-level ability to realise opportunities for commercialising RS&T

Attributes for scientific realm	Attributes for entrepreneurship realm
Motivated by knowledge for its own sake	Motivated by desire for application
Deep knowledge	Broad knowledge
Aversion to financial risk	Open to financial risk
Incremental decision maker	‘Heuristic’ decision maker
Tending to perfectionism	Satisfied with ‘good enough’
Ability to realise scientific opportunities	Ability to realise commercial opportunities

Shared attributes

Creative, lateral thinking
Vision
Seek out and create knowledge
See ideas as tools
Focus
Problem solving
Managed risk taking
Connectedness (building and using related social capital)
Perseverance
High levels of self-efficacy

Figure 3. Attributes of metacompetencies of scientific entrepreneurship.

paucity of scientific entrepreneurs is due to the exigencies such people face within innovation systems. There arises a question for public policy as to whether scientific entrepreneurship is of sufficient value to justify measures being taken to increase its incidence.

Policy challenges

Scientific entrepreneurship is not proposed as a ‘magic bullet’ alternative to current practice. But new policies and schemes aimed at fostering its development could be introduced *in parallel* with existing approaches.

In which case, it will first be necessary to allow for the *possibility* of scientific entrepreneurship. This means rejecting artificial distinctions between science and commerce (and basic and applied research) and the adoption of new mental models which expand the overlaps between science and entrepreneurship.

Such changes in perception may be resisted, for reasons described by Snow (1963) and Schön (1983) although not as much as was once the case (Slaughter & Leslie 1997). It is possible that current policy anticipates problems that do not exist and is consequently lagging behind reality on this point.

Before any resistance can be overcome, values such as the pursuit of knowledge for its own sake and for earliest publication will need to be reconciled with the values of commercialisation. This can be achieved if scientists are imbued with notions of consideration of use (Stokes 1997) and have the desire, competencies and opportunities to move with their ideas as they progress to application and ultimately the creation of public benefit (Etzkowitz 1998). A focus on these underlying competencies is likely to bear more fruit than (for example) topic-based workforce planning which operates at the wrong level for addressing what is effectively a motivational challenge.

Some scientific entrepreneurs are well recognised once they have succeeded and, in general, these are people for whom no additional policy intervention would make any difference to their propensity for entrepreneurship – although it might be possible to influence the timing of their success. Conversely there are those engaged in valuable scientific research who do not have any of the innate attributes of entrepreneurs, and in whom it would be counterproductive to try to engender scientifically entrepreneurial behaviour.

The group that is of interest is made up of those who have the necessary innate attributes but not others such as key knowledge, skills and attitudes that are able to be influenced through the creation of the right context and various other developmental measures. If these individuals can be better recognised as their competencies of scientific entrepreneurship *emerge,* it will be possible to design policies aimed at *tipping them over* into scientific entrepreneurship and increasing its overall incidence within the national innovation system.

In several countries there have been considerable efforts made in creating an appropriate context for the commercialising of RS&T, not only through structural means but more widely, for example in attempting to engender culture change and in making linkages within innovation systems. This activity is presumably intended to generate desired behaviour and to be applauded, but it is insufficient in and of itself. All levels are important in a competency model and it is at least as important to work from the bottom upwards. Yet innovation policies directed at the attributes layers are inconsistent and in their infancy. A competency approach can assist in simultaneously nurturing desired attributes and creating the appropriate context for them to find expression.

A holistic concept of competence-building systems (Tomlinson 2001) is required, implying a broadening of the conception of NIS to include agencies dealing with schooling and tertiary education. The competency-based approach is consistent with international trends in education and general management, but before it can be accepted in RS&T and innovation policy more broadly, there will first need to be deeper and more consistent consideration given to the nature of human capital. This includes acceptance of the view that merely measuring conventional indicators of human capital is insufficient for recognising its quality. While such measurement remains important, it is a particular feature of centralised systems and needs instead to be embedded in a broader view of the process by which quality is recognised.

A common language of competencies will help facilitate a faster move towards policy integration, and provide the basis for broader innovative approaches to the creation of quality in human capital. Current approaches to developing deep scientific knowledge are probably appropriate as they are, but traditional, content-based training is unlikely to bring about the attitudinal change and breadth of knowledge that are most likely to underpin the tipping-over process described above. New models (already being employed in some places) connect learners with the contexts within which they simultaneously create and apply new knowledge. Experiential, cross-disciplinary learning and a developmental approach (Ellstrom 1997) and apprentice-style (relational) approaches to competency formation are likely to be more effective (Gonczi 2002). Specifically, attention needs to be brought to bear on recognising the key attributes underlying metacompetencies as shown in Figure 3.

It has to be acknowledged that the characterisation and assessment of competencies is still problematic because most of their underlying attributes are tacit and invisible to conventional methods of measurement. More research is needed, but an interim solution is to devolve responsibility for recognising these attributes to research organisations, while retaining centralised measurement of aggregate outputs and outcomes at a higher level. This approach will raise new challenges for the ways in which science and its commercialisation are managed.

Management challenges

Frequently, policy and practice aimed at the entrepreneurial connection of science and business rely on brokering between the two. The ability of scientists to engage directly with the marketplace is quite restricted, and perceived deficits in their entrepreneurial competencies are rectified through the agency of others (a relatively passive or reactive strategy to team building on the part of the central individual). But successful entrepreneurship involves the mobilisation of other people and their resources in pursuit of what the entrepreneur is trying to achieve. Indeed, a crucial difference between those who are scientific entrepreneurs and those who are not may be that the former can, if they have a vision, collect together the team they need (a proactive strategy) rather than having the team added to them. This implies a whole new approach on the part of senior management.

Although the recent review of New Zealand's Crown research institutes (CRIs) addresses some important barriers to the effective performance of those organisations, it perpetuates the 'outside in' approach of the initial science reforms (Palmer 1994), whereby structures were built with the expectation that the scientific workforce would ultimately fit into them. An alternative approach, from the 'inside out' would be to first establish desired outcomes and the behaviours required to deliver them, and then to design enabling organisations and processes. The Crown Research Institute Taskforce report (2010) makes only two references to 'human capability' but does leave the door open for changes in the way that capability is managed.

Recognition of scientific entrepreneurship is more likely to be effective if focused on real-time behaviour and with reference to a sensitising mental model. It is multi-skilled mentors in commercial contexts who are in the best position to recognise and tip over emergent scientific entrepreneurs. The metacompetency model provides a tool for the further training and development needed in order to be able to manage tacit knowledge and other attributes, and to infer entrepreneurial behaviours and manage their development.

Where scientific entrepreneurs *are* recognised, they will need to be given opportunities to lead the commercialisation process, with the discretion to create the teams and other capabilities they need rather than those capabilities being assembled by others who do not have the required whole-of-picture insight. The corollary will be a reliance on managers' reflective judgement (Schön 1983) and resources placed at their discretion, yet no increase, and probably a diminution, of measurement-based reporting on how those resources are deployed.

Changed management practices will be possible only given the right organisational context (Ziman 1984, 1994; Bryson & Merritt undated). Entrepreneurial decision making is heuristic (Forstater 1999; Barney 2004) and not particularly compatible with corporate processes. Organisations need a high level of corporate management skill to create an environment that will incentivise and allow for both entrepreneurial and non-entrepreneurial behaviour, and to allocate appropriate levels of risk and reward. There will also need to be managed changes in the sociology of science so that scientists affirm rather than create negative peer pressure on their fellows who engage in commerce (Walton 2003: 157). For some scientific entrepreneurs there is great value to be gained from networking together (it seems that they are good at recognising each other). Modelling their behaviour on that of successful exemplars can assist scientific entrepreneurs recognise their *own* competencies, thereby enabling them to follow the same path.

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