Chapter 10
Entrepreneurship-Professionalism-Leadership: A Framework for Nurturing and Managing the R&D Workforce for a National Innovation Ecosystem

Kim-Yin Chan, Kwee Hoon Lim and Marilyn A. Uy

Abstract Today, many developed countries around the world are embracing science, technology and innovation as an important engine for economic growth. Innovation is fundamentally a human activity and a social one that involves more than any single individual's efforts. It is thus important not only to study core innovation processes but also the approach to nurturing and managing the people in the innovation system. In this chapter, we highlight four unique challenges of innovation arising from the unique management and development needs of highly specialized scientific/engineering workers for innovation, given the motivational complexity and diversity of this workforce. We propose that Entrepreneurship, Professionalism and Leadership (EPL) can serve as a broad framework to specify the dimensions of talent needed for innovation to succeed at different levels of analysis from individuals to teams, units, organizations and even the national innovation ecosystem. We discuss potential applications of EPL framework for innovation workforce development and human resource management and call for more research using this framework to better understand and thereby enhance the nurturing and management of R&D personnel for the innovation economy.

Keywords Innovation · Workforce development · Careers · Human resource management · Organization · Entrepreneurship · Leadership · Professionalism · R&D workers · Scientists

K.-Y. Chan (✉) · M. A. Uy
Nanyang Technological University, Singapore, Singapore
e-mail: AKYChan@ntu.edu.sg

M. A. Uy
e-mail: muy@ntu.edu.sg

K. H. Lim
Ministry of Defense, Singapore, Singapore
e-mail: LimKweeHoon@defence.gov.sg

M.-H. R. Ho et al. (eds.), *Entrepreneurship–Professionalism–Leadership*,
https://doi.org/10.1007/978-981-15-3121-7_10

Introduction

In the early half of the last century, the Austrian-born American economist Schumpeter (1911/1934, 1950) advocated innovation and entrepreneurship as the vital engine for economic and social change. Recognized today as a "Prophet of Innovation" (McCraw, 2009), Schumpeter's ideas were indeed ahead of his time. Today, a well-accepted definition of innovation is "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" (p. 46; OECD "Oslo Manual", 2005). Innovation experts like van de Ven et al. (2008) distinguish *invention* which is simply the creation of a new idea from *innovation* which is an encompassing process of developing and implementing a new idea: "As long as an idea is perceived as new to the people involved, it is an 'innovative idea', even though it may appear to others to be an 'imitation' of something that exists elsewhere" (p. 9).

As an economic system-level activity, innovation goes beyond individuals' ideas, discoveries, creativity or inventions. The Spanish Secretary-General for Science, Technology and Innovation, Marisa Poncela-Garcia (2016) described: "Innovation is essentially the result of a complex and usually lengthy process that may start with basic research and ends up with the introduction of new technologies, processes, products or services into the market. Many actors are involved in this procedure: researchers, technologists and business people, as well as a wide range of entities such as public, private or mixed R&D centres; innovative companies and public and private funding agencies" (p. 97). A common way to depict the complexity of innovation activity is in terms of the many forms of research—from upstream "basic research" to downstream "product development"—where the different types of research depend on different systems of funding. Some relate what they would consider the stages of the innovation process to NASA's framework of "Technological Readiness Levels"; others describe innovation in terms of "eco-systems" that translate knowledge into increased value (e.g., Autio & Thomas, 2014).

Adner (2006) described innovation *eco-systems* as "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution. …When they work, ecosystems allow firms to create value that no single firm could have created alone" (p. 2). Jackson (2011) of the U.S.'s National Science Foundation noted that the biological metaphor of an innovation eco-system recognizes "a complex set of relationships among the living resources, habitats, and residents of an area, whose functional goal is to maintain an equilibrium sustaining state" (p. 1). She saw the innovation eco-system as comprising two related economies: a research economy and the commercial economy. She also related this interdependence of R&D (where the core activity is invention) and commercialization to the idea of an innovation spectrum of activities ranging from discovery (often in academic-science/research environments) to technology demonstration (often in small businesses or "start-ups"), to development (which requires investors) and commercialization (which requires industry and/or government investment). Jackson argued that the challenge of innovation was to help ideas and inventions cross what is commonly called the “valley of death” towards commercialization. Thus, in an innovation eco-system, R&D is only one type of activity, albeit a key and driving one.

The Human Dimension and Challenges of Innovation Workforce Development

Perhaps most fundamental to the eco-system metaphor is the fact that innovation is ultimately a human activity and a social one that involves more than any single individual. In a recent literature review, Salter and Alexy (2014) highlighted that even though all new ideas originate from the individual inspirational efforts, innovation was essentially a relational activity which required the interaction of actors and functions (i.e., the team) to turn the ideas into innovation. Similarly, the U.S.’s National Science Board (2012) also recognizes the need for vibrant communities of scientists, technologists and entrepreneurs that can facilitate the flow of knowledge and information in innovation eco-systems. Taking this broad view, the National Science Board believes that the nurturing of any innovation ecosystem goes beyond R&D to include the system of education. It is therefore important not only to study the core innovation processes (e.g., from research to commercialization) but also the systems for nurturing and managing the people in the innovation enterprise, i.e., innovation workforce development and R&D human resource management.

In the last decade, increasing calls have been made for better workforce planning for the innovation and more specifically to address the unique management and development needs of highly specialized scientific/engineering workers for innovation. Writing in the *American Journal of Physics*, Smith et al. (2002) highlighted how the “training, careers and work” education of Ph.D. physical scientists was “not simply academic”. Writing in the *Nature*, Cyranoski et al. (2011) highlighted the concern that the world was producing too many Ph.D.’s without adequate concern for the available work or resources to employ these specialized talents. Such macro-level concerns related to the mismatch between education/training processes and subsequent employability are issues related to workforce development for the science, technology and innovation sector.

Today, workforce development is recognized as an emerging field of *practice* that is increasingly gaining prominence in both government policies and organizational practices (cf. Harris & Short, 2014). Beyond organizational-level processes of training, human resource development and career development, workforce development aspires towards an integrative response to the future skills needed in a sector of work at a macro/eco-system level, and inter-organizational perspective. It also recognizes the individual work motivations and concerns for employability and mobility over the course of a working career.

In an OECD document entitled *Dynamizing National Innovation Systems*, Remoe and Guinet (2002) observed that despite labor markets and education systems' impact on innovation processes, the labor market aspects were not adequately integrated in the planning of national innovation systems. Edquist (2005) also echoed the view that there "is little systematic knowledge about the ways in which the organization of education and training influences the development, diffusion and use of innovations" (p. 185). In a review of the literature on workforce skills and innovation, Toner (2011) concluded that at the macro-level evidence supported a strong causal relationship between the supply of higher levels of education, training and skills with an increased demand-for and supply-of technical and organizational innovation. Fundamentally, the evidence indicates that investment in capital equipment, innovation and human capital are broadly complementary and also mutually reinforcing (see also Lloyd-Ellis & Roberts, 2002).

However, there is still a gap in our understanding of how micro-level, individual abilities, skills, motivations and behaviors (e.g., learning) contribute to the innovation process and system. As a result, micro- and meso-level organizational researchers have called for more nuanced approaches to the management of highly talented scientific/technical experts operating in R&D contexts (e.g., Bignon & Szajnfarber, 2015; Bobadilla & Gilbert, 2015; Cabello-Medina, López-Cabrales, & Valle-Cabrera, 2011; Judge, Fryxell, & Dooley, 1997; Mignonac & Herrbach, 2003). What is the underlying motivation of scientists for their research? Is it for knowledge creation for its own sake or for innovation that results in commercial or social impact? Does this lead to clashes with grant/funding and commercialization managers or even with entrepreneurs? Are scientists and researchers adequately trained in their doctoral programs to understand the complexity of the innovation journey? Do they have the skills and abilities beyond their deep disciplinary and research expertise to understand the "markets" and to work with industry to commercialize their ideas/inventions? What is the nature of R&D careers in the innovation sector? How are such careers different from academic (e.g., tenure tracked) careers in the education sector or corporate/managerial careers? As Defillippi and Arthur (1996) noted: "Traditional ideas on employment emphasize stability, hierarchy, and clearly defined job positions for career progression…Alternative ideas emphasize continuous adaptations of firms—and so of careers—to a hypercompetitive, rapidly changing environment…However, current writings on career and human resource management—including those on 'strategic human resource management'—persist in emphasizing a vertical coordinated, hierarchic approach (Arthur & Rousseau, 1996)" (pp. 116–117). Can R&D workers depend on organizations to manage their careers, or, should they be more self-directed or "Protean" (cf. Hall, 1996) in the management of their careers?

This chapter attempts to address the more micro-level, social-psychological nature of the innovation workforce and how this affects the larger business of innovation. We begin by examining the unique challenges of the innovation workforce, including the motivations and traits of R&D knowledge workers, and the skills and behaviors that they need for performing in their innovation context (e.g., creativity, scientific/technical professionalism, innovation and entrepreneurship, collaboration and teamwork, team and organizational leadership, and career management). Next, explore the usefulness of the Chan et al. (2012) Entrepreneurship-Professionalism-Leadership (EPL) framework for guiding broader workforce and human capital development for the innovation sector of a national economy. We do this by highlighting four unique challenges of innovation that arise from the unique management and development needs of highly specialized scientific/engineering workers for innovation, given the motivational complexity and diversity of this workforce.

Challenge #1: Diverse Range of Talents Lacking Common Understanding of Innovation, Where Core R&D Workforce is Generally Better Prepared for Academia than Innovation

Noting that "The innovation ecosystem mobilizes around wicked problems", Body and Habbal (2016) argued that "it is not possible for one person to hold all the expertise and knowledge to attenuate those problems". In their view, individuals and groups representing a diverse set of disciplines need to come together to collaborate in ways that transcend their individual disciplines. They cite for example how a complex health issue could require the perspectives of a wide range of experts from medical practitioners to educators, from service providers to the health industry to providers of medical software systems, from organizations that establish accreditation and standards setting to medical ethicists, privacy advocates and guardians, from government health agencies to central government fiscal agencies and, of course, the patients or health consumers.

Unlike more established and vocationally or disciplinarily-defined workforce sectors like education, defense, healthcare, engineering/construction, informational/communications technology, journalism/media or even tourism, where workers tend to experience common and systematic educational/training, the innovation workforce requires talents from different disciplinary, industrial and occupational sectors to deal with complex problems. Innovation can also occur within any of these disciplinary or practice fields. However, this diverse range of talent brought together to innovate to address problems or challenges may lack a common understanding of the nature of the innovation process itself.

To the extent that doctoral-level scientific/R&D graduates form the core of the innovation workforce, concerns have been raised about their ill-preparedness for working beyond the more individualistic mode and basic nature of academic research. In the early 1990s, a study by the National Academy's Government–University–Industry Research Roundtable (GUIRR) indicated that while U.S.-educated scientists and engineers are well trained to conduct research, they lacked skills in management, communication, and team-based problem solving that are critical to decision making in innovation-related careers (Armstrong, 1994; COSEPUP, 1995; GUIRR, 1991). The concern for the lack of holistic training for doctoral graduates had earlier origins in the U.K. where as early as 1968, the U.K. Research Councils established a non-profit Careers Research and Advisory Centre (CRAC) to address the need for more holistic doctoral education to ensure greater employability of Ph.D. graduates beyond academia. Attention to this issue was given a boost in 2002 with the publication of a government review of the supply of people with science, technology, engineering and mathematics skills entitled *Set for Success* (Roberts, 2002) which called for the "ring-fencing" of long-term funding of more holistic researcher development through grant and organizational mechanisms, and which led to the establishment of "Doctoral Training Centres" across universities that aimed to break the apparent silos found in the apprenticeship model of doctoral training (Cressey, 2012; Lunt et al., 2014). This allowed the U.K. to establish an organization called VITAE that today implements a holistic "Researcher Development Framework" (VITAE, 2011) that is adopted by many research funders and operators in the U.K.

In 2002, a U.S. National Science Foundation-funded study of doctoral graduates also concluded that doctoral students are educated and trained too narrowly. In the same study, it was also stated that the doctoral graduates lacked transferable skills such as leading, managing or collaborating and working effectively in teams, and they were also ill-informed about employment beyond academia (see Nerad & Cerny, 2002; see also Nerad, 2004). In 2004, firms such as IBM sought to address a gap in STEM education by calling for the development of more "T-shaped" professionals with both deep, disciplinary skills/expertise and broad transferable skills like collaboration (Spohrer & Kwan, 2009). In 2011, the U.S. National Institutes of Health (NIH; which funds biomedical research) raised concerns with the sustainability of the biomedical research enterprise, in particular, with the failure of many doctoral programs to prepare graduates for jobs beyond academia (cf. National Institutes of General Medical Sciences, 2011). This led to the NIH establishing a *Broadening experiences in scientific training* (BEST) grant in 2013 (NIH, 2013) that aimed to better equip graduates for work in non-academic contexts. An OECD (2012) report observed: "The formation and careers of researchers are important policy issues and training for transferable skills—skills that apply in a broad variety of work situations—is a challenge that attracts increasing policy interest" (p. 9).

Writing in a Dutch context, Oskam (2009) noted: "In a field of work in which innovation is gaining increasing attention and where more and more work is being done in interdisciplinary teams in an open innovation environment, different requirements are now being set for the knowledge, skills and attitude of the young technical professional. The mere possession of knowledge and expertise in the individual's own field is no longer sufficient. It is now necessary to have a basic knowledge of adjacent and connecting fields in order to be a good discussion partner and collaboration partner, both within and outside the organization. The higher professionally educated engineer must therefore become more of a so-called T-shaped professional…" (p. 5). Oskam added that networking skills were also vital for effective collaboration in interdisciplinary design or research teams; he also argued that with the employment of more open innovation approaches, project teams are increasingly formed across the boundaries of companies.

In a mixed-methods field study of inventors working in 3M, Boh, Evaristo, and Ouderkirk (2014) found that scientists/researchers' expertise varied in breadth and depth (i.e., in a T-shaped manner) to relate to different aspects of innovation: "breadth of inventor expertise relates to the generation of many inventions, but not necessarily to those that are technically influential. Depth of inventor expertise enables individuals to generate technically influential inventions, as measured by patents granted. However, both breadth and depth of expertise are required for innovators to be deemed highly valuable" (p. 349). Hence, innovation workforce development can benefit from having a "T-shaped" framework that can articulate the wide range of competencies and expertise, including both deep (technical, field-specific) and broad (transferable) skills, that is broad enough to be applicable to a diverse range of talents involved in innovation work.

Challenge #2: Beyond Deep Scientific Expertise, Innovation also Requires Entrepreneurialism Which is not Inherent to Academically-Socialized Scientists

Schumpeter (1934) emphasized the intimate link between entrepreneurship and innovation when he argued that the entrepreneur is a person with the instinct to create new combinations, including new products, markets, materials and forms of organization. Today, entrepreneurship is recognized an activity involving the discovery, evaluation, and exploitation of opportunities that introduces new goods and services, new markets, work processes and materials through organizing efforts that previously had not existed (cf., Shane & Venkataraman, 2000; Venkataraman, 1997). Entrepreneurship is also associated with an orientation towards taking action or personal initiative (cf. Frese, 2007); the term entrepreneur in fact comes from the French word *entreprendre*, which means "to undertake an action". Hence, if innovation focuses on the *implementation* of ideas, core to entrepreneurial behavior is the recognition-of and initiative-to-act-on opportunities.

In their studies of the innovation process, van de Ven et al. (1999/2008) observed: "This journey typically includes entrepreneurs who, with support and funding of upper managers or investors, undertake a sequence of events that creates or transforms a new idea into an implemented reality" (p. 3). In particular, they noted that it is at the gestation stage of the innovation journey that more alert entrepreneurs or champions would act as the central forces or nodes that would connect and focus seemingly unconnected events, activities and players to create new opportunities for their organizations. Such entrepreneurs would then offer ideas or projects to the organizations as a way to solve a problem or exploit an opportunity commercially.

It is also useful to nurture more entrepreneurial capacity in the broader social system of the innovation workforce—beyond having only individual entrepreneurs. As van de Ven et al. (2008) observed: "Contrary to the view sometimes implicit in the literature that innovation consists of an entrepreneur who works with a fixed set of fulltime people who develop an idea, we observed that many stakeholders fluidly engage and disengage in the innovation process over time as their interests and needs for inclusion dictate" (p. 13). They concluded: "… innovation is not the enterprise of a single entrepreneur. Instead, it is a network-building effort that centers on the development of transactions or relationships among people who become sufficiently committed to their ideas to carry them to acceptance and legitimacy" (p. 14). Similarly, Smith (2006) noted that while at the individual-level, scientists/researchers working in an innovation eco-system need to understand markets, customer and the technology transfer process beyond their core science, technical or professional expertise; at the social, collaborative/organizational or network level, innovation also requires business-minded entrepreneurs to know how to work with scientists/researchers so that ideas/inventions can be combined and connected to relate to commercial opportunities.

Unfortunately however, entrepreneurialism is not a dominant trait of the scientists and researchers who are the core of the science, technology and innovation workforce. A long tradition of research on vocational interests has established that people differ in their vocational personalities on six dimensions which are best arranged in a hexagonal, "circumplex" model called the R-I-A-S-E-C which stands for Realistic, Investigative, Artistic, Social, Enterprising and Conventional interests (cf. Holland, 1959, 1997). Based on this approach, scientists/researchers who have strong "investigative" interests would tend to have low interest and are generally quite the opposite of enterprising types. Others highlight the contrasting "mindsets" of scientists/engineers versus entrepreneurs. In a textbook entitled *Entrepreneurship for Scientists and Engineers*, Allen (2010) remarked: "the formulaic approach to solving problems, which is inherent in both science and engineering, is the antithesis of what is required for entrepreneurship. Entrepreneurs must be comfortable with ambiguity and uncertainty, be flexible in their thinking, and be prepared to change quickly should the market give them new information that warrants it" (p. 2).

Culturally, there exists a tension between academic goals (i.e., research and teaching) and environments (e.g., academic freedom; publicness of knowledge) of universities versus their new role as economic engine of the state. Yet, at the core of the science, technology and innovation workforce is doctoral-level scientists and researchers who are trained and socialized in the academic setting of universities. Until the later part of the 20th century, the primary missions of universities were academic—focused on knowledge creation—often of a basic or fundamental nature, and knowledge dissemination or teaching. A "third mission" of universities—to become engines of economic growth (cf., Etzkowitz, 2001; Feller, 1990)—emerged with the U.S.'s 1980 enactment of the Boyh-Doyle Act, which encouraged universities to commercialize their research outputs via patents and licensing. With these developments arose the ideas of the "entrepreneurial university" (Etzkowitz, 2003) and the "academic entrepreneur" (cf. Shane, 2004). By the turn of the millennium, research intensive universities around the world started to establish Technology Transfer Offices to support and encourage entrepreneurialism and commercialization among academics (cf. Bercovitz & Feldman, 2006, 2008) and science parks to engage with industry.

A study by Lee (1996) found that faculty in highly ranked academic institutions were less in favor of academic entrepreneurship because of a concern that industry involvement or commercial-interests would restrict curiosity-driven research or their academic freedom. Studies of German academics also found that rather than for entrepreneurial motivations like economic impact and profit, many academics were motivated to engage with industry in order to acquire research funds and to learn from industry (Meyer-Krahmer & Schmoch, 1998); or, that academics were attracted to patenting as a symbolic way to signal their achievements and build their reputation in both the academic or industrial community (Göktepe-Hulten & Mahagainkar, 2010). In a large-scale survey of 1528 university researchers in the U.K., D'Este and Perkmann (2011) identified four factors that motivate academics to engage with industry, of which three were research-related (i.e., to learn from industry; access to funding; access to in-kind resources) and only one was commercial. Their results showed that commercialization was ranked as the lowest motive among the survey respondents: most academics were motivated to engage with industry in order to further their own research. In a study that interviewed 36 and surveyed 735 scientists from five major U.K. research universities, Lam (2011) also concluded that most engage in research commercialization "for reputational and intrinsic reasons" (i.e., professional motivations), and, "that financial rewards play a relatively small part" (p. 1354).

Hence, to the extent that the core of the innovation workforce (i.e., scientists/researchers) are trained and socialized in academic environments, the nurturing of entrepreneurial skills, understanding or even networks—relative to their more dominant scientific/technical expertise—may be the key to successful innovation beyond mere invention or ideation. Entrepreneurialism is not only important at the individual level but also at the innovation-system level. Commenting on the "valley of death" between product development and a market-competitive product that customers would pay for, Allen (2010) observed: "the skills and focus on the market required to move the technology through the valley are distinct from the skills required during product development" (p. 3). This reinforces the need to examine innovation from an eco-system perspective with multiple actors possessing a mix of scientific, engineering, and also entrepreneurial and management or leadership skills.

Challenge #3: The Complexity of Leading and Organizing for Innovation

If at the heart of entrepreneurship is the recognition-of and orientation to act-on *opportunities*, core to the concept of leadership is the process of influencing (including inspiring and rallying) *people* to achieve outcomes efficiently and effectively. While leadership research has generally shown that extraversion is an important predictor of leadership, meta-analyses (e.g., Feist, 1998, 2006) have also shown that scientists/researchers tend to be more introverted. A recent meta-analysis by Lounsbury et al. (2012) found that while scientists are characterized by significantly higher levels of openness to experience, intrinsic motivation, tough-mindedness (low agreeableness facet), and they also score significantly lower on assertiveness, conscientiousness, emotional stability, extraversion, optimism or visionary style—traits that are commonly associated with leadership (cf. Judge, Bono, Ilies, & Gerhardt, 2002). The personality traits of scientists/researchers also make it even more challenging to lead them—as Lounsbury et al. (2012) commented: "The unique constellation of personality traits of scientists also creates inherent difficulties for the manager of scientists. As one wag noted, 'Managing scientists is like herding cats. You can't get a scientist to work 9–5 and make breakthroughs at a given time.' (Sci-Forums.com, 2011). At the heart of most of these difficulties is the tension created by dispositionally non-conscientious scientists working in conscientiousness-driven organizations which require compliance with rules and policies, proper organizational conduct, and good citizenship behavior, developing a well-funded program of mission-relevant research, and meeting ever-higher performance standards based on criteria like citation rates and the dollar value of grants" (p. 55).

Just as entrepreneurial skills and capacities are important for innovation, leadership is also important in science, R&D, and innovation. Experts on the study of leadership and innovation have highlighted the unique challenges of leading for innovation related to both the nature of the innovation journey and process (cf. van de Ven et al., 1999), and the collaborative and networked social-organizational context in which innovation occurs. As Robledo et al. (2012) noted: "Creative work, characterized by idea generation as well as the evaluation and implementation of ideas to generate viable products (Mumford et al., 2002), is unusually complex. Individuals engaged in creative work must work with novel, ill-defined concepts in an unstable environment. The intellectually demanding nature of creative work implies that an unusually wide range of skills and expertise will be needed. Thus creative work is likely to be collaborative, pointing to the importance of social skills for those involved" (p. 141).

Viewed as a process, innovation can be described as a nonlinear cycle of divergent and convergent activities that may repeat in unpredictable ways over time (van de Ven et al., 1999). When divergent (i.e., creative, exploratory) activities are dominant, the kind of leadership needed is pluralistic or shared where different leadership roles are "distributed" across the actors. When the innovation journey is in a "convergent" (or implementation or exploitation) phase, "unitary" (i.e., directive yet consensus-building) leadership is needed. Some have described the need for such highly flexible forms of leadership as "ambidextrous" (Rosing, Frese, & Bausch, 2011). van de Ven et al. (2008) note: "many entrepreneurs are replaced by professional managers because the former often flounder in growing the innovation into a self-sustaining business" (p. 45). Because of the importance of trust and openness needed for the inherent uncertainty and risk involved in innovation, van de Ven et al. (1999) state: "Entrepreneurs and managers cannot control innovation success, only its odds" (p. 65). Efforts to organize for innovation therefore need more distributed, people-centred leadership than management by command and control.

In a review of 30 years of leadership research in R&D contexts, Elkins and Keller (2004) observed: "The R&D environment is a unique work context that is laden with leadership challenges. Project leaders are confronted with rapid changes in science and technology, difficulties in assessing R&D contributions and personnel with work values, experiences, and attitudes that are much different from other types of employees" (p. 3). They also highlighted how the R&D environment has become increasingly more competitive and diverse, and how it increasingly relies on alliances and outsourcing, is focusing more on development than research activities, and where there are greater demands on the reduction of project cycle time. In this context, they argued that effective R&D leadership is ever more critical. Thus, an important aspect of innovation workforce development concerns how one raises the quality of leadership needed to organize the people or "talents" for the complex and challenging innovation journey across dynamic (at times weak or loose, at other times strong or tightly-networked) organizational settings and contexts.

Challenge #4: "Boundaryless" and "Protean" Nature of Careers in Innovation

In a historical review of "National Innovation Systems", Freeman (1995) describes how the first specialized R&D departments were established in German industries in 1870 and suggests that until the 1960s, these R&D units were seen as the source of innovations. From this perspective, one could broadly say that until the later part of the last century, scientific research for innovation mainly occurred in bureaucratic, organizational settings of firms, universities or public sector research organizations whereby scientific or research careers were organizationally managed: If universities had their tenure-tracked academic careers, large firms like P&G implemented dual-tracked career systems, where they would distinguish between scientific versus management paths for managing their scientific talents.

Towards the later part of the 20th century, social scientists studying the general nature of work and careers started to observe the emergence of new forms of careers and the breaking of traditional employment relationships between individuals and employers. Hall (1996) for example introduced the concept of "Protean careers" to describe "a career that is driven by the person, not the organization, and that will be reinvented by the person from time to time, as the person and the environment change". For Hall (1996), "The traditional psychological contract in which an employee entered a firm, worked hard, performed well, was loyal and committed, and thus received ever-greater rewards and job security, has been replaced by a new contract based on continuous learning and identity change". At about the same time, Arthur (1994) also introduced the concept of "Boundaryless careers" which emphasized "independence from, rather than dependence on, traditional organizational career arrangements" (p. 6; Arthur & Rousseau, 1996). For them, examples of such careers were found in academia, where individuals would draw validation and marketability from outside the present employer; and in the "stereotypical" Silicon Valley career, that move across the boundaries of separate employers.

To a large extent, it can be said that scientific careers in innovation today mirror the shifts from traditional, linear and organizationally managed careers towards more Protean, mobile and boundaryless careers. Several researchers of scientific/Ph.D. careers have observed that today's Ph.D. graduates and post-doctoral fellows pursue more diverse career paths, unlike most of their predecessors who took a linear career path from doctoral to postdoctoral training, and ultimately to tenure-track faculty positions. Making reference to several National Research Council Reports and academic publications, Fuhrmann et al. (2011) observed changing career patterns among scientists and new challenges faced by those who do pursue the academic path. Lee, Miozzo, and Laredo (2010) also observed: "many Ph.D.-trained scientists enter private sector jobs other than research or technical departments in manufacturing. They often serve as consultants in knowledge-intensive business firms. The nature of their jobs is interdisciplinary, cross-organizational and international…In some other instances, science and engineering Ph.D's might even choose jobs that are outside the conventional technical occupations and outside occupations such as dedicated managers or consultants/experts" (p. 872).

Increasingly, career guidance for R&D workers has also started to recognize the "widening funnel" of jobs (see pp. 8–9, VITAE, 2013) for doctoral level graduates in the innovation sector beyond academic jobs. Commenting on the NIH's BEST program, Meyers et al. (2015) reviewed several national reports and commentaries that analyzed the numbers, composition, career outcomes, and trajectories of the U.S. biomedical workforce and found that a large majority of the graduates of the biomedical training programs were found to be in careers other than tenure-track or undergraduate faculty positions. These included careers in government, regulatory science and academic administration, industry/biotechnology, science writing and communication, and public policy. They concluded: "there is a growing consensus that the full range of career paths should be included and defined such that tenure-track academia is only one possibility among many other options—all being viewed as successful outcomes" (p. 2).

Beyond an awareness of the diversity of career paths for scientists/researchers in innovation, there is also recognition of the need for such highly specialized talents to have a high degree of mobility, which is integral to the concept of boundaryless careers. Innovation work which is highly project based, and especially under competitive funding regimes, and where employment is often based on short-term contracts (cf. relatively more stable and predictable employment offered in corporate or academic/teaching settings). The nature of innovation work also requires scientists to have high levels of career mobility across employment settings from academia, to public sector science-technology organizations (STOs) to industry R&D (Kaiser, Kongsted, & Rønde, 2015; Kitagawa, 2015). Today, the need to support researcher physical mobility is recognized at the highest policy levels. For example, in 2005, Europe adopted a Charter for Researchers and a Code of Conduct for the Recruitment of Researchers that aimed to make research an attractive career, which is a vital feature of its strategy to stimulate economic and employment growth. In 2014, the European Union launched its Horizon 2020 program for Research and Innovation which not only aimed to fund innovative and important research projects, but also to develop researchers more holistically for employability, and to support researcher mobility in the Union.

In an innovation eco-system where R&D talents would regularly enter and exit innovation projects to pursue boundaryless careers within the industry, the individuals need to take career risks to flow across organizational or employment contexts to work on ideas and problems at different stages of innovation process, where they do not necessarily have permanent employment contracts but work on project-contracts and thus cross company boundaries over time (Arthur & Rousseau, 1996; Inkson, Gunz, Ganesh, & Roper, 2012; Tams & Arthur, 2010). They would therefore benefit from a framework that can help them to "construct" their careers (cf. Savickas, 2005). They also need to be more mobile, have a more boundaryless career perspective and support for (macro) innovation to occur in a competitive global economy. All these suggest the need for more boundaryless career framework—both to help scientists think about their careers subjectively in career space or to map scientific job options and career paths in multidimensional, functional space, for which the EPL is one such framework.

Motivational Complexity of a Diverse Innovation Workforce

Psychologically, the above discussion indicates how innovation depends on a diverse range of talents with different traits, motivational orientations, competencies and skills that vary in scientific/technical, entrepreneurial, and managerial dimensions at different stages of the innovation journey or process. Correspondingly at the eco-system level, different "logics" are needed in the workforce for innovation to succeed.

Given the heterogeneous motivations in the innovation workforce, various researchers (e.g., Ángel & Sánchez, 2009; Cabello-Medina et al., 2011; Judge et al., 1997) have called for a more nuanced approaches to the management of highly talented scientific/technical experts operating in R&D contexts. Recognizing the "tensions, conflicting logics and orders of worth" in R&D work settings, Bobadilla and Gilbert (2015) commented: "It has also been observed that scientific and technical experts have very distinctive career orientations, value systems and reward preferences, necessitating a different psychological contract with this 'rare resource' (Bobadilla, 2014) and different management of it". In a field study of the challenges of managing highly specialized, scientific and technical experts in several R&D firms, Bobadilla and Gilbert (2015) found that three different competing logics co-exist to create tensions in R&D work: "a *technical* logic marked by the world of inspiration, a *market* logic based on the market world and a *managerial* logic inspired in the industrial world" (p. 226). They argued against any "one size fits all" approach to managing the R&D experts, who primarily operate via a technical (or "professional") logic. Instead, they suggested that "the way to move forward in managing knowledge workers lies in the enrichment and deepening of arrangements and the hybridization of logics, practices and roles, rather than in the increasing sophistication of managerial tools that are very similar from one company to the next and whose efficiency is questionable" (p. 232).

Hence, it is useful to have a conceptual framework that can represent the different logics (or motivations/orientations) of the workforce in an innovation system. Such a conceptual framework should also be broad enough for application across levels of analysis from the individual to the firm and innovation eco-system or workforce.

Entrepreneurship-Professionalism-Leadership as a Broad Conceptual Framework

In 1989, Kanter explored the (multi-level) relationship between the individual-level careers and the macro-level national economic outcomes. She presented a framework of three principal career forms defined by its own logic—*bureaucratic* (or leader/managerial), *professional*, and *entrepreneurial* careers—as a way to think about careers at the macro, organizational, and even national socio-economic levels. If bureaucratic or managerial career logic was characterized by advancement and hierarchy, professional careers were characterized by craft, skill, knowledge or reputation; while entrepreneurial logic was characterized by a desire to create new value from opportunities. Interestingly, Kanter's three meta correspond well with Bodadilla and Gilbert's (2015) observations of the motivational dynamics operating in R&D firms.

While Kanter described the three career forms as three different *types*—each with their own logic, Chan et al. (2012) conceptualize the three forms as *dimensions of career space* such that all individual careers can be defined as vectors in a three-dimensional entrepreneurial, professional, and leadership (EPL) subjective career space. To the extent that the three dimensions of EPL career space are justified on the basis of the contextually-derived career frameworks proposed by Kanter (1989) and Schein (1978) at national/economic and organizational levels, Chan et al. (2012) suggested that the EPL framework can be readily adapted "for conceptualizing and diagnosing the human resource capacities of organizations and segments of a national workforce". They suggested, "One can, for example, measure the EPL competencies and motivations of individuals and then aggregate this data for the purpose of organizational- or national-level human resource planning (e.g., for talent management or adjusting workforce development and education policies)" (p. 81).

With its potential for multilevel application, we propose that Chan et al. (2012) EPL framework can serve as a broad schema that can address the above challenges of innovation workforce development. Firstly, with only three broad theoretically-justified dimensions, EPL can serve as a parsimonious framework to articulate the wide range of "T-shaped" competencies and expertise, including both deep/technical and the broad/transferable skills needed in the diverse range of talents involved in innovation work (see also Chap. 8 of this book). Secondly, the EPL framework also includes entrepreneurship as a dimension which is a vital capacity needed in both the core scientific/researcher workforce and the larger innovation eco-system. Thirdly, the EPL framework includes leadership as a dimension without specifying the specific kind of leadership or social-organizational context (e.g., hierarchical vs. distributed/flat). This allows for more specification of the specific kinds of leadership and organizational capacities that are needed as part of developing the innovation workforce. Finally, as presented in Chan et al. (2012) research, the EPL framework can help people think of their careers in multidimensional and boundaryless ways, which we have argued above is increasingly needed for the worker in the innovation sector.

The next section discusses ways in which the EPL framework can be used to guide the development of the innovation workforce and its management in organizational settings.

Potential Applications of EPL Framework for Innovation Workforce Development and Human Resource Management

Education, socialization and training of early career researchers for innovation. As mentioned, countries such as the U.S., U.K. and some other countries in the Europe have taken active steps to address the need to broaden doctoral education to ensure greater employability of graduates for work beyond academic settings. In doing so, some have developed and adopted competency models to guide the training and development of scientists/R&D workers. Two of the more well-established frameworks are the U.K.'s VITAE RDF (VITAE, 2011) and the U.S.'s National Postdoctoral Association's Core Competencies (NPA, 2004) which is the basis for the Science Careers "MyIDP" system (see Fuhrmann et al., 2011) that is popularly adopted by many U.S. universities. To the extent that some of these frameworks attempt to address the skill gaps for general employability, they may not provide adequate emphasis for the preparation of doctoral graduates for innovation. Table 10.1 is our attempt to map the skills in these well-established frameworks in relation to Chan et al.'s EPL dimensions. Clearly, if entrepreneurship is an important skill or capacity needed for innovation, then it seems that both of these frameworks may need more emphasis on developing entrepreneurial skills to prepare graduates for innovation work.

Beyond incorporating E, P & L skills into doctoral programs, it is also useful for R&D organizations employing such talents to socialize them to better understand the nature and importance of E, P and L development throughout their careers—in relation to the complex and dynamic nature of innovation work. Such socialization initiatives can also allow for building collaborative networks across individuals with varying E, P and L profiles. The latter may in turn raise the possibility of putting together R&D teams with a mix of E, P and L talents and skills—thereby enhancing the adaptability and resilience of the teams in the face of uncertainty inherent in the innovation journey.

Table 10.1 Mapping of U.K.'s VITAE RDF and U.S.'s postdoctoral association core competencies in relation to Chan et al. (2012) EPL dimensions

Framework	Core competencies for researcher development	EPL dimensions
VITAE's RDF	*Domain A: Knowledge and Intellectual Abilities*	*P*
	A1. Knowledge base	P
	A2. Cognitive abilities	P
	A3. Creativity	E-I
	Domain B: Personal Effectiveness	*L*
	B1. Personal qualities	L
	B2. Self-management	L
	B3. Professional and career development	L
	Domain C: Research Governance and Organisation	*P*
	C1. Professional conduct	P
	C2. Research management	P
	C3. Finance, funding and resources	P
	Domain D: Engagement, Influence and Impact	*L-E*
	D1. Working with others	L
	D2. Communication and dissemination	L
	D3. Engagement and impact	L-E
U.S.'s postdoctoral association's six core competencies	*A. Discipline-Specific Conceptual Knowledge*	*P*
	A1. Analytical approach to defining scientific questions	P
	A2. Design of scientifically testable hypotheses	P
	A3. Broad based and cross-disciplinary knowledge acquisition	P
	A4. Detailed knowledge of specific research area	P
	B. Research Skill Development	*P*
	B1. Research techniques and laboratory safety	P
	B2. Experimental design	P
	B3. Data analysis and interpretation	P

(continued)

Table 10.1 (continued)

Framework	Core competencies for researcher development	EPL dimensions
	B4. Effective search strategies and critical evaluation of the literature	P
	B5. Grant application and scientific publishing processes	P
	C. Communication Skills	*L-P*
	C1. Writing	P
	C2. Speaking	P
	C3. Teaching and mentoring	L
	C4. Interpersonal communication skills	L
	C5. Special situations	L
	D. Professionalism	*P-L*
	D1. Assess and uphold workplace etiquette, performance standards, and project goals	P
	D2. Comply with rules, regulations, and institutional norms	P
	D3. Respect, evaluate, and enhance the intellectual contributions of others	P
	D4. Advance and promote the discipline by participating in public and professional service activities, such as professional societies, editorial and advisory boards, peer review panels, and institutional committees	P
	D5. Advance and promote the discipline by participating in partnerships with government agencies, foundations, and/or nonprofit organizations, such as funding agency grant panels or other advocacy/advisory boards to contribute to the advancement and promotion of the discipline	P
	D6. Identify and manage apparent and actual conflicts of interest, ethical violations, and violations of expected professional behavior	P-L

(continued)

Table 10.1 (continued)

Framework	Core competencies for researcher development	EPL dimensions
	E. Leadership and Management Skills	*L*
	E1. Personnel management	L
	E2. Project management	L
	E3. Leadership skills	L
	E4. Serving as a role model	L
	F. Responsible Conduct of Research	*P*
	F1. Data ownership and sharing	P
	F2. Research with human subjects	P
	F3. Research involving animals	P
	F4. Identifying and mitigating research misconduct	P
	F5. Conflicts of interest	P

Noting that "innovation is implicitly a team activity, which relies on participants understanding at least some aspects of each other's expertise as well as effective communication across areas" and that "studies in technology entrepreneurship recommend integrated approaches to educating students to operate in this space" (pp. 389–390), Thursby, Fuller, and Thursby (2009) describe an NSF-funded graduate education program called "Technological Innovation: Generating Economic Results" (TI:GER®) which brought science and engineering Ph.D., MBA students and JD (Juris Doctor) students to examine the technical, legal, and business issues involved with moving fundamental research to the marketplace. The core idea of such a program can also be adopted in the socialization of the diverse range of workers in innovation organizations and settings. Similarly, it would also be interesting if some of the U.K.'s doctoral training centers could also be configured based on the E, P & L mix of talents and developmental emphases.

On the same basis, organizational HR can also adopt EPL as a broad framework to support the holistic, T-shaped development of scientific/engineering staff. Boh et al. (2014) found that scientists/researchers at 3M could be categorized into specialists with deep expertise, generalists with breadth of expertise, and T-shaped "polymaths" who had both deep and broad expertise. They concluded: "Organizations should not necessarily cultivate all their inventors to become polymath inventors. Instead, an organization should build an eco-system made up of specialist, generalist and polymath inventors. Organizations can also consider these archetypes when they make hiring decisions for inventors. An individual with diverse interests, who likes to work on different and new things, may be a good candidate for a generalist, whereas an individual with impeccable focus and perseverance to keep working on a single problem could be a potential specialist. As for potential polymath inventors, we suspect such individuals would need to be cultivated, which means that organizations need to provide room for individuals to develop both breadth and depth simultaneously, if they have the inclination to do so" (p. 364). The EPL framework is thus one way to capture of the idea of breadth and depth, but in terms of transferable (E & L) skills, and deep, technical (P) knowledge and skills.

Hiring, selecting and forming teams and collaborative networks with a mix of capacities needed to traverse the innovation journey from idea development to idea implementation. In a literature review on "Hiring an innovative workforce", Hunter, Cushenbery, and Friedrich (2012) remarked, "With innovation emerging as a key priority for a significant portion of the workforce, it becomes imperative that organizations be adequately prepared to recruit, select, and retain individuals capable of undertaking the difficult work of innovation" (p. 126). However, their review focused on the predictors of individual-level *creative* performance (e.g., domain specific expertise and skills, broad knowledge base, creative processing and various cognitive abilities) and did not appear to address the broader innovation journey which includes also idea implementation and commercialization. In a review of "Team Innovation", van Kippenberg (2017) concluded: "For many innovations (e.g., new product development, business model innovation), teams typically need to mobilize resources, support, and collaboration outside the team to make the innovation reality (e.g., Alexander & van Knippenberg, 2014). This is no trivial observation: Most ideas for innovations never make it to implementation, and ideas that are more creative may often be less likely to be implemented because they carry a greater (perceived) risk of failure than more incrementally creative ideas. In that sense, the bigger challenge in team innovation may not be the development of innovative ideas but their implementation" (p. 226). In a recent analysis of R&D manpower data collected in 938 Singaporean firms, Faems and Subramanian (2013) concluded that "size is not the only relevant R&D manpower characteristic in explaining firms' technological performance… that it is also important to assess the actual composition of the R&D work-force in terms of demographic and task-related sources diversity to fully grasp the technological performance implications of firms' investments in R&D employees" (p. 1631). From this perspective, one can ask: How could one think of the hiring of R&D talent to ensure diversity at various levels from innovation eco-system to firms or even teams?

From these perspectives, the EPL framework can be used to guide the hiring of R&D talent for innovation because it would include elements of entrepreneurial capacity needed to address the risks at different stages of the innovation journey/process, while also including elements of leadership capacity needed to rally, align and motivate the diverse groups of people to move from ideas to implementation in both innovation teams and collaborative R&D networks. Having such a mix of skills in the talent pool can in turn better enable the possibility of forming innovation project teams with a mix of E, P and L skills and orientations that can help move ideas and discoveries along the innovation journey towards implementation. As featured in studies on team composition (Chi, Huang, & Lin, 2009; Post, 2012; Somech & Drach-Zahavy, 2013), the strength of any team lies on the mix of talents, diversity of skills, orientations and motivations amongst the individuals. In meta-analysis of the relationship between team composition and performance, Bell

(2007) concluded that the composition of a team in terms of individual attributes can help us to understand why some teams are more innovative than others. For example, it was found that team performance is higher on teams where members on average are more conscientious, agreeable, open to experience and emotionally stable.

While traditional approaches to team composition mostly looked at configuring a team of different personalities and team roles, in the context of innovation, we think it will be useful to think of team composition in terms of a mix of EPL skills and motivations. This is, however, not about typing people into E or P or L, but recognizing that each individual can have different EPL strengths in terms of skills and/or motivations as illustrated in Fig. 10.1. In this regard, EPL can serve to provide a broader framework for conceptualizing the wide range of qualities needed for innovation to occur from the individual to the team/group or organizational level.

Career development and support of scientists/researchers for innovation careers. The establishment of organizations like VITAE in the U.K., and adoption of the ScienceCareers MyIDP system across U.S. universities were driven primarily by concerns for the general employability of doctoral graduates beyond academic jobs in higher education. An OECD (2012) survey of transferable skills training across various countries noted: "Today, career paths are evolving owing to the greater use of science and technology (S&T) in some industries, the large numbers of Ph.D. graduates relative to the demands of the academic job market, the increasing circulation of workers among research occupations, and policies that encourage intersectorial mobility" (p. 16).

However, we have also argued that innovation careers tend to be more boundaryless, and that innovation can also be effective if there is greater career mobility for researchers across different employment settings (e.g., from universities to researcher institutes to industry R&D or to "start-ups"). Just as VITAE and the NIH's BEST researchers (cf. Meyers et al., 2015) have attempted to describe the career multiple paths or trajectories for scientists, one could attempt to code the various jobs for scientists in the broader innovation ecosystem according to E, P and L skill demands, so that individuals can better prepare and equip themselves with the necessary skills for the path that fits their interests and strengths. Figure 10.2 illustrates this idea by

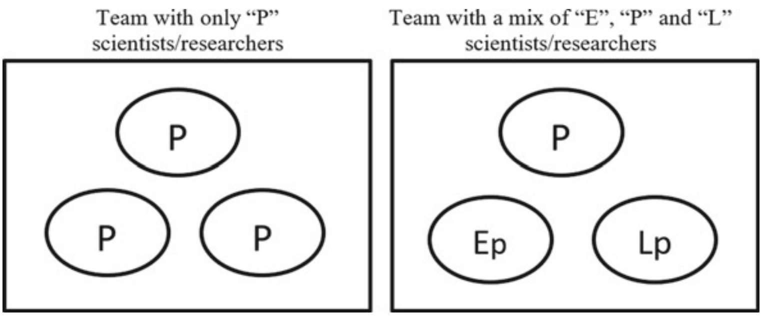

Fig. 10.1 Team compositions based on Chan et al. (2012) E, P and L dimensions

EPL Dimensions	Narrow horizon – mainly in known & safe "P" type of jobs in academia/research labs	A little wider – mainly research based, with some movements to "L" and "E" types of jobs	Still research based but transferring research skills to non-academic settings	Wider mobility to non-research jobs in different job settings	Using transferable skills rather than specific knowledge across different job settings
L		Administrator		Production manager Research Councils	Any 'graduate level' job: -Accounting -Law -Marketing -Production -Admin Personnel Private sector Not-for-profit sector Small or medium enterprise Large organization Service sector Manufacturing Government
P	Research staff – new contract	Research Fellow Technical support Lecturer	Government lab Museum/gallery Research Institute Research Council, Charity, private company Small or medium enterprise, R&D	Publishing Scientific/public policy advisor Government 'desk researcher' Teaching schools/colleges Clinical advisor	
E		Entrepreneur	Consultancy firm or independent consultant Your own 'spin-off' business	Consultancy Legal or patents Technical sales/marketing	Self-employment Start your own business
	Nearby	Still close	A little further	Away from research	Anything goes

Increasing breadth of career paths

Fig. 10.2 Vitae's "widening horizons funnel" of job options for PhD graduates mapped to Chan et al. (2012) "E", "P" and "L" dimensions (note: adapted from Vitae's *The Career-wise Researcher*, 2013, pp. 8–9) attempting to map VITAE's "widening funnel" of job options (see VITAE, 2013) for doctoral graduate scientists in a broader innovation ecosystem in terms of EPL skill "demands". Having such a mapping of possible jobs in the innovation ecosystem based on the EPL framework can help the highly specialized R&D workers to plan their careers and to take charge of their career development, instead of only depending on their organizations in these aspects. This is particularly important if the researchers are to have career mobility to work across disciplines, organizational and geographic boundaries.

The EPL career aspiration feedback system described in Chap. 12 in this book can also be adapted to help R&D workers to understand their motivations and efficacies in EPL dimensions, and to guide them in planning their career development to prepare for different stages of innovation work. Such initiatives could attempt to address challenges in the early professional socialization and the (lack of) holistic training/education and subsequent (lack of) employability of doctoral researchers if professional development is left solely to academia. Also recognized are the fundamental realities of scientifically-driven innovation, including rapid change/obsolescence, complexity and competition, and the fact that scientists and researchers need supportive environments to dare to take the risks to constantly challenge, learn, adapt, create and move ideas to market.

Performance management, talent assessment and leader development for innovation. While the previous section focused on the individual scientist/researcher's responsibility for managing their careers (and development), many scientists/researchers also operate as employees in industrial, academic or public sector scientific organizations which are concerned with their performance in relation to the organization's mission, which is often not in the individual's control (e.g., timing, competition, market lack of readiness). Also, as Robledo et al. (2012) commented: "scientists and engineers tend to identify more with their field, or profession, than with the organization. Thus they are likely to be more responsive to professional evaluation than to evaluations coming from their leader or organization" (p. 141). Moreover, innovation endeavor requires team effort and a good mix of talents (e.g., leadership skills, professional expertise, and entrepreneurial skills) over a lengthy process of taking ideas to the market where the results entail a certain level of risk and uncertainty. This, in turn, poses a challenge in the performance management of R&D talent in that there is a need for differential performance management to account for the different kinds of work performed in the innovation process. There is really no one-size-fits-all approach when it comes to the performance management of the R&D workers.

Writing in *Washington Research Evaluation Network's Management Benchmark Study*, Jordan and Malone (2002) noted that while performance information is required for effective management and for demonstrating the relevance and value of R&D work to funders and stakeholders, publicly-funded R&D organizations find that existing assessment approaches and tools are inadequate for current requirements because of the different nature of performance at different stages of the innovation process. They therefore developed a logic model for the R&D program and identified the core skills needed for performance at different stages of the innovation process.

In this regard, we have mapped the EPL dimensions on the core skills identified by Jordan and Malone (see Fig. 10.3) as a way to illustrate how Chan et al. (2012) EPL framework can used as a tool for assessing performance at different stages of the innovation process.

Often tied to performance management is the separate goal of "talent management" in organizations, which is driven by concerns for identifying and nurturing a pipeline of organizational leaders for the organization. On one hand, it is not difficult to argue that everyone in the innovation system is a "talent" to the extent that each individual brings to the innovation process a highly specialized set of skills and experiences. On the other hand, there is still a need for institutional and organizational leadership in various parts of the innovation eco-system. Observing that "traditional models of leadership tend to ignore the importance of scientists and engineers in an organization" (p. 140), Robledo et al. (2012) called for more research on scientific leadership as a unique phenomenon. One way to understand the complexity of leadership in innovation is via the competing values framework. In a study sponsored by the U.S. Department of Energy, Jordan (2005) generated a competing values framework that captures four most common perspectives and models of attributes for R&D organizational effectiveness. We believe that the EPL can be mapped on the core attributes and skills identified in the framework which is particularly useful for R&D leadership. The first model in this competing values framework emphasizes the importance of *human resources development* including Leadership attributes such as valuing the individual, building teams and teamwork, and commitment to employee growth. The second model looks at *internal resources and processes* covering Leadership (and management) attributes such as providing capital, knowledge resources, ensuring good technical management and insisting on efficient, low burden systems. The third model concerns *innovation and cross-fertilization of ideas* which emphasizes Professional and Entrepreneurial attributes and skills such as encouraging exploration, risk taking, integrate ideas, internally and externally, and encouraging change and critical thinking. The fourth model is about *setting and achieving relevant goals* and includes Leadership attributes such as clearly define goals and strategies, plan and execute well and build strategic relationships.

The innovation ecosystem can benefit from some concept of how talent can be optimized "organizationally", e.g., to identify the potential CEOs, CTOs, or Chief Scientists, or who can be the best start-up entrepreneurs or even venture capitalists. Figure 10.4 illustrates the use of EPL framework for the assessment and development individuals' future potential for innovation in a multidimensional way, beyond focusing on them only professionally or leadership-wise/managerially as is common in corporate organizational settings.

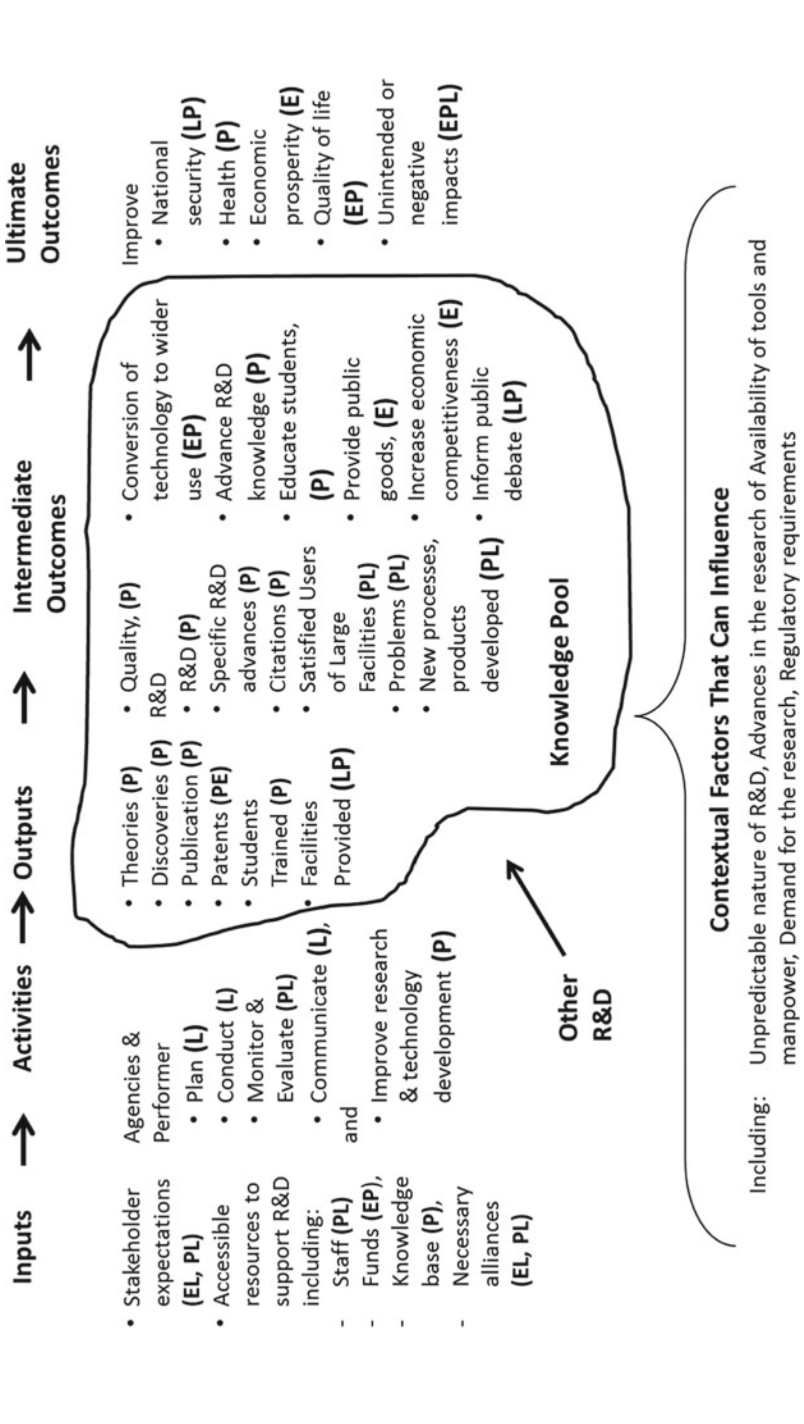

Fig. 10.3 Mapping of Jordan and Malone's Logic Model for R&D process/program (2002) with Chan et al. (2012) "E", "P" and "L" skills and motivations

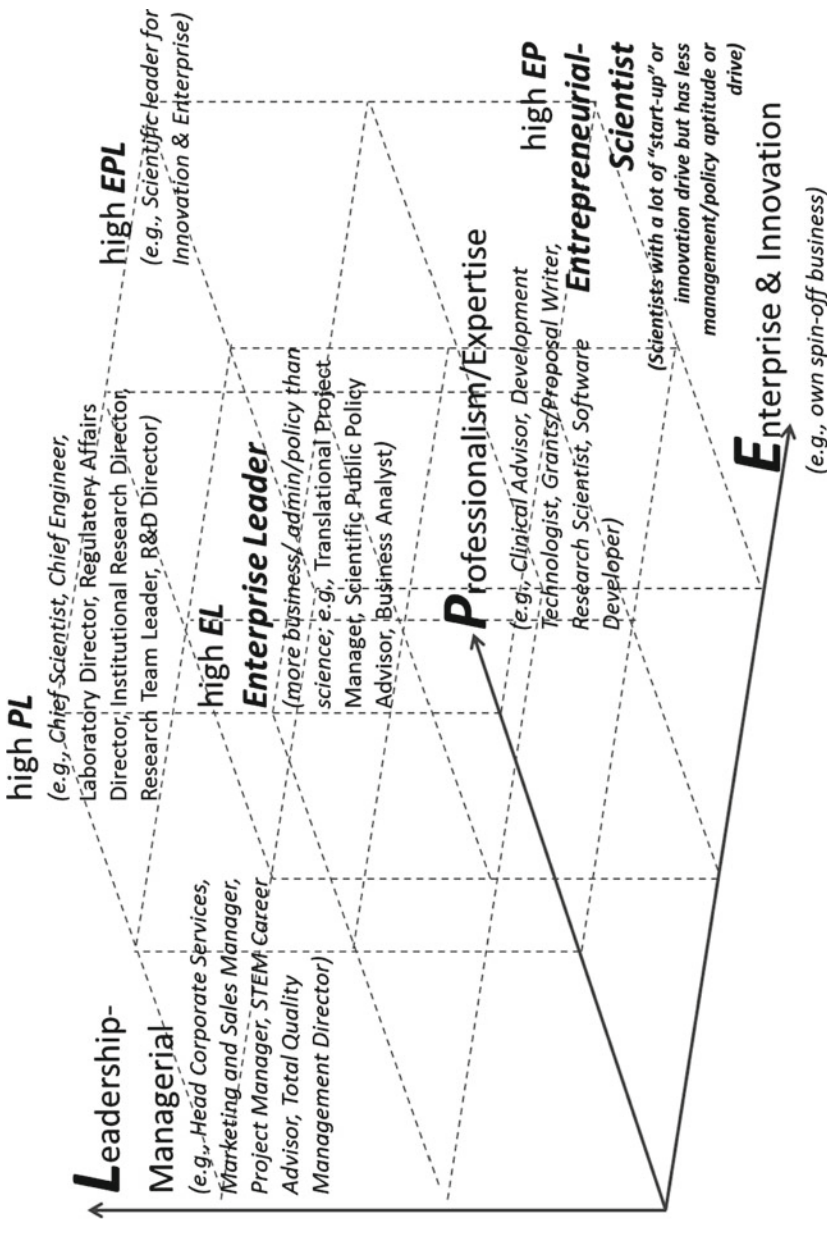

Fig. 10.4 Adapting Chan et al's EPL Framework for assessing and developing future innovation talents and "potentials"

Conclusion: Towards EPL Human Capital Mapping of the Innovation Sector

In a commentary on Singapore's journey to build its innovation eco-system, the Chairman of Singapore's Agency for Science, Technology and Research, Lim (2016) highlighted the need for a right mix of talent to drive innovation and enterprise: "we must pay particular attention to the development of talent to translate research into original products or services with new business models, and to help create Singapore's future economy. The starting point is always excellent science. The end goal is to bring benefits to society and we need our talent to span the spectrum of activities from research and innovation to high-growth enterprise" (p. A20).

This chapter has explained how Chan et al.(2012) EPL can serve as a broad framework to specify the dimensions of talent needed for innovation to succeed. Conceptually, the EPL framework can be applied in a manner that allow aggregation at multiple levels (from individuals to teams, to units & organizations and national innovation ecosystem) to articulate the human resource capabilities needed for innovation to work. Specifically, the E & L dimensions articulate the transferable capacities that highly specialized, technical (P) scientists/engineers/R&D workers generally lack either dispositionally or from their academically-based doctoral education/socialization.

In contrast to Kanter's (1989) sociological description of E, P and L as different career "logics", Chan et al.'s articulation of E, P & L as *dimensions* does not categorize people into discrete E or P or L "types"; instead, it suggests that everyone can grow themselves in E, P & L dimensions over a career—which may be especially vital for innovation, where careers may need to be highly mobile and boundaryless for optimal innovation. From a developmental perspective, it would be useful to study how both dispositional and educational experiences result in doctoral R&D graduates with different EPL profiles. Research could also examine how researchers with different EPL profiles fit into different types of R&D work in the innovation spectrum and how different leadership roles in an innovation system may require individuals with different E, P & L skills and motivations.

The three dimensions (E, P and L) can be applied beyond representing the individual-level subjective career space; they can also be used to represent objective space of many different jobs or roles at the team, organizational and national innovation eco-system levels. Researchers could also examine how innovation team or organizational E-P-L composition affect outcomes in different contexts (by type of R&D or level of analysis).

Schumpter (1934) suggested that innovation often derives from the combination or recombination of different ideas; the innovation process also requires the intermixing of people and scientists with different motivations and logics. To the extent that the EPL framework makes no assumption that E, P or L orientations are nonconflicting—it would be useful to examine how different agents in an innovation journey with different E, P and L profiles succeed or fail to collaborate with each other to move ideas into implementation to create economic and/or social impact.

References

Adner, R. (2006). Match your innovation strategy to your innovation ecosystem. *Harvard Business Review, 84*(4), 98–107.

Alexander, L., & van Knippenberg, D. (2014). Teams in pursuit of radical innovation: A goal orientation perspective. *Academy of Management Review, 39*(4), 423–438.

Allen, K. R. (2010). *Entrepreneurship for scientists and engineers*. Upper Saddle River, N.J.: Prentice Hall.

Ángel, P. O., & Sánchez, L. S. (2009). R&D managers' adaptation of firms' HRM practices. *R&D Management, 39*(3), 271–290.

Armstrong, J. (1994). *Is basic research a luxury our society can no longer afford? The bridge*. Washington, DC: National Academy Press.

Arthur, M. B. (1994). The boundaryless career: A new perspective for organizational inquiry. *Journal of Organizational Behavior, 15*(4), 295–306.

Arthur, M. B., & Rousseau, D. M. (1996). Introduction: The boundaryless career as a new employment principle. In M. B. Arthur, & D. M. Rousseau (Eds.), *The boundaryless career: A new employment principle for a new organizational era* (pp. 3–20). New York: Oxford University Press.

Autio, E., & Thomas, L. (2014). Innovation ecosystems. In M. Dodgson, D. Gann, & N. Phillips (Eds.), *The Oxford handbook of innovation management* (pp. 204–288). Oxford, UK: Oxford University Press.

Bell, S. T. (2007). Deep-level composition variables as predictors of team performance: A meta-analysis. *Journal of Applied Psychology, 92,* 595–615.

Bercovitz, J., & Feldman, M. (2006). Entpreprenerial universities and technology transfer: A conceptual framework for understanding knowledge-based economic development. *The Journal of Technology Transfer, 31*(1), 175–188.

Bercovitz, J., & Feldman, M. (2008). Academic entrepreneurs: Organizational change at the individual level. *Organization Science, 19*(1), 69–89.

Bignon, I., & Szajnfarber, Z. (2015). Technical professionals' identities in the R&D context: Beyond the scientist versus engineer dichotomy. *IEEE Transactions on Engineering Management, 62*(4), 517–528.

Bobadilla, N. (2014). *A longitudinal study of the effects of slack reduction on creativity in R&D and creative teams*. Unpublished dissertation, Sorbonne University, Paris, France.

Bobadilla, N., & Gilbert, P. (2015). Managing scientific and technical experts in R&D: Beyond tensions, conflicting logics and orders of worth. *R&D Management, 47*(2), 223–235.

Body, J., & Habbal, F. (2016). Chapter 2: The innovation ecosystem. In B. Banerjee & S. Ceri (Eds.), *Creating innovation leaders: Understanding innovation*. Switzerland: Springer International Publishing.

Boh, W. F., Evaristo, R., & Ouderkirk, A. (2014). Balancing breadth and depth of expertise for innovation: A 3M story. *Research Policy, 43*(2), 349–366.

Cabello-Medina, C., López-Cabrales, Á., & Valle-Cabrera, R. (2011). Leveraging the innovative performance of human capital through HRM and social capital in Spanish firms. *The International Journal of Human Resource Management, 22*(04), 807–828.

Chan, K. Y., Ho, M.H.R., Chernyshenko, O. S., Bedford, O., Uy, M. A., Gomulya, D., Sam, Y.L., & Phan, W.M.J. (2012). Entrepreneurship, professionalism, leadership: A framework and measure for understanding boundaryless careers. *Journal of Vocational Behavior, 81*(1), 73–88.

Chi, N. W., Huang, Y. M., & Lin, S. C. (2009). A double-edged sword? Exploring the curvilinear relationship between organizational tenure diversity and team innovation: The moderating role of team-oriented HR practices. *Group and Organization Management, 34*(6), 698–726.

Committee on Science, Engineering, and Public Policy (COSEPUP). (1995). *Reshaping graduate education for scientists and engineers*. Washington, DC: National Academies Press.

Cressey, D. (2012). PhDs leave the ivory tower: UK doctoral training centres prepare students to run a lab–or work outside academia. *Nature, 484*(7392), 20–21.

Cyranoski, D., Gilbert, N., Ledford, H., Nayar, A., & Yahia, M. (2011). The Ph.D. factory. *Nature, 472*(7343), 276–279.

D'este, P., & Perkmann, M. (2011). Why do academics engage with industry? The entrepreneurial university and individual motivations. *The Journal of Technology Transfer, 36*(3), 316–339.

DeFillippi, R. J., & Arthur, M. B. (1996). Boundaryless contexts and careers: A competency-based perspective. In M. B. Arthur & D. M. Rousseau (Eds.), *The boundaryless career: A new employment principle for a new organizational era* (pp. 116–130). New York: Oxford University Press.

Edquist, C. (2005). Systems of innovation: Perspectives and challenges. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), *The Oxford handbook of innovation* (pp. 182–208). Oxford: Oxford University Press.

Elkins, T. J., & Keller, R. T. (2004). Best practices for R&D project leaders: Lessons from thirty years of leadership research. *International Journal of Innovation and Technology Management, 1*(01), 3–16. pp. 181–208.

Etzkowitz, H. (2003). Research groups as 'quasi-firms': The invention of the entrepreneurial university. *Research Policy, 32*(1), 109–121.

Etzkowitz, H. (2001). The second academic revolution and the rise of entrepreneurial science. *IEEE Technology and Society Magazine, 20*(2), 18–29.

Faems, D., & Subramanian, A. M. (2013). R&D manpower and technological performance: The impact of demographic and task-related diversity. *Research Policy, 42*(9), 1624–1633.

Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality & Social Psychology Review, 2*(4), 290–309.

Feist, G. J. (2006). How development and personality influence scientific thought, interest, and achievement. *Review of General Psychology, 10*(2), 163–182.

Feller, I. (1990). Universities as engines of R&D-based economic growth: They think they can. *Research Policy, 19*(4), 335–348.

Freeman, C. (1995). The 'National System of Innovation' in historical perspective. *Cambridge Journal of Economics, 19*(1), 5–24.

Frese, M. (2007). The psychological actions and entrepreneurial success: An action theory approach. In J. R. Baum, M. Frese, & R. A. Baron (Eds.), *The psychology of entrepreneurship* (pp. 151–188). Mahwah, New Jersey: Lawrence Erlbaum Associations.

Fuhrmann, C. N., Halme, D. G., O'Sullivan, P. S., & Lindstaedt, B. (2011a). Improving graduate education to support a branching career pipeline: Recommendations based on a survey of doctoral students in the basic biomedical sciences. *CBE-Life Sciences Education, 10*(3), 239–249.

Fuhrmann, C. N., Hobin, J. A., Lindstaedt, B., & Clifford, P. S. (2011). *My IDP*. American Association for the Advancement of Science. http://myidp.sciencecareers.org/.

Göktepe-Hulten, D., & Mahagaonkar, P. (2010). Inventing and patenting activities of scientists: In the expectation of money or reputation? *The Journal of Technology Transfer, 35*(4), 401–423.

Government University Industry Research Roundtable (GUIRR). (1991). *Industrial perspectives on innovation and interactions with universities*. Washington, DC: National Academy Press.

Hall, D. T. (1996). Protean careers of the 21st century. *The Academy of Management Executive, 10*(4), 8–16.

Harris, R., & Short, T. (2014). Conclusion: Workforce development—More than the sum of its parts? In T. Short, & R. Harris (Eds.), *Workforce development: Strategies and practices* (pp. 341–358). Springer: Singapore.

Holland, J. L. (1959). A theory of vocational choice. *Journal of Counseling Psychology, 6,* 35–45. https://doi.org/10.1037/h0040767.

Holland, J. L. (1997). *Making vocational choices* (3rd ed.). Odessa, FL: Psychological Assessment Resources.

Hunter, S. T., Cushenbery, L., & Friedrich, T. (2012). Hiring an innovative workforce: A necessary yet uniquely challenging endeavor. *Human Resource Management Review, 22*(4), 303–322.

Inkson, K., Gunz, H., Ganesh, S., & Roper, J. (2012). Boundaryless careers: Bringing back boundaries. *Organization Studies, 33*(3), 323–340.

Jackson, D. J. (2011). *What is an innovation ecosystem?* (pp. 1–11). Arlington, VA: National Science Foundation.
Judge, T. A., Bono, J. E., Ilies, R., & Gerhardt, M. W. (2002). Personality and leadership: A qualitative and quantitative review. *Journal of Applied Psychology, 87*(4), 765.
Judge, W. Q., Fryxell, G. E., & Dooley, R. S. (1997). The new task of R&D management: Creating goal-directed communities for innovation. *California Management Review, 39*(3), 72–85.
Jordan, G. B. (2005). What matters to R&D workers. *Research-Technology Management, 48*(3), 23–32.
Jordan, G. B., & Malone, E. L. (2002). Performance Assessment. Chapter 6 in Washington Research Evaluation Network's Management Benchmark Study.
Kaiser, U., Kongsted, H. C., & Rønde, T. (2015). Does the mobility of R&D labor increase innovation? *Journal of Economic Behavior & Organization, 110,* 91–105.
Kanter, R. M. (1989). Careers and the wealth of nations: A macro-perspective on the structure and implications of career forms. In M. Arthur, D. Hall, & B. Lawrence (Eds.), *Handbook of career theory* (pp. 506–522). Cambridge, UK: Cambridge University Press.
Kitagawa, F. (2015). Crossing boundaries between science and innovation-career mobility and impacts of graduates of the UK Industrial Doctorate Centres. *International Journal of Technology and Globalisation, 8*(1), 51–63.
Lam, A. (2011). What motivates academic scientists to engage in research commercialization: 'Gold', 'ribbon' or 'puzzle'? *Research Policy, 40*(10), 1354–1368.
Lee, H. F., Miozzo, M., & Laredo, P. (2010). Career patterns and competences of PhDs in science and engineering in the knowledge economy: The case of graduates from a UK research-based university. *Research Policy, 39*(7), 869–881.
Lee, Y. S. (1996). "Technology transfer" and the research university: A search for the boundaries of university-industry collaboration. *Research Policy, 25*(6), 843–863.
Lim, C. P. (2016, August 2). Importance of right mix of talent to drive innovation, enterprise. *The Straits Times*, p. A20.
Lloyd-Ellis, H., & Roberts, J. (2002). Twin engines of growth: Skills and technology as equal partners in balanced growth. *Journal of Economic Growth, 7*(2), 87–115.
Lounsbury, J. W., Foster, N., Patel, H., Carmody, P., Gibson, L. W., & Stairs, D. R. (2012). An investigation of the personality traits of scientists versus nonscientists and their relationship with career satisfaction. *R&D Management, 42*(1), 47–59.
Lunt, I., McAlpine, L., & Mills, D. (2014). Lively bureaucracy? The ESRC's doctoral training centres and UK universities. *Oxford Review of Education, 40*(2), 151–169.
McCraw, T. K. (2009). *Prophet of innovation*. Harvard university press.
Meyer-Krahmer, F., & Schmoch, U. (1998). Science-based technologies: University-industry interactions in four fields. *Research Policy, 27*(8), 835–851.
Meyers, F. J., Mathur, A., Fuhrmann, C. N., O'Brien, T. C., Wefes, I., Labosky, P. A., … Friedlander, M. J. (2015). The origin and implementation of the broadening experiences in scientific training programs: An NIH common fund initiative. *The FASEB Journal, 30*(2), 507–514.
Mignonac, K., & Herrbach, O. (2003). Managing individual career aspirations and corporate needs: A study of software engineers in France. *Journal of Engineering and Technology Management, 20*(3), 205–230.
Mumford, M. D., Scott, G. M., Gaddis, B., & Strange, J. M. (2002). Leading creative people: Orchestrating expertise and relationships. *The Leadership Quarterly, 13*(6), 705–750.
National Institutes of General Medical Sciences. (2011). *Investing in the future: Strategic plan for biomedical and behavioral research training* (pp. 1–20). Baltimore, MD: NIGMS.
National Institutes of Health. (2013). *NIH Director's biomedical workforce innovation award: Broadening experiences in scientific training (BEST) funding opportunity announcement RFA-RM-12-022*. Bethesda, MD: National Institutes of Health.
National Postdoctoral Association. (2004). *NPA Postdoctoral Core Competencies*.
National Science Board. (2012). *Research and development, innovation and the science and engineering workforce*. Arlington, Virgina: National Science Foundation.

Nerad, M. (2004). The PhD in the US: Criticisms, facts, and remedies. *Higher Education Policy, 17*(2), 183–199.

Nerad, M., & Cerny, J. (2002). Postdoctoral appointments and employment patterns of science and engineering doctoral recipients ten-plus years after Ph. D. completion. *Communicator, VXXXV, 7,* 1–6.

OECD (Organisation for Economic Cooperation and Development). (2005). *Oslo Manual. Guidelines for Collecting and Interpreting Innovation Data*.

OECD (Organisation for Economic Cooperation and Development). (2012). *Transferable skills training for researchers: Supporting career development & research*.

Oskam, I. F. (2009, July). T-shaped engineers for interdisciplinary innovation: An attractive perspective for young people as well as a must for innovative organisations. In *37th Annual Conference–Attracting students in Engineering* (vol. 14). Rotterdam, The Netherlands.

Post, C. (2012). Deep-level team composition and innovation: The mediating roles of psychological safety and cooperative learning. *Group and Organization Management, 37*(5), 555–588.

Poncela-Garcia, M. (2016). Policy coherence for developing and steering innovation ecosystems. In *Revolutionising EU innovation policy* (pp. 97–113). UK: Palgrave Macmillan.

Remoe, S., & Guinet, J. (2002). *Dynamising national innovation systems*. OECD Publishing.

Roberts, G. G. (2002). *SET for success: The supply of people with science, technology, engineering and mathematics skills: The report of Sir Gareth Roberts' review*. London: Department of Trade and Industry and Department for Education and Skills.

Robledo, I. C., Peterson, D. R., & Mumford, M. D. (2012). Leadership of scientists and engineers: A three-vector model. *Journal of Organizational Behavior, 33*(1), 140–147.

Rosing, K., Frese, M., & Bausch, A. (2011). Explaining the heterogeneity of the leadership-innovation relationship: Ambidextrous leadership. *The Leadership Quarterly, 22*(5), 956–974.

Salter, A., & Alexy, O. (2014). The nature of innovation. In M. Dodgson, D. Gann, & N. Phillips (Eds.), *The Oxford handbook of innovation management* (pp. 26–52). Oxford, UK: Oxford University Press.

Savickas, M. L. (2005). The theory and practice of career construction. In S. D. Brown & R. W. Lent (Eds.), *Career development and counseling: Putting theory and research to work*. Hoboken, NJ: Wiley.

Schein, E. H. (1978). *Career dynamics*. Reading, MA: Addison-Wesley.

Schumpeter, J. A. (1934). *The theory of economic development*. Cambridge, MA: Harvard University Press.

Schumpeter, J. A. (1950). *Capitalism, socialism and democracy* (3rd ed.). London: Allen & Unwin.

Shane, S. A. (2004). *Academic entrepreneurship: University spinoffs and wealth creation*. Edward Elgar Publishing.

Shane, S., & Venkataraman, S. (2000). The promise of entrepreneurship as a field of research. *Academy of Management Review, 25*(1), 217–226.

Smith, K. R. (2006). Building an innovation ecosystem: Process, culture and competencies. *Industry and higher education, 20*(4), 219–224.

Smith, S. J., Pedersen-Gallegos, L., & Riegle-Crumb, C. (2002). The training, careers, and work of Ph. D. physical scientists: not simply academic. *American Journal of Physics, 70*(11), 1081–1092.

Somech, A., & Drach-Zahavy, A. (2013). Translating team creativity to innovation implementation: The role of team composition and climate for innovation. *Journal of Management, 39*(3), 684–708.

Spohrer, J., & Kwan, S. K. (2009). Service science, management, engineering, and design (SSMED): An emerging discipline–outline and references. *International Journal of Information Systems in the Service Sector, 1*(3), 1–31.

Tams, S., & Arthur, M. B. (2010). New directions for boundaryless careers: Agency and interdependence in a changing world. *Journal of Organizational Behavior, 31*(5), 629–646.

Thursby, M. C., Fuller, A. W., & Thursby, J. (2009). An integrated approach to educating professionals for careers in innovation. *Academy of Management Learning & Education, 8*(3), 389–405.

Toner, P. (2011), *Workforce skills and innovation: An overview of major themes in the literature* (OECD Education Working Papers No. 55). Paris: OECD Publishing. http://dx.doi.org/10.1787/5kgk6hpnhxzq-en.

van de Ven, A.H., Polley, D., Garud, R., & Venkataraman, S. (1999/2008*). *The innovation journey*. New York: Oxford University Press [* paperback edition].

van Knippenberg, D. (2017). Team innovation. *Annual Review of Organizational Psychology and Organizational Behavior, 4,* 211–233.

Venkataraman, S. (1997). The distinctive domain of entrepreneurship research. *Advances in entrepreneurship, firm emergence and growth, 3*(1), 119–138.

VITAE. (2011). *Vitae Researcher Development Framework*. Cambridge, U.K.: Career Advisory Research Centre Ltd. https://www.vitae.ac.uk/vitae-publications/rdf-related/researcher-development-framework-rdf-vitae.pdf.

VITAE. (2013). *The career-wise researcher*. Cambridge, U.K.: Career Advisory Research Centre Ltd. https://www.vitae.ac.uk/vitae-publications/guides-briefings-and-information/the-career-wise-researcher-vitae-2013.pdf.

Kim-Yin Chan is an Associate Professor in Organizational Behavior and Human Resource Management at the Division of Leadership, Management & Organization of Nanyang Business School, Nanyang Technological University. He received his Ph.D. from the University of Illinois at Urbana-Champaign in 1999 majoring in Industrial-Organizational Psychology with a minor in Quantitative Psychology. He has published in the Journal of Applied Psychology, Journal of Vocational Behavior, Personnel Psychology, Journal of Career Assessment, Multivariate Behavioral Research, and Educational and Psychological Measurement, and is also the lead author of Military Leadership in the 21st century: Science and Practice, published by Cengage Learning in 2011. His current research focuses on understanding careers and leadership motivation in the 21st century.

Kwee Hoon Lim is a defence psychologist with the Singapore Armed Forces where her work involves personnel selection and assessment and advising commanders on matters pertaining to psychological readiness and organizational behavior and development. She was seconded to Singapore's Agency for Science, Technology and Research as an internal OD consultant for two years to develop and implement a Talent Master plan to realize the potential of A*STAR scientific talent through enhanced human and social capital development. She received her BA in Psychology with Honors from the University of Calgary, Canada in 1989 and a Master of Arts in Instructional Design and Technology from Nanyang Technological University in 2012. She has presented at the International Congress of Psychology and the International Military Testing Association conference, and has published articles in various in-house journals and as part of a monograph.

Marilyn A. Uy is an Associate Professor in the Division of Strategy, International Business, and Entrepreneurship at the Nanyang Business School, Nanyang Technological University, Singapore. She completed her Ph.D. at the Leeds School of Business, University of Colorado at Boulder (USA). Her research spans the broad areas of psychology of entrepreneurship, work motivation, and emotional well-being. She uses longitudinal approaches such as experience sampling method, weekly or daily diary method, and multi-wave surveys in conducting empirical research. Her articles have been published in premier journals including Academy of Management Journal, Journal of Applied Psychology, Journal of Business Venturing, Entrepreneurship Theory and Practice, Human Relations, and Organizational Research Methods, among others. She has been appointed as Editor (Associate Editor equivalent) of Entrepreneurship Theory and Practice and has been serving on the editorial review boards of Journal of Business Venturing, Strategic Entrepreneurship Journal, Applied Psychology: An International Review, and Small Business Economics. Since joining NTU Singapore in 2011, she has attracted competitive research funding worth more than S$3 million.