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How University-based Principal Investigators Shape a Hybrid Role Identity

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Abstract

This paper examines the role identity of university based principal investigators (PIs), as well as the learning mechanisms that underpin this position. PIs have become the focus of increasing research attention which has argued that they, along with universities and funding bodies, form an increasingly crucial tripartite in public research environments. Although the PI position is well recognised among scientific peers and research institutions, a role identity is still emerging and remains ill-defined. This issue requires research attention as having a clear role identity is fundamental to performing a role effectively. Our analysis draws on interviews with 41 health science PIs in New Zealand to develop a PI role identity learning framework. We find that the PI role identity is made up of four roles – science networker, research contractor, project manager, and entrepreneur - that are mutually reinforcing throughout the research process, and which together form a hybrid science-business role identity. Furthermore, we identify two learning mechanisms – learning through experience and violation – and show how these are formative for role identity when transitioning to an ill-defined position. Based on our findings we discuss a number of practical implications for PIs, universities and funding bodies.

Keywords: principal investigators; role identity; learning; publicly funded science

How University-based Principal Investigators Shape a Hybrid Role Identity

'You are always learning about being a PI (Principal Investigator) but the art of research and science has changed so much over the last 20/30 years. It is now all about survival, how you position your research, how you position yourself, who you align with, who you know in the field and things like that. It has all become very strategic. If you don't learn and embrace those things you cannot survive. That's not just a philosophical statement, I'm saying it based upon my own experience' (Interview informant)

1. Introduction

Policy makers are increasingly recognising universities as important entrepreneurial ecosystem actors that stimulate and support economic and societal activities within the localities and regions that they inhabit (Guerrero et al., 2016). Recent studies highlight how the core missions of entrepreneurial universities - teaching, research and technology transfer – have a positive economic impact (see Budyldina, 2018; Eseley and Miller, 2018; Guerrero and Urbano, 2012) and play a critical role in growing and developing local intellectual capital (Treguattrini et al., 2018). At the micro level of entrepreneurial universities are scientists in the Principal Investigator (PI) role who shape science that attracts funding and complete research that delivers a wide range of impacts - economic, societal, health, technological, regulatory and human capital (see Cunningham and O'Reilly, 2019) - to boost the development and growth of entrepreneurial ecosystems.

PIs can be defined as the lead scientists on publicly funded research projects and programmes. Academic scientists transition to the PI position when they secure a competitive funding grant and assemble a team to carry out the project under their leadership (Melkers and Xiao, 2012). Together with their host university and the funding body, PIs form a crucial tripartite in publicly funded research. However, as a dual agent answerable to both their institution and funding body, PIs experience significant pressures (Cunningham et al., 2014). On the one hand, PIs operate within institutions that are becoming increasingly entrepreneurial in nature (Guerrero et al., 2012, Kalar and Antoncic, 2015). In addition to

this, funding bodies wish to see tangible policy relevant outputs from their investment as well as a range of other impacts. Despite their pivotal position in forging scientific futures within this tripartite of science, little if any research attention has elucidated the role identity of PIs and how this is learnt. This is problematic as having a clear role identity is fundamental to performing their role effectively, and critical to supporting the development of entrepreneurial ecosystems.

Identity details the meanings individuals attach to themselves while roles are social positions that hold behavioural expectations and responsibilities to others (Merton, 1957). Together, role identity explains self-defintion, which arises from the 'goals, values, beliefs, norms, interaction styles and time horizons' associated with a role (Ashforth, 2000: 475). In work settings, professional role identities refer to people's definition of self within their professional community, which arises from their enactment of roles (Chreim et al., 2007; Goodrick and Reay, 2010). Although professional role identities are often stable (Gioia, 1998) and resistant to change (Chreim et al., 2007), circumstances can induce adaptation and role transition. Role transitions occur when there is a change in job content or the status of one's position (Glaser and Strauss, 1971; Nicholson, 1984). The addition of new roles brought about by such transitions instigates changes in the role identity. Learning is at the nexus of changes in role identity (Hall, 1971). This learning is particularly important when the new role identity is ill-defined as there is an absence of role models (Ibarra, 1999) and social validation (Pratt et al., 2006) to guide the learning.

Although the position of PI is recognisable within academic communities and universities and generally regarded as a significant career milestone (Cunningham et al., 2019), in practice there remains a lack of clarity on PI responsibilities (Mangematin et al, 2014; O'Kane et al., 2015a). A burgeoning but fragmented stream of literature highlights many of the role complexities scientists encounter when they transition to the PI position

(Casati and Genet, 2014; Luukkonen, 2012; Kidwell 2013; McAdam et al., 2010; O'Kane 2018). PI role requirements are more complex than just being an excellent scientist. PIs must design and shape research projects, mobilise and lead scientific networks, and deploy and manage resources efficiently to address national/international funding calls and deliver science advancement/policy objectives that are increasingly required to have a scholarly, economic and societal impact. Another issue that remains poorly understood is how PIs learn new roles as they transition to the position. In practice, PI are individual scientists who take on additional role responsibilities for which they have often not received any formal role preparation. While no research has directly examined PI role identity learning, a number of studies have alluded to how PIs learn on the fly (Kreeger, 1997) or on the job (Cunningham et al. 2016; 2014; O'Kane et al., 2017), gradually accumulating PI practices as they add new learnings.

The purpose of this paper is to examine the roles that make up university based PIs' role identity, as well as the learning mechanisms that underpin the enactment of the role identity. To address this issue we draw on emerging literature on PIs and combine this with theoretical insights on identity and learning to develop a conceptual model framing how scientists transition to the PI position through role learning. We utilise interviews with 41 university based health science PIs publicly funded in New Zealand. As shown by Giacalone et al. (2018), in the health science context, funding source (e.g. industry or public funding body) can have a significant influence on both PI effectiveness and the type of research funded.

Our findings unearth the complexities that underpin the emerging PI role identity. We find that PIs have a multi-role identity and that this role identity demands a dual learning mechanism. Based on these findings, we develop a novel PI role identity learning framework. Our research makes a number of notable contributions. First, we crystallise the PI role

identity around four core roles: science networker, research contractor, project manager and entrepreneur. We argue these roles are mutually reinforcing throughout the research process, and together represent a role identity that has a hybrid science-business form. Second, we identify two learning mechanisms – learning through experience and violation – and show how learning is formative for role identity when transitioning to a position with an ill-defined identity. Based on our findings and framework we argue that learning through experience is utilized to enact new roles and responsibilities closely aligned with one's core sense of self, while learning through violation is required for roles and responsibilities that are more foreign to one's sense of self. Our results also provide some significant practical implications for PIs, funding bodies and universities that coalesce around the need for them to work together to establish role clarity and to generate more appropriate support and professional development opportunities for PIs, particularly with respect to PI role preparation.

The remainder of this paper is structured as follows. In Section 2 we discuss the importance of PIs and what the literature generally says about their roles and how these might be learnt. Section 3 details the research design and Section 4 presents the research results. Section 5 discusses the implications of these findings for theory and practice. The paper concludes in Section 6 with summary comments and ideas for future research.

2 Theoretical background

2.1 PI role identity

Role identity arises from the 'goals, values, beliefs, norms, interaction styles and time horizons' associated with a role (Ashforth, 2000: 475), while professional role identity relates to how roles are enacted in work settings (Chreim et al., 2007; Goodrick et al., 2010). Most research on role identity in science has centred on the general academic community's attempts to reconcile academic and commercial goals (Ambos et al., 2008; Jain et al., 2009;

Meek and Wood, 2006). Cohen et al. (2017) show how academic entrepreneurs must completely recombine social, spatial, intellectual and institutional aspects of their 'old' academic selves to launch and fund new ventures. In comparison, little if any research has focused on elucidating the role identity of PIs.

The PI role identity is emerging and becoming increasingly prominent in a shifting research environment. Specifically, together with their host university and the funding body, PIs now form a crucial tripartite in publicly funded research. Within the university, PIs operate within institutions that are becoming more entrepreneurial in nature (Guerrero and Urbano, 2012, Kalar and Antoncic, 2015). There is an expectation that academic researchers will undertake research that in addition to publication outputs will generate entrepreneurial capital (Audretsch 2012), commercialisation and academic engagement (Perkmann et al., 2013) and ultimately economic development and social change (Klofsten et al., 2019). On the other hand, funding bodies wish to see tangible policy relevant outputs from their investment. Public funding is regarded as a vehicle to generate valuable scientific knowledge (Salter and Martin, 2001), higher and longer spanning publication outputs (Kastrin et al., 2018), capacity development among the science community (O'Kane et al., 2018), greater industry engagement (Bozeman and Gaughan, 2007), broader research networks (Callon, 1994) and spin-off development (Vincett, 2010), all activities that lead to improved regional and national performance (Etzkowitz and Leydesdorff, 2000).

In essence, PIs must operate as a dual agent answerable to both their institution and funding body. Scholars have alluded to PIs' intermediary role in entrepreneurial ecosystems. For example, in influencing, shaping and then driving research programmes it is noted that PIs engage with and synthesise the objectives of funding bodies, industry and universities (Cunningham et al., 2014). PIs simultaneously govern (navigate and reconcile) funding body-, university- as well as project-level control mechanisms to deliver value for multiple actors

in an entrepreneurial ecosystem (Cunningham et al., 2019). As argued by Cunningham et al (2018: 137) “it is not the institutions, but rather individual scientists and academics who generate innovative ideas and novel research trajectories that can form the basis for value creation for other actors such as firms, government regulators etc.”

However overall, little if any empirical research attention has specifically examined the role identity of PIs. It is our contention that, in order to better understand the driving forces underpinning how scientific futures are forged through universities and funding bodies, it is necessary to clarify who PIs are, namely how they enact their as of yet poorly defined role identity.

2.2 PI roles

In the paragraphs that follow we review literature pertaining to PIs, presenting this in the form of four roles (organizers, visionaries, research managers and entrepreneurs) that appear central to PIs’ emerging role identity.

PIs must be adept *organizers*. As explained by Hicks and Katz (2011: 138-139):

> “The individual "PI" is something of a fiction in that a person's capacity for obtaining competitively awarded grant funding will be shaped by other possible units of analysis … groups, that is colleagues in various stages of career development who collaborate with and work for the person, and in so doing shape their ideas and help to execute their research”

PIs must form and coordinate competitive research teams. The type of collaboration formed by PIs is a key determinant of success in competitive research funding (Melkers et al., 2012; Poti and Reale, 2007). Colatat (2015) report how the Defence Advanced Research Projects Agency (DARPA) intentionally stimulate funded scientists to form novel forms of collaboration. Park, Lee and Kim (2015) emphasise how funding bodies use observable attributes of the research team when determining funding allocations. A key challenge for PIs is demonstrating that sufficient competency exists within the collaboration. Azoulay et al. (2011) report how the policies of research agencies tend to over emphasise the importance of

track records. Sorin and Hannum's (2013) analysis of the distribution of American Recovery and Reinvestment Act (ARRA) funds by the National Institute of Health (NIH) concluded that the majority of the funds went to PIs who already had non-ARRA NIH grants, resulting in a high concentration of research funding among existing PIs. Furthermore, scholars report how young and inexperienced research scientists can be disadvantaged or viewed as less capable when applying for research grants (Luukkonen, 2012)

More generally, the importance of PIs' organizing skills is apparent in how effectively organized science collaborations can positively influence research productivity (Defazio, Lockett and Wright, 2009; Lee and Bozeman, 2005); impact (Lee, Walsh, Wang, 2015; Rijnsoever and Hessels, 2011) and novelty (Bercovitz and Feldman, 2011; Heinze and Bauer, 2007; Lee et al., 2015). Effectively organized collaborations also help shape scientific careers and facilitate science and technical human capital development (Bozeman and Mangematin, 2004). Senior and experienced PIs "bring to bear hard-won wisdom, practical knowledge of research strategies, extensive social capital or large-scale research funding" (Bozeman et al., 2015: 3). This can assist early career researchers learn about the complex requirements of building a scientific careers (Bozeman et al., 2004) and moving onto independent research (Laudel and Glaser, 2008; Stephan 2012). Of course, to the advantage of more experienced PIs, including less experienced researchers in collaborations can also bring much needed "drive, knowledge from more recent training and a willingness to work hard at a variety of research roles" (Bozeman et al., 2015: 3)

PIs are also *visionary* in how they envision novel research trajectories. In an academic science context, PIs apply 'strategic foresight' (Iden et al., 2017) to capture, induce and respond to future changes. According to Mangematin et al. (2014),when shaping and articulating research agendas PIs envision publication outputs, how the proposed field of science will develop and the potential for new markets from research application. Casati et al.

(2014) identify a number of strategic practices ("focusing"; "innovating and problem solving"; "shaping"; "brokering") that PIs utilize, with 'shaping' detailing how PIs try to implement their scientific vision. Cunningham et al. (2015) show that PIs seek to remain cognisant of market, social, science and policy developments and adapt their projects accordingly to ensure their science visions remain relevant. To secure funding resources, O'Kane et al. (2015) show how proactive PIs utilize high and low levels of funding body conformance respectively to deepen existing and/or articulate new research trajectories that are in line with their longer term science vision. Kidwell (2014) shows how PIs set about realizing their vision through the purposeful mobilization of resources (talent, equipment, lab space and research opportunities) and the agile selection of work environments (e.g. moving university or into industry) that are most supportive of their research ambitions at different points in time.

PIs must be competent *research managers*. Once a predominantly individual activity, resourced research work is now typically larger in scale (Lee et al. 2015). Science based research programmes are manifested in more complex bureaucratically organised activities, including division of labor, standardization and formalization, hierarchy, and decentralization (Murayama, Nirei and Shimizu, 2015). Thus, although long recognised for their leadership role in science laboratories (Latour and Woolgar, 1986; Stephan, 2012), there is increasing recognition that PIs must also be effective managers (Cunningham et al., 2014). O'Kane et al. (2015) provide a detailed overview of role definitions from a range of prestigious international research institutions that outline the wide range of managerial responsibilities bestowed on PIs including: designing and scheduling the research project; financial management and sign-offs; recruitment, supervision and mentoring of staff; preparing progress reports; and ensuring project deliverables are met. Cunningham et al. (2015) show that PIs have significant human resource responsibilities. They must recruit, motivate and

supervise the requisite expertise, monitor project partners, attend to under performers, and integrate inter-disciplinary and cross cultural expertise. Boardman and Ponomariov (2014) propose that PIs with previous managerial knowledge are more likely to utilise structured and authoritative styles of management. Cunningham et al. (2016) offer some interesting insights on the breadth of activities that PIs must engage in and how managing their time allocation across these activities influences research impact and reach. Essentially, PIs must ensure there is effective horizontal collaboration within their teams. Team members, some performing experimentation, others reporting, other writing breakthrough papers or engaging with industry etc., are accountable to each other through the management and coordinating role of PI (Conti et al., 2015).

PIs also act as *entrepreneurs* to translate their research and maximise its impact beyond scholarly contribution. In academic context, entrepreneurs are those involved in "any activity that occurs beyond the traditional academic roles of teaching and/or research, is innovative, carries an element of risk, and leads to financial rewards for the individual academic or his/her institution" (Abreu and Grinevich, 2013: 408). Consistent with this view, O'Kane (2018) finds that PIs forward integrate in the research and innovation process to interact more collaboratively with TTO executives in order to formulate impactful grant applications and capture IP. Baglieri and Lorenzoni (2014) show how PIs both create value when conducting research projects that address technical problems and market needs, but also capture some of that value when they translate their applications or technologies. For example, through spin-off creation PIs can increase the impact of their research outputs by influencing and then exploiting market boundaries or roadmaps. Scholars have also highlighted PIs' entrepreneurial attitudes in relation to spin-off formation (Del Giudice et al., 2017) and university proof of concept processes (McAdam et al., 2010).

PIs as entrepreneurs also create value and impact through their boundary work. Cunningham et al. (2018) argue that PIs' boundary spanning works builds collective value motives that form the basis by which they on the one hand generate, co-create and capture value for multiple stakeholders (e.g. users, regulators, firms, government) and on the other hand minimise value destruction and loss of public good impact. In terms of industry, Boehm and Hogan (2014) find that PIs act as boundary spanners who identify and exploit market needs by establishing and managing stakeholder networks with industry. Taking an entrepreneurial ecosystem perspective, Cunningham et al (2019) argue that PIs are important public policy agents through their unique capacity to enhance SME competiveness through engagement. Offering further support fort this view, Kidwell (2013) find that PIs identify structural holes and create trust between the lab and industry to achieve their scholarly and commercial goals. More specifically, detailing four boundary spanning activities - extrapolation, seeking, aligning and anticipating – Kidwell show how PIs' role identity has progressed from one of research scientists who occasionally innovate to sustained innovators. Table 1 summarizes the studies that directly focus on PIs, specifying how each study relates to the four roles. We next consider two mechanisms by which PIs learn these core roles.

Table 1: Summary of PI studies and their relationship to PI roles

Study	Focus	Method	Relevant PI role	Illustrative findings (to role)
Sorin and Hannum, (2013)	Examine the effect of ARRA funding on creating and retaining research jobs.	Quantitative methods applied on secondary data taken from NIH database.	Organizer	PIs assemble teams of credible researchers and admin/support staff to win or extend grants, thereby creating or retaining jobs.
Luukkonen (2012)	Reports on ERC grant application peer review practices	Qualitative method based on 20 interviews	Organizer	PIs need to be good at organizing and managing their teams. Early career starting grants help to train researchers to build key skills and expertise in this area.
Azoulay et al. (2011)	Examine the productivity of Howard Hughes Medical Institute (HMMI) funded investigators, who have longer award cycles than NIH.	Comparative econometric analysis of two PI groups, i.e., HMMI investigators vs. control group.	Organizer	HMMI PIs, who are encouraged to experiment intellectually and receive active feedback, organise and produce more research with higher impact.
O'Kane et al. (2015)	Categorize PI strategic behaviors in applying for competitive research grants.	Qualitative method based on 30 interviews.	Visionary	In combining strategic posture (reactive and proactive) with varying degrees of conformance to funding body needs, PIs realize their research visions in different ways.
Casati & Genet (2014)	PIs practices for organizing coordinating funded research.	Qualitative method based on 20 interviews.	Visionary	PIs envision new research paradigms but also exploit nearer term outcomes and solutions for existing markets.
Kidwell (2014)	Explore the personal actions and experiences of PIs and how they navigate their PI role.	Multiple case-study method (n=4) based on interviews and observations.	Visionary	PIs mobilize resources to enact their research agendas. They make risky but purposeful decisions to move from institutions that do not share their vision.
Conti and Liu (2015)	Examine the link between science laboratory output and its personnel composition, numbers and types of employees/students.	Quantitative case study of laboratories at MIT.	Manager	Personnel composition of laboratories is an important determinant of laboratory productivity. Therefore, PIs as laboratory managers have to pay special attention to forming and managing personnel composition.
Cunningham et al. (2015)	Examine the managerial challenges faced by PIs implementing funded projects and programmes.	Qualitative method based on 30 interviews.	Manager	To be effective, PIs needs to act as managers in their job. However, they face three key managerial challenges around project management, project adaptability and project network management.
Cunningham et al. (2014)	Study the inhibiting factors (political-, institutional- and	Multiple case-study method (n=30) based on interviews	Manager	PIs without any specific management training adopt a hybrid role of research management and leadership. Without

	project-level) faced by 'autonomous' PIs	and documentary analysis.		admin support, they have to spend more time on management rather than scientific work.
Boardman and Ponomariov (2014)	Examine the effect of management knowledge in university research centres.	Qualitative method based on 21 National Science Foundation Centres.	Manager	PIs with management knowledge take a more structured and authoritative approach to organisation and management in university research centres
O'Kane (2018)	Examine the interactions between TTO executives and publicly funded PIs within universities.	Qualitative method based on 42 interviews.	Entrepreneur	PIs are engaging more closely with TTOs executives – these engagements help PIs to better incorporate impact and commercialisation intentions in their grant proposals.
Del Giudice et al. (2017)	Examine the role of a country's culture in influencing the entrepreneurial attitudes of PIs.	Data from Eurobarometer 2012 survey analysed.	Entrepreneur	PIs act as 'explorative entrepreneurs' to capitalize on the intellectual property developed in universities. The entrepreneurial culture of a country is a key driver that can make PIs and their research groups more competitive than international counterparts.
Baglieri and Lorenzoni (2014)	Examine how PIs affect new technology trajectories and shape market boundaries.	5 illustrative case histories.	Entrepreneur	Lead user PIs exhibit superior capabilities in turning a generic technology into several market applications, with no negative effects on their academic role.
Boehm and Hogan (2014)	Examine how the networks in scientific knowledge collaborations are initiated and maintained from a multi-stakeholder perspective.	Case-study method with 82 interviews.	Entrepreneur	PIs play a lead role in establishing and managing stakeholder networks. PIs are better placed than TTO managers to act as boundary spanners in bridging the gap between science and industry.
Kidwell (2013)	Examine how PIs expand their functional roles to become brokers for the commercialisation of their technologies.	Multiple case-study (n=4) based on interviews and observation.	Entrepreneur	PIs purposefully engage in brokering roles - which fall under extrapolating, seeking, aligning and anticipating needs of the market – to engage with industry.
McAdam et al. (2010)	Explore the role and influence of the PIs in proof of concept processes within university-science park incubators using an absorptive capacity perspective.	Multiple case-study (n-6) method based on interviews and secondary data.	Entrepreneur	Universities that support academic entrepreneurship see PIs and their performance increase in proof of concept processes. PIs may disengage with these processes when universities do not recognise/reward these activities.

2.3 PI role identity learning mechanisms

Role transitions occur when there is a change in job content or the status of one's position (Glaser et al., 1971; Nicholson, 1984). Enacting new roles during role transitions requires learning. As is the case for PIs, this learning is particularly important when the new role identity remains ill-defined and there is an absence of role models (Ibarra, 1999) and social validation (Pratt et al., 2006). This lack of role identity guidance means there can be a "continual renewal of discretionary possibilities and recurring novelty of job demands" (Nicholson, 1984: 186). Building on these ideas, we present two learning mechanism by which PIs learn the roles we identified through the literature.

First is learning through experience. At the firm level this is manifested in accumulated learning by doing (Beneito et al., 2014). Similarly, at the individual level where professional boundaries are unclear, individuals 'explore' a new role identity (Nicholson, 1984), simultaneously shaping the parameters of the associated roles as they learn and experience them. Individuals learn to modify and reshape how they define themselves when undertaking roles that involve new behaviours, capabilities and types of interaction (Van Maanen and Schein, 1979). They learn to re-evaluate and revise who they are and how they are seen (Strauss, 1997: 102). Dutton et al.'s (2010) "adaptive identity perspective" explains how individuals who experience or anticipate role changes develop and learn new skills and roles and that this coincides with identity modifications and new definitions of self that reduce levels of conflict with new internal (e.g., personal goals) and external (e.g., role expectations) standards. Empirically, Ibarra (1999) shows how junior professionals transitioning to a more senior advisory positions learn their new role identity by initially experimenting with provisional selves. Such trial periods help "bridge the gap between their current capacities and self-conceptions and the representations they hold about what attitudes and behaviours are expected in the new role", which is not yet established as a "fully

elaborated professional identity" (p.765). Similarly, Cohen et al. (2017) show how first time academic founders search and navigate novel domains of work for which they have little experience (i.e. seeking funding for their new venture) by recombining aspects of their old professional domains.

While no research has yet directly examined PI role identity learning, a number of studies have alluded to PIs learning on the fly (Kreeger, 1997) or on the job (Cunningham et al. 2016; 2014; O'Kane et al., 2017), gradually accumulating the PI role identity as they add new role learning. Thus, we define learning through experience as an incremental process where individuals gradually accumulate role learning and shape the new role identity as they experience it.

Second is learning through violation. Role identity violations occur when what someone is doing in their work no longer aligns with who they think they are or are supposed to become (Pratt et al., 2006). The identity to which they are accustomed no longer provides sufficient meaning and guidance for the new roles being undertaken (Hogg and Terry, 2000). Violations are akin to identity threats, where one's sense of self is called into question by potential harm to the value and meaning of their identity (Kreiner and Sheep, 2009; Petriglieri, 2011). Violations occur during role transitions when new role requirements suddenly challenge individuals' autonomy and core identity (Maurer and London, 2015). Having an obligation to fulfil new roles can violate one's internal sense of self (Ibarra et al., 2010). Such circumstances can stimulate role identity learning as individuals set about reconciling the discrepancy. Pratt et al. (2006) show how various customisation processes ('patching', 'enrichment' and 'splinting') are used to learn new role identities during major career transitions that violate senses of self. Petriglieri (2011) propose that individuals learn to enact a number of identity –protection and -restructuring responses to maintain or eliminate role identity threats respectively. Thus, learning role identity through violation is

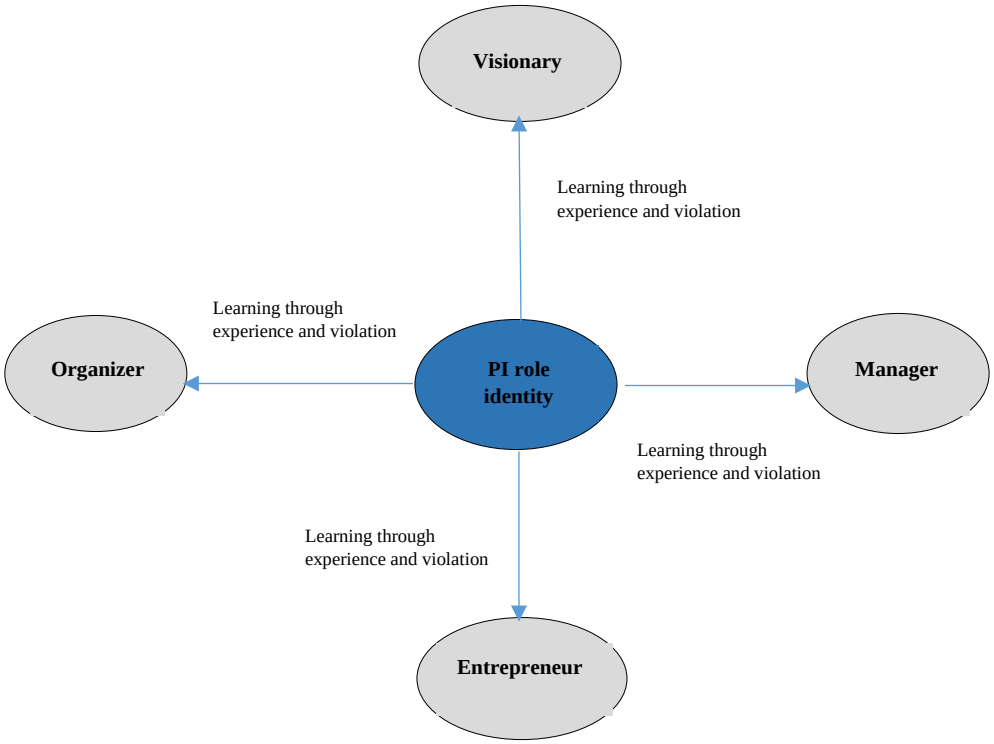
more reactionary and abrupt than incremental. Individuals may alter the meaning of new role identities once it is clear that the necessary role requirements are not as anticipated or conflict with current versions of self (Petriglieri, 2011, Pratt et al., 2006).

Once again, while no literature has directly examined PI role identity learning, a number of studies do indirectly point to PI learning through violation. For example in terms of the visionary and organizer roles, Mangematin et al. (2014) suggest that PIs must not only learn how to pursue their research vision through the formation of temporary organizational structures, they must also learn to plan for further funding beyond the lifetime of these temporary projects. In terms of the manager role, it is reported that PIs are frustrated with the lack of tailored professional management development training they receive (Cunningham et al., 2014). In related literature, Cassanelli et al. (2017) find that principal researchers spend too much time on management duties for which they are under-trained. Similarly, Maurer and London (2015) explain the complex 'role identity shifts' that innovative and creative individuals experience when they are asked, but insufficiently supported, to transition from a position of individual contributor to leader or manager in organisations that expect and reward innovation. Finally in terms of the entrepreneur role, while it is suggested that our understanding of PIs' role in research commercialisation is poorly developed (McAdam et al., 2010), a number of studies show how PIs encounter difficult challenges when engaging with TTO executives (Cunningham et al., 2015; O'Kane, 2018). Specifically, it is found that PIs must contend with skill deficiencies in areas related to overvaluing IP as well as marketing, selling and pushing protected technology towards the market. Elsewhere, Mangematin et al. (2014) highlight the lack of training PIs receive to undertake the boundary crossing activities expected of them, while Cunningham et al. (2014) allude to the difficulty PIs experience in reconciling competing timelines and expectations between funding bodies and industry. These points are consistent with a more general tension between science and business

mandates in academia, tensions that are increasingly prevalent with the continued emergence of academic entrepreneurship (Siegal and Wright, 2015). Illustrating these tensions, O'Kane et al. (2015) show how TTO executives struggle to project science and business identities to academics and university management respectively. Ambos et al. (2008) show how individual scientists struggle more than their institutions to combine and reconcile the tensions that exist between academic and commercial work goals. Jain et al. (2009) find that scientists attempt to enact a hybrid role identity with a primary academic self and a secondary commercial persona when participating in technology transfer activities. Also, Meek and Wood (2016) propose that scientists need to undertake purposeful and distinct identity adaptations when responding to university initiatives to encourage commercialisation engagement.

In sum, our focus is on examining the roles that make up the PI role identity, as well as the learning mechanisms that underpin the enactment of this increasingly prominent role identity. Figure 1 presents our conceptual framework on PI role identity learning. Based on the literature we have reviewed, we expect both learning mechanisms are relevant to each of the four roles identified. However, in this research we are interested in untangling this to uncover the *primary* learning mechanisms associated with each role. Our finalized research question therefore reads, what are the roles that underpin university PIs' role identity, and what are the primary learning mechanisms associated with these roles? Next, we present the study's research design.

Figure 1: Conceptual framework: PI role identity learning



3. Research design

To examine PI role identity learning we focus on health science PIs funded through the Health Research Council (HRC) in New Zealand as a case of study. Case studies are useful in generating and developing theory in under-researched areas (Siggelkow, 2007), and a theoretically informed case approach provides a valuable means with which to communicate study findings (Buchanan and Dawson, 2007). Expanding on this point, given the importance of methodological fit for undertaking high quality field research, and within this, the appropriateness of exploratory qualitative research for studying a nascent phenomenon (Edmondson and McManus, 2007), which accurately reflects the status of PI role identity within the literature, a case analysis of HRC PIs through qualitative research is suitably justified. Central to our research design is the acceptance of HRC funded PIs as

'knowledgeable agents' (Gehman et al., 2018) who can give unparalleled insights on what they are trying to do and what they are experiencing as they enact the role identity of PI.

HRC funded research is highly cited internationally and outperforms other NZ funding sectors on quality and impact of publication outputs (HRC Annual Report 2016). From 2011-2015 field-weighted citation impact for NZ publications in medicine was 1.72, which is significantly above the Organisation for Economic Co-operation and Development (OECD) average of 1.23; and publications in health professions was 1.34 compared with an OECD average of 1.16 (NZ Health Research Strategy 2017-2027).

3.1 Data collection

We initially compiled a dataset of HRC funded research over a two-year period. We contacted all PIs within this dataset to request an interview. In total, 110 PIs were contacted and 41 agreed to participate. All but two of the PIs were university based, the outliers based in hospitals having recently moved from a university position. We were conscious of the need to capture sufficiently diverse evidence of role enactment and learning across a range of PI types and career stages/titles. Illustrating this point, the final list of informants included: twelve new PIs (first successful grant) and 29 experienced PIs (i.e., previously and/or currently held a grant); 23 were male and 18 were female; a range of different funding types (in terms of duration and funding amount) including projects, programmes, feasibility studies and emerging research grants. Informants were anonymised to facilitate more open interviews discussions. Table 2 provides a full breakdown of PI informants. As per the varying timescales of the funded projects/programmes (12-60 months), when research interviews took place some informants were close to completing their funded projects (i.e. the 12 month projects) while others were beginning or mid-way through theirs (i.e. the 24, 36 and 60 month projects/programmes). Although the 29 experienced PIs could draw on insights from previous

funded research activities, it is important to note that all informants had ongoing funded research projects at the time of interview so problems with recollection were reduced.

Table 2: PI titles and project details

PI Details			Project Details		
Gender	**New/Experienced**	**PI Title**	**Project Type**	**Duration**	**Project value**
Male	E	Dr - Research Leader	Project	36 months	$750,000-$1m
Female	E	Research Professor	Project	36 months	$1m-$1.25m
Male	E	Professor – Research Director	Project	36 months	$1m-$1.25m
Male	E	Ass Professor	Project	24 months	$250,000-$500,000
Female	N	Dr – Senior Lecturer	Project	36 months	$1m-$1.25m
Male	E	Research Professor	Project	36 months	$750,000-$1m
Male	E	Professor – Clinical Director	Project	18 months	$550,000-$750,000
Male	E	Research Professor	Project	24 months	$750,000-$1m
Female	E	Ass Prof - Senior Research Fellow	Project	36 months	$1m-$1.25m
Male	N	Dr – Senior Lecturer	Emerging research grant	36 months	$0-$250,000
Male	E	Professor- Research Director	Programme	60 months	$4.25m-$4.5m
Male	E	Professor – Research Director	Project	14 months	$250,000-$500,000
Female	N	Dr – Senior research Leader	Feasibility	12 months	$0-$250,000
Female	E	Professor – Research Director	Programme	36 months	$3.5m-$3.75m
Female	N	Dr - Lecturer	Emerging research grant	36 months	$0-$250,000
Female	E	Professor – Research Director	Feasibility	12 months	$0-$250,000
Male	N	Dr – Senior Lecturer	Project	36 months	$1m-$1.25m
Female	E	Dr – Senior Research Fellow	Project	36 months	$500,000-$750,000
Female	N	Dr – Senior Lecturer	Emerging research grant	36 months	$0-$250,000
Male	N	Dr - Lecturer	Emerging research grant	36 months	$0-$250,000
Male	E	Professor – Research Director	Project	36 months	$1m-$1.25m
Female	E	Research Professor	Feasibility	12 months	$0-$250,000
Female	N	Dr - Lecturer	Emerging research grant	36 months	$0-$250,000
Male	E	Professor - Research Director	Programme	60 months	$3.5m-$3.75m
Male	E	Research Professor	Feasibility	12 months	$0-$250,000
Male	E	Dr – Senior Research Fellow	Project	60 months	$1m-$1.25m
Female	E	Professor- Deputy VC of Research	Project	36 months	$1m-$1.25m
Female	N	Dr – Senior Lecturer	Feasibility	12 months	$0-$250,000
Male	E	Professor – Research Director	Programme	60 months	$4.75m-$5m
Female	E	Ass Professor/Ass Dean of Research	Feasibility	12 months	$0-$250,000
Male	E	Professor – Research Director	Programme	36 moths	$4m-$4.25m
Male	E	Dr – Medical Consultant	Project	36 months	$1m-$1.25m
Male	N	Dr – Research Leader	Emerging research grant	32 months	$0-$250,000
Female	E	Dr – Research Leader	Project	30 months	$1m-$1.25m
Male	E	Dr – Clinical Specialist	Project	36 months	$1m-$1.25m
Male	E	Professor – Research Director	Feasibility	12 months	$0-$250,000
Female	N	Dr – Senior Lecturer	Project	36 months	$1m-$1.25m
Male	N	Dr – Senior Research Fellow	Emerging research grant	24 months	$0-$250,000
Female	E	Dr – Research Director	Project	36 months	$1m-$1.25m
Male	E	Professor – Research Director	Feasibility	12 months	$0-$250,000
Female	E	Dr – Research Leader	Project	36 months	$1m-$1.25m

Semi-structured interviews with all 41 PIs lasted between 50-90 minutes. Seven of the interviews were conducted by phone or skype with the other 34 conducted face to face at the PIs' home institution. Interview discussions focused on four broad areas, 1) How and why they became PI and how they prepared for position 2) perceived critical success factors for being an effective PI, 3) challenges and coping mechanisms, and 4) the perceived novelty of being PI. We asked, where relevant, that informants provided examples to support their views. Although these four areas guided all interviews, discussions were flexible and interesting issues raised were probed further and incorporated in subsequent interviews. In this sense, interviews became more structured as themes emerged in our preliminary note taking and analysis. After 41 interviews, the occurrence of significant repetition and an absence of new insights within the data suggested a saturation point had been reached (Strauss and Corbin, 1998). All interviews were transcribed amounting to 780 pages text.

3.2 Data analysis

Data analysis involved a number of steps. First in relation to analyzing PI roles, two members of the research team independently coded the interview transcripts line by line. Initially, this coding was done deductively using insights from the four PI roles identified through the literature – organizer, visionary, manager, and entrepreneur. Cross checking each other's coding allowed the researchers to remove duplicates and codes regarded as less relevant to PI roles. Examples of first order deductive codes used include 'collaboration' and 'perils of youth/inexperience' for organizer; 'science vision proactivity', 'ambition', research planning' surveying and adaptation' for visionary; 'human resource tasks', workload and timing', 'training', institutional support' for manager; and 'industry engagement', 'protecting identity' and commercializing science' for entrepreneur.

Next the same researchers coded the transcripts inductively in an iterative manner, frequently moving between the data, the inductive insights that were emerging as well as the aforementioned deductive first order codes. The use and combination of distinct empirical phases, i.e. theoretical deductive coding followed by inductive data-inspired coding that confirmed, developed and refined the initial theoretical informed insights, is consistent with the abductive method described by Miles et al., (2014). Once again, discussions between the researchers during this iterative process facilitated agreement on the most prominent first order codes across all transcripts, and to what extent some were more prominent in certain PI transcripts (e.g. as per Table 2) over others. In total 28 first order codes were identified.

In the next stage, using axial coding (Strauss and Corbin, 1998), the researchers concentrated on synthesising the first order deductive and inductive codes into themes. These themes emerged from an iterative process in which the researchers repeatedly went through informant quotations associated with the various first order codes looking for patterns that would allow them to be grouped into higher level themes. For example, PIs engagement with policy makers, users and industry resulted in the theme 'boundary spanning' being formed. The final step in our analysis of PI roles involved integrating these higher level themes into four modified and deeper PI roles – *science networker (from organizer), research contractor (from visionary), project manager (from manager) and entrepreneur (unchanged)*. For example, in relation to the researcher contractor role, this emerged after it was found that the three themes relating to 'pursuing a science vision through funding', 'bounty hunting funding' and 'acting as funding guardian' were all related to each other and were more accurately captured through the research contractor title than the visionary role title Our use of inductive and axial coding to develop modified role titles for PIs is inspired by Gioia et al. (2013) work which explains how first order codes can be combined and developed into higher order themes and categories (i.e. roles) by consulting literature but also taking creative

leaps that are more informed by data. In sum, the modified roles to emerge through our exploratory research approach provide deeper theoretical insights on the role identity of PIs than are currently available in the literature (Edmondson et al., 2007).

Second, in relation to our analysis of the learning mechanism for these modified roles, the researchers together re-analysed the quotes associated with the themes underpinning each modified role. The purpose of this step was to deductively code for evidence of role learning as set out by the mechanisms identified through our review of the literature: *learning through experience* and *learning through violation*. Thus, where quotes associated with themes underpinning a particular role provided evidence of role exploration, gradual learning and role shaping, as they *primarily* did for 'science networker', we assigned the mechanism *learning through experience*. In contrast, where quotes associated with themes underpinning roles provided evidence of reactive learning as a consequence of intrusive or unwelcome threats to identity, as they *primarily* did for research contractor, project manager and entrepreneurs, we assigned the mechanism *learning through violation*. This learning mechanism was uncomfortable for PIs as it was manifested in learning related to roles for which they were unprepared and untrained, therefore violating PIs' core sense of academic selves. Once again, during this process consideration was given to what extent both learning mechanisms were more prominent among certain PIs (e.g. as per Table 2) over others.

A comprehensive overview of these two steps of analysis is provided in Table 3 and 4 below. In Table 3, we clarify in brackets frequency of use, number of supporting quotes and original role title for first order codes, related themes and modified PI role respectively. In Table 4, we provide some illustrative quotations on how they primary learning mechanism were identified for each role. In the next section we present evidence to support these findings.

Table 3: Overview of data coding process

1

First order codes (frequency of use)	Second order themes (num of quotes)	Modified PI role (original role title)	Primary learning mechanism
• Collaboration (53) • Funding experience (34) • Required expertise (69) • Incorporate track record (58) • Build trust in team (48) • Perils of youth/inexperience (18) • Capacity development (14)	Inability to work alone (28) Manage team appearance (31)	**Science Networker (Organizer)**	**Through experience**
• Science vision – proactivity (36) • Ambition (45) • Research planning (51) • Surveying and adaptation (30) • Funding cycle pressures (26) • Tight timelines (35) • Researcher retention (27) • Livelihood (28)	Setting research vision (29) Bounty hunting funding (21) Guardian of peers and programmes (22)	**Research Contractor (Visionary)**	**Through experience** **Through violation**
• Human resource tasks (51) • Finance and budgeting (28) • IP and legal (15) • Workload and timing (40) • Training (48) • Institutional support (45)	Project versus research management (35) Responsibilities versus resourcing (41)	**Project Manager (Manager)**	**Through violation**
• Policy engagement (57) • User engagement (15) • Industry engagement (48) • Protecting identity (27) • Selling science vision (25) • Articulating potential research value/impact (38) • Commercializing science (29)	Boundary spanning (30) Science vendor (17)	**Entrepreneur (Entrepreneur)**	**Through violation**

2

Table 4: Illustrative examples of role learning mechanisms

Mechanism	Role	Illustrative quote	Details
Learning through experience	Science networker	'Going on committees is really helpful because you learn what they are looking for and how they respond and so it's been all learning on the job really'	Through their involvement on funding panels, PIs incrementally learn how review processes work and how decisions are made.
Learning through violation	Research contractor	"Grant writing is a huge pressure because I'm research only, my wife is research only and we have a mortgage so when you have to look after your own salary it can be tough"	The reality of the pressures to acquire additional funding to support your own career and personal life, or that of your staff, can be difficult to manage and accept.
Learning through violation	Research contractor	"We're always under pressure for money, we are funded at the moment but if we don't get a grant this time round we could be a little bit dicey at the end of next year. We've been living this way for 15 years. You have to constantly get on the treadmill, especially for the sake of the people in your group who are reliant on the money for a career. There needs to be an alternative model"	
Learning through violation	Entrepreneur	'Demonstrating a health benefit or ROI or getting it into clinical practice in five years is incredibly difficult. It takes a hell of a long time because doctors don't want to do something new that they're uncomfortable with. They want to do what they know works based on experience. One paper showing a clear benefit isn't going to change most doctors' practice'	Translating research results into practice can be difficult and outside of the PIs control – learning to manage this given the increasing expectations for impact from funding bodies can be difficult.

4. Findings

> 'I've got the publications in Nature and Journal of Science etc., I've got the grant money before to suggest that I can do it, we've got the preliminary data, we've got the collaborators from industry already interested in the work so yeah it's all just really challenging now'

In examining the roles underpinning the role identity of PIs, our research provides evidence that being a PI is multifaceted and challenging. As illustrated in the comment above from one respondent, PIs anticipate the need to portray proficiency in a range of areas including generating research outputs, funding experience, risk management and stakeholder engagement. Even then, such is the level of ambiguity associated with the position that it remains unclear to research scientists in the PI role what exactly is required of them and

whether they are doing enough. Our results shed some light on this subject. First, we find that the PI role identity is underpinned by four core roles. Second, as part of academic researchers' transition to this new position, we identify the most dominant (as opposed to exclusive – we elaborate on this in Section 4.1) learning mechanisms underpinning the enactment of each of these roles. Building on Table 3 and 4, we present our findings by combining evidence on how each role is enacted and the associated primary learning mechanisms

Science Networker. To shape and credibly pursue innovative research agendas, PIs must act as effective science networkers. Our findings provide evidence that the idea of working alone is incongruent with being PI. PIs formulate the most competitive and appropriate research group they can for the research being proposed. PIs ensure sufficient experience and track record exist within the collaboration, even though on some occasions the exact contributions of all collaborators is not clear. These points are illustrated in the following comments from informants:

> 'It is pretty clear that working by yourself just isn't going to get you anywhere. The committees have to rate the science and the CV. The downside of that of course is that people pad out their applications with all these big wigs and their CVs who clearly don't have a very defined role'

> 'There are critical points in projects where you are not quite sure it's going to work. You need to demonstrate a sort of backup plan for how you would deal with these things. That is where the experience and standing of the research team carries some weight. They see you've been down these sorts of pathways before and that you have dealt with these difficulties'

Thus to be competitive, PIs enter a game of sorts in which they carefully form and manage the appearance of their research collaboration so that it conveys legitimacy and increases the chances of receiving positive evaluations from external reviewers:

> 'Your team has to have the appearance of being able to do it and have the right public persona, so there's a bit of a game to play there'

***Primary learning mechanism: learning through experience*.** As science networkers, PIs unlearn the notion of (funded) science as an individual endeavour and instead learn to

become proficient at networking and effective team formation. Our results provide unanimous evidence that PIs learn through experience (e.g. submitting previous grants, sitting on review panels) the importance of forming suitable collaborations that have, not just the necessary expertise to undertake the research, but also sufficient status, track record as well as experience in running funded projects. PI learn that forming effective collaborations can be as important as the proposed research idea and helps to build trust and confidence that the research can be managed throughout the process. These points are reflected in the following comments (see also Table 4) from PI informants:

> 'Without the support of colleagues it would be very difficult to get this grant because they are well known in their area and already received XXX funding. Even if the project is good the committee need to trust that there are people behind me that can lead. You need to show a wealth of knowledge and ideas and method'

> 'You find that they (PIs) must line up with certain people to get funding so it has moved away from what it was like when I was able to get a XXX grant when I first arrived as a sole PI. I have to watch what I say to people now in terms of my willingness to go on grants because I think you should take it very seriously'

Research Contractor. PIs shape and articulate novel and competitive research trajectories. In pushing the boundaries of their field, PIs are and wish to be visionary in their approach. They look to take control of and achieve their science vision through funding programmes. As explained by one PI informant:

> 'My thinking is that with a seven per cent (success) rate you've got to have a bloody interesting idea which is just a bit nimble, it's new thinking, it's flash. You've got to have an idea which people go 'shit that's really great. I love that'.

However, PIs cannot solely rely on their original and visionary thinking to acquire resources that enable them to pursue their research ambitions. PIs ultimately act as research contractors, whereby they enter specified agreements to undertake research projects on behalf of funding bodies. PIs must therefore become adept at weaving their science vision within such contracts. Specifically, PIs must carefully adapt their research value propositions to meet the needs and expectations of funding bodies. As explained by one respondent:

> ‘In applying for contestable funding you are in some way constrained because they’re often telling you what they want. They put out a voluminous amount of material that changes every year around certain investment signals so some effort has to go into making sure that the idea or proposed work you want to take forward can be or does in fact fit within their framework’

PIs also carefully analyse investment signals at a government level and ensure their proposed research is sufficiently aligned with and can contribute to policy priorities through funding body investment channels:

> ‘I certainly don’t just write a grant application. I place my idea into the context of what the XXX is looking for. I make the argument about how it fits with government policy because in the area of health service delivery policy is really important. I make sure I know how it fits in with national and regional policy, as well as with government agencies’

In addition, increasing competition for external funding and institutional pressure to bring in external resources means PIs have to continuously survey funding opportunities and pursue those most appropriate.

> ‘You never keep still; it’s constantly about looking for those funding opportunities. You can self-congratulate yourself one day but the next day there’s another grant proposal needed if you want to keep a person employed or you want to keep that research going’

***Primary learning mechanism: learning through violation*.** Although PIs explained how they gradually learn (i.e. through experience) to weave their research objectives into funding body and policy priorities, our results show that the primary learning mechanism for the research contractor role is one of violation. Specifically, a consequence of successfully acquiring competitive funding is that it brings significant unforeseen pressures and obligations for PIs. Informants explained how they suddenly realised that they were responsible for sustaining and developing the careers of those who they recruited to their teams and labs. At a human level, PIs develop relationships with their staff and become familiar with their personal and family circumstances (e.g. immigration status, mortgage, children etc.) and as a consequence feel significant pressure to acquire additional funding to sustain their livelihoods. At a professional level, PIs come to realise that any gap or delay in funding cycles risks destabilising the research team with some high calibre technicians and postdocs potentially

moving on and/or needing to be replaced. These views are supported in the following comments from PI informants:

> 'I've got two technicians and now I've a second postdoc starting in November, so you've got to manage their salaries, next year is crunch time. I have to get something for them to stay on'

> 'The timeline is crazy. If I'm applying for a new grant that starts on the 1st July, I'll hear about it in early June. This means that all my staff that are employed, including senior scientists who have been with us for 17 years, don't know until two weeks before their contract is up whether they've got a job. It's just absolutely ridiculous'

As is evident in the following comments from respondents, operating in the face of such uncertainty can have a detrimental impact on the continuity and quality of the research group as well as their progress towards broader research objectives:

> 'An issue that you have to confront after getting one grant is the challenge of having to bring in additional money to maintain momentum required to achieve something important'

> 'They don't think that you might actually already have people employed that's ending in three weeks. It is incredibly stressful trying to keep people's jobs going like that. Also, put yourself in their shoes, this guy has got a mortgage, he's got a partner and he doesn't know whether he's got a job in three weeks, you're daft not to be looking around'

The considerable and unforeseen nature of this pressure amplifies the need for PIs to continuously pivot in search of new funding opportunities, acting as bounty hunters in their pursuit of competitive funding. Persistent grant writing and adapting and refining based on feedback become the norm. This search for new funding contracts encroaches on PIs' capacity to think about, plan or actually do science work, a development which directly challenges or violates their core sense of academic selves. The following comment from an informant reflects this point:

> 'I decided the last two years that getting a grant would be my immediate strategy. I've focussed on that literally to the exclusion of everything else. I could have been writing up more papers (but) I just said, 'well this is severe grant writing time'. So if it's just been not giving up, taking in feedback every single round and adjusting'

Project Manager. Primarily affiliated with undertaking and leading research work, once research scientists acquire external funds and transition to the position of PI, they simultaneously become responsible for significant, often multi-million dollar financial

budgets together with a substantial range of administrative (e.g. report writing), human resource (e.g. recruitment, motivation, supervision, conflict facilitation), legal (IP and contract management) and media duties among others. In effect, through their research leadership and overarching operational responsibility, PIs become managers of newly formed (albeit it temporary) project enterprises. As succinctly explained by one informant:

> 'Essentially PIs are like captains of ships or CEOs of small companies. You've got to multi-task, you've got to get the most out of people and there is a lot of strategic decision-making involved'

Primary learning mechanism: learning through violation. Our findings provide evidence that many of the tasks associated with this project manager role violate PIs' core academic identity, which in turn triggers the necessary role learning. This is illustrated in the following comments from one research informant who struggles to reconcile the conflicting strategic and administrative responsibilities bestowed on them as PI:

> 'Figuring out holidays for staff or figuring out overhead budgets…(with)...funding success you get thrown into these roles, I mean I've probably got $10 million at my disposal at the moment. Not many people in New Zealand are expected to manage that budget and then be told to do every piece of administration that goes with it'

PI informants unanimously explained how surprised they were at the scale of the management and administrative duties that came with preparing and coordinating research grants. In most instances, the element of surprise was not just the actual management responsibilities, but even more so the lack of support provided by their institution and their own sense of being ill-prepared and deficient in the necessary training to perform these tasks. In particular, PIs spoke about feeling 'out of their depth' with respect to legal matters, managing multi-million dollar financial budgets, and being expected to independently learn how to recruit and mange people employed as part of the research. As explained by two respondents:

> 'I find it quite ironic that I've got a million dollar grant with absolutely no training for how to run it. Sometimes I feel completely out of my depth or I don't know what I'm doing with the financial management. If I was running a small business then I would have people helping me to run it but as a PI I don't feel I have any training or support from the university at all'

> ‘Nobody tells you how to do it…looking at these balance sheets and budgets I didn’t understand how important they were. When you’re applying for these grants you’re almost assuming you’re not going to get them and then all of a sudden you’re expected to have all these skills and you’re stuck in terms of what you said you were going to do’

Thus, notwithstanding PIs’ recognition of the need to enact and learn new tasks as part of a role transition, the nature and scale of the tasks coupled with a sense of injustice at the lack of support and training provided appears to alarm them. Learning through role violation is apparent in how PIs not only have to learn how to address these new management tasks, but also how they must quickly learn how to protect time for their core science work.

> ‘I try to spend at least three full days in the lab, which is a huge workload for me when I’m trying to write grants and papers and do all the other management and administrative work (but) I’m learning that I need to pull back more and rely on my staff to focus on these. It is a constant tension’

Entrepreneur. Akin to entrepreneurs, through their research work PIs are expected to generate value by undertaking and translating impactful science (e.g. research commercialisation). Informants explained that while it was once acceptable for PIs to define research outcomes somewhat loosely, timelines to demonstrate meaningful research impact had now become far tighter:

> ‘Before, if you could demonstrate the likely benefit for health, the timeframe was less important, now there’s real pressure on shorter timeframes. They (Funding Body) want you to be able to demonstrate a health outcome within say five years’

PIs recognise that funders prefer to see them develop a stock of knowledge and research outcomes that extends beyond scholarly contributions and which will be of value and interest to a range of external stakeholders.

> ‘The danger all funding bodies are trying to fight is that people just do their own little bit of research, write a publication – done. Feather in their cap. Their peers say ‘what a great publication. Good for you.’ You’re a world expert and it is all about academic freedom. But has anything changed for the patient? Not a bloody thing’

To effectively fulfil these expectations and responsibilities, our findings provide evidence that similar to business entrepreneurs, PIs are effective boundary crossing agents who engage with a range of stakeholders that can help them improve their value creation potential. For

example, as illustrated in the following comments, PIs can engage with user communities and policy makers to assist with translation and creating value from research outputs.

> 'We like to think that our questions are important and that someone is listening. We are not only working with the community, we're working with the Ministry, everyone knows what we're doing and there's already someone ready to take on the answer'

Engaging with industry agents also provides a means of acquiring additional funding that can cover shortfalls and add greater certainty and longevity to PIs' research programmes.

> 'We engage with drug companies. It's a very valuable source of income that gives us jobs and allows us some further certainty that's not provided in the competitive funding model'

> 'One industry player is interested in contributing research funding. It's a good opportunity to pick up a wee bit of extra money. They've got certain things they want us to do that normally a funder doesn't say anything about'

Primary learning mechanism: learning through violation. Enacting an entrepreneurial role as PI is not straightforward for all. As remarked by one informant 'I've had to become quite skilled at explaining what the importance of our work is'. Our findings indicate that some PIs struggle to access the expertise necessary to sufficiently articulate value creation or align their proposed research with funding and policy priorities (see Table 5). As explained by one informant, unless they learn to adapt their approach and address these points, researchers' ability to acquire competitive funding and to become a PI can be compromised:

> 'You have some research groups that have drifted off the map and haven't got funding anymore, not necessarily because they're bad scientists, it's just that they don't meet whatever the criteria is at the moment…some labs will sit back and concentrate on their science and hope that that will get them funded and it doesn't sometimes'

A particular challenge for PIs as entrepreneurs relates to their boundary spanning engagements with industry. For example, a number of PI informants explained that they struggle in their efforts to initiate and negotiate valuable contracts with industry agents. Without institutional support to facilitate learning in this area, PIs often endeavour to pursue and formalise their own industry engagements but feel the resulting arrangements are inadequate (see Table 5). PIs' boundary spanning learning as entrepreneurs is also activated by their management of established engagements with industry agents as these can threaten

their academic freedom and more accustomed work practices. As illustrated in the comments below, tensions can arise around reaching agreement on the overall purpose and direction of the research collaboration, the differing pace of work between science and industry and also in evaluating the value of outcomes and in deciding how to use them.

> 'It is important to engage with industry as industry driven research can solve specific problems that industry needs and that is important and appropriate. It is a mistake though if their involvement becomes too major a component of your research effort because if you drive your research solely by what industry knows it needs tomorrow, you will never make breakthroughs into what industry didn't know it needed'

> 'Working with industry is quite revealing. It shows how their concerns are different, their timelines are definitely different and what they want out of research is different. They want a market pitch, while we seek the scientific truth, they want to something that works and will sell'

Therefore although uncomfortable, an important learning for PIs is how to balance the research requirements and expectations of industry involvement with the deliverables of their core (publicly funded) research programme. They must learn how to maintain industry interest and commitment to the research without allowing this influence to jeopardise their academic freedom and publishing imperatives. However as illustrated in the comment presented below, on occasion the violations cannot be reconciled through PI learning and adaptation and as a consequence, PI boundary spanning engagements can end abruptly. It is therefore important that PIs refrain from becoming overly reliant on such engagements and forgo their ability to progress independently. Table 5 presents summary details and further illustrative evidence on each of the four PI roles uncovered together with the respective primary learning mechanisms.

> 'I got intervention money for two of my big studies and I collaborated with XXX but in the end they terminated the funding relationship. The alignment of interests with industry partners may not last long, especially if they are being prepared for sale or change strategic direction, then they care much less about social issues than they originally did. I mean industry can be very quick to pick you up, but also very quick to dump you'

Table 5: Summary and supplementary evidence of roles and primary learning mechanisms

PI Role as	Illustrative Evidence	Primary Learning Mechanism	Illustrative Evidence
Science networker ▪ Working alone is insufficient ▪ Form team and manage its appearance – 'play the game'	'In all honesty, sometimes it is necessary to have certain people on the team because they might be essential 'go to' people, but the reality is if they're operating like that they'll probably be happy to interact with you anyway and they don't necessarily need to be salaried on the grant, so often it is all a game' 'It was really about assembling a team who could bring the necessary skills…one of the critical things in being PI is being able to assemble a team, know the right people, networks, connections'	**Experience** ▪ Establish trust, credibility and reputation in science through collaborative team persona – bringing together people with the necessary expertise, status, track record and funding experience	'Unless you have experienced, highly fundable people on your team with good track records who help to guide and show the way then some are not going to get funded no matter how good the idea is.…I've reviewed for the XXX and I've seen what I thought were really very good projects which should have been funded, but didn't for these reasons' 'We have form in this area, our team and network has delivered to date and we all benefit from that….scientists can learn a lot in these networks and increase their chances of being involved in activities that are highly fundable'
Research contractor ▪ Survey opportunities - become 'bounty hunters' in their continuous search for funding contracts to achieve vision ▪ Carefully align core research interests to be positioned within the requirements and expectations of the funding body	'I'd really like to get funding for areas in women's health that we're particularly interested in and that are maybe not too controversial. But we've got to eat therefore we put things in that help us eat, if we don't get grants, we don't have a job' 'Grant funding is short-term, it may be only three years. It's a very disjointed way of achieving your research goals. There is only a six per cent success rate for HRC money so you've got to really plan. We are involved in project and programme grants that look at both diabetes and drug discovery around cancer so you have to have your fingers in a lot of pies, it is very hard to focus on just one thing if you want to secure funding'	**Violation** ▪ Become 'guardians' of their research staff – under pressure to sustain livelihoods and careers ▪ Realise that research programmes and retention of quality staff are threatened by short term funding contacts ▪ Less time to do/ plan science work as a consequence of 'bounty hunting'	'You have all these people you employ for six or twelve months work but that is it in terms of a contract. They're often great people that you want to retain but you just don't have the money to pay them until another project comes through and in the interim they've gone and got another job so creating that established research workforce with good people is very difficult in this role' 'Success breeds more obligations. You just end up putting another ball in the air, particularly in terms of staffing issues. I employed two new post-docs and a junior research fellow after being successful with some grants and all three of them bought houses. It means I've got three guys who really want to stay in the lab, which is tremendous, but it also means I've got to find more grants to keep those people going so its just endless' 'The amount of time we spend writing grants every year is absolutely huge. I don't get any time to think any more...there is very little time to actually sit down and spend an hour or two actually thinking about what research I want to do next'
Project manager ▪ PIs balance the leading and conduct of science work with significant operational and administrative tasks.	'What frustrates me most is the ever increasing shift of all processes here to electronic form which essentially means they get pushed back to us. Take HR, you used to have a HR person that dealt with timesheets, recruitment, the contracts, legal requests, everything. Now it all comes through your computer so I have to do it all and struggle to make time for other work'	**Violation** ▪ Nature and scale of admin duties surprise PIs ▪ Lack of understanding and training/support on how to undertake many tasks	'Our grant was for $4 million, it's a biggie, and I've got no guidance in how to run it or to manage the people involved. The university system is completely useless at this. It is just something you have to do and you have to interact with the bureaucracy and know how to do all this crap that you don't really want to do because it's a waste of time' 'I do a lot of things where I'm often thinking 'someone else could be doing this and I could actually have time to read papers which I don't have time to do anymore'. You know you can't really lead an effective research programme if you're constantly doing administrative stuff for your grants'
Entrepreneur ▪ Clearly articulate potential value and impact from research ▪ Engage stakeholders who can help with or benefit from research application ▪ Capture and exploit research value through commercialisation	'You must have someone to help with the latter end of the project in terms of usability or translating the research. In this particular situation we have researchers as well as policy people from the Ministry and I think XXX liked that deliberate link' 'Our work is very expensive so I've also had to raise a lot of money from the private sector. They actually contributed a lot to the intervention' 'We have our own spin-out company XXX so anything we do we'll pass on (the IP) and put it in the pipeline. XXX have a track record of getting things into the market so we can show that we can do it'	**Violation** ▪ PIs struggle to articulate value creation potential. ▪ PIs feel uncomfortable and ill-equipped to develop boundary crossing contracts with industry, ▪ Boundary crossing engagement with industry surface conflicting work practices and PIs can struggle to protect academic freedom. ▪ Engagements can end abruptly.	'We can have brilliant interventions but if they're going to cost too much money then no-one is ever going to implement them. We know we need more help to get our head around cost effectiveness and what data you collect and how you calculate and demonstrate cost effectiveness and value' 'We need assistance to set up interactions with companies and to get good contracts negotiated so that researchers can focus on the science. For one project I negotiated contracts myself. I had no idea what I was doing and initially I was too cheap because they (the firm) agreed straight away. In the end I realised that I'd go a bit harder and see what I could get out of them but to me that wasn't my job. I'm not a business guy, I'm a scientist so I really felt that I was not supported to the level that was beneficial to the university' 'When working with a Swedish firm the whole rationale and timelines for doing science was completely different. Some of the things they did were rushed and they probably thought I was slow as a wet week. For example, in trying to identify a new drug, I was more interested in how the compounds they found worked and they would say they're not interested because they can't make a drug out of the compound. I'd say 'well actually it's very effective if we understand how it works we might be able to make something druggable'. That was tension'

4.1 Variation 'within' roles

As outlined in our data analysis in Section 3.2, across both stages of analysis we tracked the extent to which the roles and learning mechanisms we uncovered were evident or prominent among all PI informants. In this section, to further enrich the validity and depth of our research findings, we report on two notable features to emerge from this tracking analysis.

First in relation to the roles, for the most part each of the nine themes underpinning the four roles (see Table 3) incorporated supporting evidence from the majority of the 41 PIs. In this sense, based on the data we collected and analysed we are confident that the four roles we uncovered are representative of university-based health science PIs' role identity, controlling for gender, title, level of experience, funding amount or type. The only exception to this is, rather unsurprisingly, we did not find much evidence relating to the entrepreneurship sub-theme 'science vendor' (i.e. first-order codes: articulating value/impact and science commercialisation) among PIs funded with feasibility studies.

Second, the salience of the two *primary* learning mechanisms varied somewhat between new and experienced PIs across the four roles. In terms of learning through experience the science networker role and specifically 'managing team appearance', there was a greater emphasise among experienced PIs (identified by title and number of grants held) on capacity development when forming collaborations. In contrast, new and more junior (as identified by title) PIs placed greater emphasis on sourcing collaborators with funding experience and track record. Notably, the latter approach resulted in more instances in which collaborators were included without clearly defined roles. The following comment illustrates this point:

> 'Nowadays it is more likely that an inexperienced person who is going to do 90% of the work is the named PI with all the big hitters deliberately positioned behind them to help out along the way with their expertise but with very limited time commitment. Getting the right support group seems increasingly important'

In terms of the research contractor, as outlined in our findings our results provide evidence of a dual learn mechanism for this role. On the one hand, PIs spoke of the need to weave their research objectives into the guideposts and signals provided by policy makers and funding bodies. On the other hand, we found that the primary or most dominant form of learning in our data related to role violations. Specifically, we found that experienced PIs and PIs with larger programmes (identified by funding amount and type) were more likely to learn through violation the pressures of having to act as guardians of their research staff and research programmes in order to progress their overall research visions. In contrast, the learning of new and earlier career PIs was more associated with the pressures of bounty hunting for grants, and within this, somewhat extreme views in relation to adjusting to the reality of having to adapt or compromise on their research goals. These points are illustrated in the following comments from two PI informants:

> 'It's just constantly admin applications for five/six months (each year). I've more or less applied for all funding available at the moment, it is the only way to get money for research'

> 'You often write something up that you know could get funded as opposed to writing a grant solely based on something you would love to do'

In terms of the project manager role, learning through violation was the primary learning mechanism identified. Interestingly however, although not prevalent in our data, our findings did provide some evidence that new PIs felt less 'violated' by the associated project management and administrative responsibilities, as illustrated in the comments below. A possible explanation for this is that these 'newer' PIs have grown accustomed to these responsibilities having more likely than not witnessed their senior peers undertake these seemingly obligatory tasks during their early career training.

> 'I'm just getting my head around that (project management) now and I'll be much better the next time, so it is *learn as you go'*

> 'As go the different levels of post grad and PhD you start to get responsibility for training and supervising new students that come through. As a postdoc I also had quite a high level of managerial roles because the person I worked for had a number of huge grants'

Similarly for the entrepreneur role, while learning through violation was the primary learning mechanism identified, there were a number of PIs who did not experience such violations. For example a number of experienced and more senior PIs explained that they were quite comfortable protecting their academic freedom when managing industry relationships. In addition, a new PI explained that, in comparison to their colleagues, engaging with industry and commercialising research outcomes was something they actively pursued and enjoyed when conducting research. These two points are illustrated in following comments from PI informants.

> 'Certainly once they've (industry) agreed to fund us they don't have an influence on the publishing side or the interpretation and writing up'

> '(Some) often think first about the application and then think back to the science but of course most people in this business start the other way around. There is an explosion in talk about translational research but it is something I really believe in whereas some people try really hard to make themselves fit in that box and have that link'

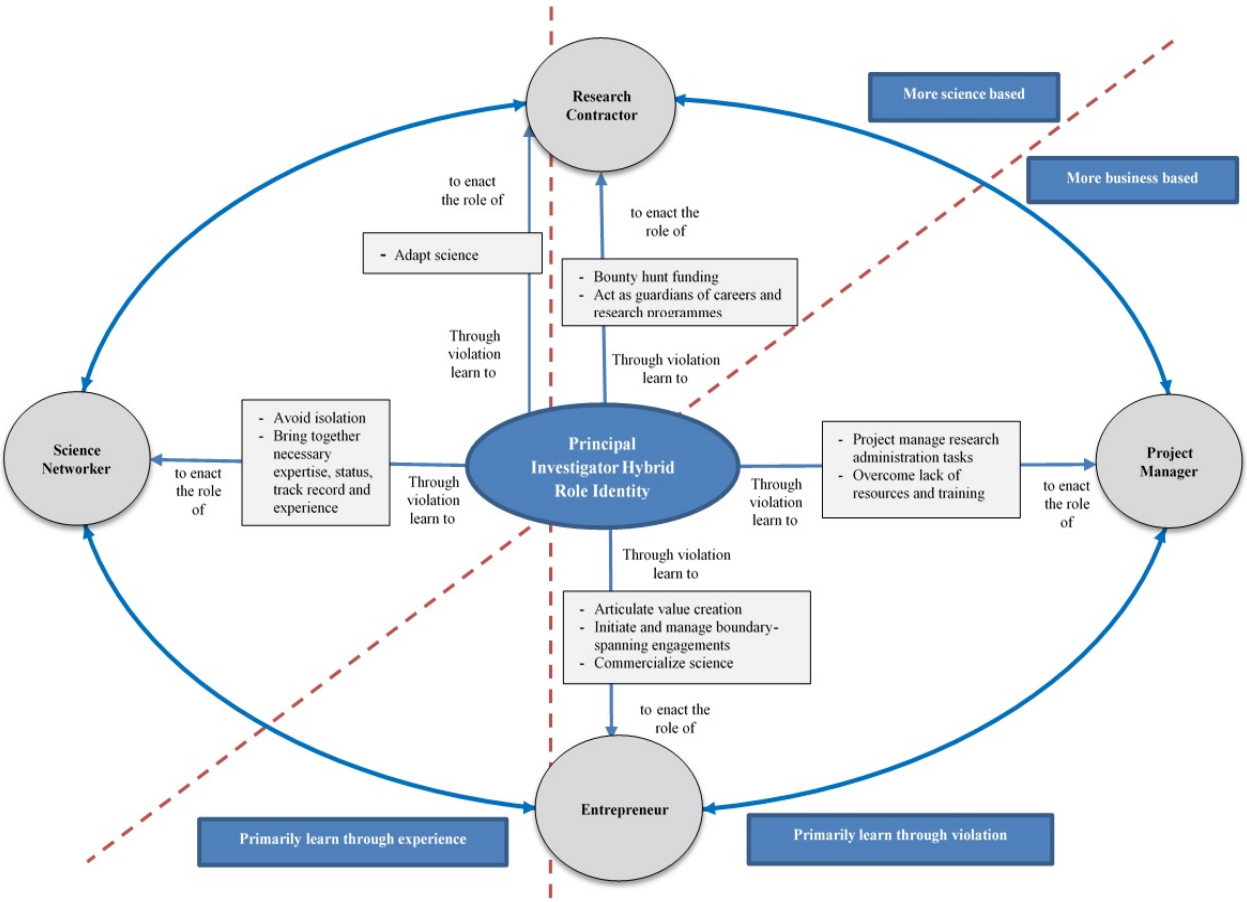
Thus, while we identify through our data the *primary* learning mechanisms associated with PI roles, it is important to acknowledge that these are not exclusive mechanisms and there will naturally be some variation and exceptions to this, as is the case in our data.

5. Discussion

The purpose of this research was to elucidate the roles that underpin university PIs' role identity (in a health science context), as well as the primary learning mechanisms associated with these roles. We find that PIs have a multi-role identity comprised of four roles and that this role identity is facilitated by a dual learning mechanism, one experience based the other violation based. Based on these findings, we develop a novel PI role identity learning framework (see Figure 2). In the paragraphs that follow we explain two key contributions that these research findings offer, the first relating to the hybrid nature of the emerging PI role

identity and the second, the dual learning mechanisms underpinning the enactment of this role identity.

Figure 2: PI role identity learning framework



Through the identification of four roles - science networker, research contractor, project manager and entrepreneur - our first contribution is a crystallisation of the PI role identity amidst a burgeoning but fragmented literature base on PIs. Although studies have pointed to PIs' brokering (Cunningham et al., 2018; 2019), visionary (Mangematin et al. 2014; O'Kane et al. 2015), entrepreneurial (Casati et al., 2014; McAdam et al., 2010; O'Kane 2018, boundary spanning (Kidwell 2013) and managerial (Conti et al. 2015; Boardman et al. 2014) responsibilities, the implications of these findings have largely been considered in isolation.

Indeed, despite increasing interest and research attention in PIs (Kastrin et al. 2018), an integrated, consolidated and clear understanding of the PI role identity has to this point not materialized in the field.

We address this gap in the literature through the identification of four roles, however as illustrated in Figure 2, our study goes further to provide a more nuanced understanding of the PI role identity. Our findings show how research scientists transitioning to the PI position enact a hybrid science-business role identity. While similar ramifications for the role identity of research scientists simultaneously pursuing academic and commercial goals have been discussed in the literature (see Ambos et al., 2008; Cohen et al., 2017 Jain et al., 2009), our research on publicly funded research scientists extends this discussion to the emerging literature on PIs. As is evident in our findings, to be effective PIs must simultaneously deepen their proficiency in traditional academic science oriented tasks as well as expand their skillset to become more active and effective as business managers and entrepreneurs. More specifically, our findings provide evidence on how, on the one hand PIs as scientists exploit and build appropriate collaborative networks as well as continuously survey the objectives and expectations of funding bodies and policy makers and then align and/or develop their scientific vision through these. However on the other hand and more akin to a business management role, PIs manage the operational-level implementation of their research intentions including all administrative tasks. PIs' business responsibilities also extend to articulating the value and impact of their research and capturing this value through boundary spanning activities and research commercialisation. Notably, value creation and capture within PIs' business identity is not restricted to commercial outcomes and market audiences. As public funding underpins their research activities, PIs' hybrid science-business role identity incorporates a form of social or societal entrepreneurship. Perhaps due to health science context of our study, a focus on social value creation (e.g. new clinical treatments or

drug development) was particularly prominent in our results. Our findings on the nature of PIs' role identity extends previous literature on hybrid identities in science, making it more in line with recent calls to consider how academic science incorporates societal impact, which Fini et al (2018, p.8) define as a "change or benefit to the economy, society, culture, public policy or services, health, the environment, or quality of life from new or improved products or services based on scientific knowledge"

Further reinforcing our findings in relation to the hybrid nature of the PI role identity, what becomes apparent in our results is that all four PI roles are integrated or mutually reinforcing across multiple stages of the research process. Specifically, the roles we uncovered do not belong exclusively to any particular stage (e.g. initiation, implementation etc.) of the research process. For example, while skills related to the science networker role seem most relevant for initiating collaborations and research projects, from our findings they can also be understood as relevant and important for 'bounty hunting' within the research contractor role or 'boundary spanning' engagement within the entrepreneurial role. This overlapping of roles (in this case for networker and contractor) is illustrated in the following comment from one PI informant:

> 'I still have students and colleagues in health, economics, computer science, bio-engineering. To be honest, in the environment where we get one third of the funding per capita compared with Australia, one fifth of the UK, one tenth of the States, the only way to survive is to have a number of feelers out at any one time. Not one iron in the fire. The risk of not being funded is just too high'

Thus, our findings suggest that to be an effective PI, proficiency across all four roles is necessary as elements of each may be needed to be proficient at others across all stages of the research process. There is no one time when one role alone is required or sufficient. PIs may need to cross boundaries (entrepreneur role) to form interdisciplinary collaborations (networker role); PIs envisioning and adaptation of science objectives (research contractor role) is relevant to their articulation of value creation (entrepreneur role); productive bounty hunting (research contractor role) may have implications for project management challenges;

their management and administrative skills (project manager role) will be relevant to acting as a guardian and bounty hunting (research contractor role) respectively etc. Overall, our findings provide evidence that PIs need to be proficient in four mutually reinforcing roles that together represent a hybrid science-business role identity.

Our second contribution relates to the learning mechanisms underpinning the enactment of PIs' hybrid role identity. We show how learning is formative for role identity when transitioning to a position with an ill-defined role identity. Through these results, our study complements existing theoretical perspectives on learning and constructing new role identities (Chreim et al., 2007; Ibarra, 1999; Pratt et al., 2006). However, our study findings also provide a number of novel contributions within this area. Most fundamentally, our research builds on and substantially expands previous literature alluding to PIs' 'on the job' learning (Cunningham et al. 2016; 2015; 2014; Kreeger, 1997; O'Kane et al., 2017). Indeed, to the best of our knowledge our research is the first to specifically examine PI role learning. Another contribution is the identification of two learning mechanisms related to enacting a new role identity, namely learning through experience and learning through violation.

On the one hand our findings provide evidence that PIs gradually learn through experience that the collaborations and networks they develop need to establish credibility and trust by bringing together teams with appropriate research expertise, track record and funding experience. They also learn, often through trial and effort across successive funding rounds, how to better position or align their research intentions with the objectives and expectations of funding bodies. Building on prior theoretical perspectives on identity transitions and construction, our findings show how PIs simultaneously experiment with and shape new roles as they learn them (Cohen et al. 2017; Ibarra, 1999; Nicholson, 1984). Through this experimentation and experiential learning, PIs clarify who they are in how they enact their role responsibilities (Battard and Mangematin, 2013; Dutton et al., 2010). Interestingly, our

findings would suggest that when transitioning to a new role, learning through experience is most appropriate for enacting and learning new roles and responsibilities (see Figure 2 - science networking and adapting science vision) closely aligned with one's core sense of self.

On the other hand, we show that PIs' learning is also induced by role identity violations (Pratt et al., 2006; Ibarra et al., 2010). The violations manifested as challenges or threats to individuals' sense of self (Kreiner et al., 2009; Maurer et al., 2015) generate learning of the new role identity. This learning is evident in a number of ways in our results. For example, after acquiring research funding, PIs unexpectedly find they need to bounty hunt for additional funding in order to retain staff so that both their careers and the PIs' own research programme(s) can be sustained. Bounty hunting, acting as guardians and a broad and continuous range of research management related tasks for which they are unprepared or trained result in PIs having less time to be hands on with their science, in essence they must forgo elements of their core academic identity. PIs also encounter unforeseen challenges in articulating how their research can be translated for value creation and in establishing and maintaining productive boundary crossing engagements without excessively trading off their core academic selves. Thus, the violations arise from PIs encountering role responsibilities that do not align with who think they are supposed to become. The consequential learning through violation occurs in a number of ways such as forcing PIs to develop new skills, making PIs alter their perception of what the PI role identity is (Petriglieri, 2011) and identity destruction through unlearning (Akgun et al., 2006; Hedberg, 1981). Again, our findings would suggest that when transitioning to a new role, learning through violation is most appropriate for enacting and learning roles and responsibilities (see Figure 2 – project manager and entrepreneur) that are more distant from one's core sense of self. Overall our contribution in relation to these dual learning mechanisms unearth the complexities that underpin the emerging PI role identity.

Finally our results offer some noteworthy practical implications for PIs, research institutions and funding bodies. For PIs, our study clearly highlights the challenges and complexities they will encounter when transitioning to a position that, although having a well-established role title among peers and institutions, continues to have an ill-defined role identity. Our findings show that PIs experience legitimate uncertainties and fears when transitioning to the position as their role identity does shift and the necessary training and support is often not readily at hand. Our results encourage PIs to seek out appropriate organisational and peer support in order to cope and deal effectively with their transition to the role. However, our study will also help PIs to expect and be better prepared to cope with previously unforeseen pressures and the different obligations of the role. PIs can reflect on our findings to see where they need to become more effective, thus encountering less role violations as they transition to the role. As illustrated in our findings, variation in role learning needs will naturally occur. Some PIs become preoccupied with unforeseen research management and guardian responsibilities, while others become burdened by boundary spanning activities. Our research findings will help PIs to enter the role with their eyes wide open. Ignoring our findings will prolong the ambiguity surrounding the role and result in increasing frustration among the PI community which may ultimately lead to suboptimal project outcomes and a greater sense of role violation.

For universities and funding agencies, our research shows there is a pertinent need for these institutions to provide supports that enable scientists in the PI role to be effective. Universities need to consider how they can provide appropriate professional development support, resources and mentoring that afford PIs the time and space to adapt to and learn the PI role identity. In essence, this requires universities to invest in talent development and role preparation processes that equip nascent PIs with the necessary knowledge, understanding and confidence to pursue and thrive in the PI position, given that some of their activities will

naturally illicit individuals questioning their own purpose as PIs and scientists/academics. Our research findings strongly concur with the ideas put forward by of Adler et al. (2009) who indicate that leaders of publicly funded research need to be legitimised more by their university management. As well as the aforementioned provision of enhanced PI training, university management should consider insisting (not just allowing) that PIs allocate time to broadening and improving their PI specific skillset, purposefully recruiting researchers who excel as PI research leaders, and/or open well publicised complementary career tracks within the institution that better recognise the diverse roles and responsibilities of being a PI and how these actors positively impact the strategic imperatives of the university

While funding agencies have a clear focus and mandate on selecting the best and original research projects, PIs are now required to meet and exceed an array of outcome metrics expected by these funding agencies. Therefore, there is a need for such agencies to incorporate some specific supports for PIs which they could fund individually or collectively. Moreover, given the influence funding agencies have with respect to universities and public research organisations, they could begin to persuade such institutions to provide the necessary level of support for nascent PIs, particularly with respect to PI role preparation, as well as sharing role learning and best practice within respective institutions and discipline areas. Furthermore, in designing public research programmes and determining funding allocations, we believe funding agencies should take greater account of the range of PI roles uncovered in this research, and what constitutes 'PI effectiveness' within these, while balancing this against maintaining the research excellence and quality focus that underpins their overall funding allocation mandate. In essence, greater attention is required on evaluating observable attributes of PIs in the decision making that determines funding allocations. A final practical implication of this research that builds on that presented above is that funding bodies and university management need to talk more. It is little use if university

management concentrate on improving internal processes for growing and supporting PIs if funding bodies are not also being informed of the complexities PIs are experiencing in the role, and vice versa in the case of funding bodies communicating with university management on the heighted and diverse role expectations for scientists who successfully acquire competitive funding. Universities, funding bodies, PIs and up and coming scientists will all benefit from greater legitimacy and transparency around the PI role identity, however, this can only be achieved by each of these parties working together, providing feedback on their experiences and developing appropriate support mechanisms.

6. Conclusion

The central motivation behind this research is the belief that principal investigators, together with universities and funding bodies, form an increasingly crucial tripartite in entrepreneurial ecosystems and research environments (Cunningham et al., 2018; 2019). Although the PI position is well established among scientific peers and research institutions, its role identity is till emerging and remains ill-defined. Having a clear role identity is fundamental for PIs to perform their role and effectively foresee and forge the future through scientific, technological and business avenues. To this end, we examined the roles of university based PIs, as well as the learning mechanisms that underpin the enactment of their role identity. To do so we drew on theory related to role transitions, role identity and role learning as well as a burgeoning but fragmented literature base on PIs.

Our research, in the context of research on 41 health science PIs, makes a number of notable contributions. First, we crystallise the PI role identity around four core roles: science networker, research contractor, project manager and entrepreneur. We argue these roles are intertwined and mutually reinforcing throughout the research process, and together represent a role identity that has a hybrid science-business form. Second, through the identification of

two learning mechanisms – learning through experience and violation – we show that learning is formative for role identity when transitioning to a position with an ill-defined role identity. In essence, our research suggests that PIs must balance both experience- and violation–based learning mechanisms to become proficient at identifying and shaping novel academic research trajectories whilst simultaneously having the capacity to manage the research, as well as the enterprising aspirations (Erikson et al., 2015) to develop, capture and translate value within it. Based on our findings we discuss a number of practical implications for PIs, research institutions and funding bodies. These implications primarily centre on creating appropriate support and professional development opportunities for PIs to better facilitate role learning and to manage uncertainty. Our research findings can help the tripartite communities of universities, funding agencies and scientists progress towards a commonly understood role definition and universally accepted practice interpretation of the PI role identity, something which can mitigate against some of the role challenges PIs are currently experiencing when transitioning to the position. Such role clarity is necessary to support new generations of PIs across all discipline areas.

Our study is not without limitations and some aspects deserve closer attention by future researchers. Given some of the variation in role enactment and learning reported within our findings (e.g. experienced versus first time PIs), we encourage future researchers to closely examine such issues as gender, career stage, type of grant etc. to understand the deeper complexities of PI role identity and learning. Another worthy area of study involves focusing on PIs where their funded projects failed to attain the desired project outcomes. How did such project failures influence or be influenced by PI role identity enactment? We encourage future researchers to incorporate a longitudinal learning lens in order to examine how PIs learn over the duration of a project or across different funding cycles, an approach that would be beneficial for understanding how PI role identity and learning evolves over

time. Utilizing qualitative methods that would help examine for causal links (see MacDonald et al., 2016) between the roles and learning mechanisms uncovered in this research could also prove very beneficial for theory and practicing PIs and funding bodies. Furthermore, we focused on a single country and research programme. Our study is focused on health science PIs but the discipline norms and traditions may not necessarily pervade into other disciplines in the natural, physical and social sciences or across different national cultures. While acknowledging this as a potential weakness, the level of access to PIs that we gained through our study design does mitigate against this limitation to some degree. Moreover, in designing the study we had to make pragmatic choices in relation to access and data collection depth versus breadth. Nevertheless, our study should be expanded to include other disciplines, publicly funded research programmes and agencies across different geographic territories and science and technology policy regimes. Focusing on PIs that are exclusively involved in public value orientations funded research (similar to health science) such a criminal justice, climate, family and children may unearth even further PI role identities and learning mechanisms. In addition, expanding studies to other types of research institution such as public research organisations and private R&D labs would also yield valuable insights.

Declaration of Interest

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