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Understanding university technicians' role in creating knowledge exchange routines and capabilities: a research agenda

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Abstract
Knowledge exchange (KE) is becoming a strategic imperative for universities globally. Research examining KE has tended to focus on a limited and select group of stakeholders. This paper builds on calls for a wider consideration of KE activities and other contributors to the KE agenda. The technical community is one such group that has received little attention or acknowledgement of their part in KE. We argue that the technical community makes a significant yet overlooked contribution to a broad array of KE activities. Technicians are problem solvers that often undertake work that their academic counterparts could not do—as users and managers of complex equipment to enable innovation. To date the literature provides limited understanding of the technician's role and a lack of conceptualization of the contribution of technicians in KE. Adopting a micro-foundation approach, we present a conceptual framework which draws on the multi-level categories of individuals, processes and structures. We take a broader perspective of KE by including activities such as working with external businesses, enabling access to facilities and providing analysis, and contributing to public engagement and training. By synthesizing contemporary research with recent policy work we reveal the potential contribution of technician's talent, know-how and boundary spanning activities. We conclude with a structured agenda and conceptual framework to help guide future research, showing how investigating the integration of individual, process and structural factors affecting technicians can help reveal new insights into KE capability development at the university level.

Keywords Technicians · Knowledge exchange · Micro-foundations

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1 Introduction

1.1 The contemporary significance of knowledge exchange and the technical community

Knowledge exchange (KE) has become a strategic imperative within higher education institutions (HEIs). Viewed as a key mechanism in delivering the 'third mission' for universities, KE seeks to promote innovation and growth through the deployment of novel science and technology (Audretsch & Belitski, 2021; Cunningham et al., 2019; Miller et al., 2014, 2018). In its broadest sense KE encompasses multiple transfer and exchange activities (in and across university boundaries) facilitating entrepreneurial and innovative activity (Hayter et al., 2020). Yet, until recently, research into KE has tended to be restricted to a narrow range of activities, namely technology transfer and commercialization (Marzocchi et al., 2023). This has been compounded by attention being limited to a select group of stakeholders such as faculty members in the research team (De Silva, 2016; Wright, 2014), technology transfer professionals (Soares & Torkomian, 2021) and early career researchers (Treanor et al., 2021). We build upon calls for a wider consideration of KE activities and a consideration of other contributors to the KE agenda that academic and policy-oriented discussion has largely neglected (Hayter et al., 2020). The technical community is one such group that to date has received little attention or acknowledgement of their part in KE (Noke et al., 2022; TALENT, 2020). This is a significant oversight as the technical community has great capacity to translate theory to practice and facilitate change, yet their roles and contribution are poorly understood (Wragg et al., 2023). Our understanding of how to develop KE capability is likely to be sub optimal unless the circumstances needed to stimulate and support *all* employees in HEIs to support KE are considered.

Technical roles are not always viewed with the same esteem as other key players within the research community (Barley, 1996; Lewis & Gospel, 2015; Wragg et al., 2023). Yet, technicians are problem solvers using ingenuity and creativity to solve practical problems using tacit techniques and procedures (Lewis & Gospel, 2015). These qualified individuals (ranging from apprentice level through to PhD) are users, managers, installers and supporters of complex equipment, requiring specialist training and practical experience to conduct their job effectively (Lewis & Gospel, 2015). The tasks that they undertake to support research and KE are often ones that their academic counterparts could not perform (TALENT, 2022). We propose, therefore, that we need a better understanding of their unique contribution to the KE process, where their expertise clearly provides solutions to complex problems (Lewis, 2019).

The UKRI-Research England funded TALENT program published a report in 2020 exploring the role of technicians in KE. It highlighted the vital contribution they make through the management of facilities and their expertise and ability to bring research to life. Furthermore, the report highlighted that their work is not restricted to the internal workings of the University, often their work extends to working with external partners providing and contributing solutions to real world problems. We see technicians by the very nature of their role as agents orchestrating the sharing of know-how. Therefore, it is not surprising that technicians have been found to be historically significant for the diffusion of knowledge (Mokyr, 2005; O'Connor, 2023). Yet, the fundamental issue emphasized in

the TALENT report is that KE remains implicit in their role—as Professor Trevor McMillan, The Chair of Research England's KE Framework steering group attests; *"as a sector we are not explicitly recognising the contribution made by our technical staff to KE either internally or externally in our dialogue with the public and with partners"* (p.2). As technicians appear to have such a significant role to play within the university's KE agenda (Noke et al., 2022; TALENT, 2020), then we require both theoretical, and empirical insights of the KE process and the contribution technicians may offer.

The aim of this paper is to deepen our understanding of KE, by proposing a research agenda that seeks to understand how this missing group of actors—technicians, who have largely been absent from the research discourse (TALENT, 2020) contribute to the development of KE capabilities and routines. The antecedents that determine the emergence and development of dynamic capabilities and organization routines, in this case KE, has long been argued to be driven by micro-level phenomena (Gavetti, 2005; Helfat & Peteraf, 2003; Salvato & Rerup, 2011). As such we adopt a micro-foundations lens (Felin et al., 2012, 2015). As human interactions are the primary source of knowledge and knowledge exchange, going beyond the level of the organization is necessary (Felin & Foss, 2009). Thus, we explore how actors and/or the context interact and integrate to enable organizational outcomes (Hughes et al., 2020), as *"we lack proper understanding into the micro-foundations of technology transfer process"* (Al-Tabbaa & Ankrah, 2019 p. 562). Guided by the three micro-level categories, individual, process and structure, as suggested by Felin et al. (2012) we review the extant literature on KE. We theoretically build upon the somewhat limited literature pertaining to technicians. In doing so we present a conceptual framework of technicians' potential contribution to KE capabilities and identify potential research questions to guide future research in this area.

1.2 Definition of technicians within a changing university landscape

Attempts to define a 'technician' have proven elusive, yet we need a working definition to advance our research agenda. The TALENT Commission report (TALENT, 2022) describes the roles technicians undertake which include research, teaching, KE, involvement in health and safety, sustainability initiatives, maintenance, infrastructure and much more. This reflects not only the wide range of roles the technical community encompasses but the wide range of responsibilities it covers. Thereby proposing one definition is extremely challenging. For this paper, we propose to adopt the following working definition from the UKRI's Technicians Commitment Action Plan:

> "Technicians use their technical expertise and knowledge and their partial, analytical and management skills to make a range of vital contributions to research and innovation, including (but not limited to):
>
> - Delivering the goals of a research and innovation project
> - Maintaining and developing the environment, standards, resources, materials and facilities needed to deliver research and innovation
> - Teaching others in the design, use and analysis of research techniques and methodologies
> - Managing budgets, procurement and teams directly associated with research projects, equipment, instruments and research resources" (UKRI, 2021, p. 6)

This definition is a marked contrast with the limited prior academic research that has focused on technicians, which posited that technicians held lower-level positions in an organization and should be considered simply as a laboratory apprentice. Barley and Bechky (1994), for instance, state that technicians are viewed as lower in status, with less formal training and theoretical knowledge than the scientists they work with. This represents the historical view that technicians were a resource and were individuals that did not require autonomy within the laboratory setting. Rather their function was to ease and accelerate the workload of other research team members (Owen-Smith, 2001). The overriding concept was that of academic prowess dominating the research team, illustrated in Shapin's (1989) examination of Boyle's laboratory. She depicts how technicians were stigmatized as a resource to be managed rather than an integral member of the research community "at one extreme, technicians might be seen as mere sources of physical energy and as muscular extensions of their master's will" (Shapin, 1989, p. 557).

The principal narrative has often sought to separate technical and academic skills—however affirmation needs to be stressed that "this does not reflect the reality of how academics and technicians work together" (TALENT, 2022, p. 5). The TALENT Commission report confirms that this disconnect in how technical roles were viewed remains, but the subservient view of technicians is increasingly anachronistic and there is an emerging acceptance that technicians hold a certain kind of power accrued from their organizational position. Barley and Bechky (1994) draw attention to technicians as the coordinators between the material world (of experiments and instruments) and the symbolic world (of interpretation and inscription). More recent work highlights that technicians are not only capable of acting as knowledge repositories within the research setting (Furman & Stern, 2011) but in fact technicians may also enable scientific breakthroughs (Conti & Liu, 2015). In the UK context, we observe a change in the strategic importance afforded to the technical role, with technicians ascending the hierarchy in universities with job titles now including Director of Technical Skills and Strategy and Director of Research Technology and Technical Strategy. These new roles demonstrate a recognition of the strategic role technicians can undertake in universities.

In the UK, policy work has begun to draw attention to the value that technicians offer, as Lord Sainsbury articulates in The TALENT Commission report; *"I have long believed that technicians are one of the keys to unlocking innovation and harnessing emerging technologies"* (TALENT, 2022, p. 4). This is a breakthrough, as in the UK context, in the drive for innovation the discourse all too often focuses on emerging technologies and the equipment required to enable innovation. Rarely is consideration given to the people, the expert technical skills, roles and careers required to enable the use of these technologies (TALENT, 2022). We observe significant momentum behind this change in emphasis across the UK policy landscape. For instance, in quick succession we have seen the Science Council's Technician Commitment, the Gatsby Foundation's Technicians Make it Happen campaign, Midlands Innovation TALENT program and the newly formed UKRI-Research England funded Institute for Technical Skills and Strategy. These pioneering initiatives have collectively not only highlighted the need to support the role of technicians particularly within universities, but they have also sought ways to unlock their unrecognized potential. There has been a fundamental emphasis to build regional and national support networks to safeguard these vital technical skills (Commitment, 2022; TALENT, 2022). As the current discourse begins to shift, there is an urgent requirement for theoretical and empirical knowledge to draw level. We require an appreciation of how KE is developed and sustained through a deeper understanding of how the technical community (in its diverse forms and levels) underpins the routines and capabilities of KE in universities.

1.3 Transitioning from knowledge transfer towards knowledge exchange

Globally universities face increased pressure to go beyond the activities of teaching and research. The expectation is now to contribute to utilizing new knowledge and innovations to deliver benefit to the broader society (Sengupta & Rossi, 2023). We are amid a shift from the 'ivory tower' mode of knowledge creation, towards engaged research. This drive towards the Third Mission is led by a strategic requirement to deliver impact alongside external non-academic stakeholders, collectively referred to as KE. Within the UK, changes in policy interventions have resulted in KE being recognized as a core strategic operation for universities (Lockett et al., 2015). UK universities have had to strategically respond to such external challenges, altering their engagement in research, teaching, and KE to compete for public and private sector funding (Hayter et al., 2020; Hewitt-Dundas, 2012; Horner et al., 2019). Fundamentally, KE has become an important capability (Sengupta & Rossi, 2023) for universities to demonstrate economic and social impact to funders.

However, the prior art is of limited use for university leaders working in this new milieu. The legacy of earlier research on knowledge/technology transfer provides a linear representation, depicting the process as beginning with scientific breakthroughs leading to the commercialization of the technology. Historically research was preoccupied with outcomes such as patents, licenses, royalty agreements, or start-up creations (Schaeffer et al., 2020). This rather static view did little to consider the dynamic nature of innovation. Increasingly, this 'knowledge transfer' approach and its associated activities are judged as overly narrow, and constrains understanding of how university-based knowledge is shared and accessed across the boundaries (including government, universities, industry and civic society) (Carayannis & Campbell, 2009; Perkmann et al., 2013).

The UK Knowledge Exchange Concordat (2020) attempts to address this limitation through providing a broader definition of 'knowledge exchange' as "a collaborative, creative endeavour that translates knowledge and research into impact in society and the economy. KE includes a set of activities, processes and skills that enable close collaboration between universities and partner organisations to deliver commercial, environmental, cultural, and place-based benefits, opportunities for students and increased prosperity" (Knowledge Exchange Concordat, 2020). Clearly such KE is driven by university engagement with a diverse range of individuals (Benneworth & Jongbloed, 2010). Yet Marzocchi et al. (2023) argues certain activities, actors and contexts encompassing KE remain poorly understood. Developing a firmer understanding of KE in its broadest sense is imperative. For example, Marzocchi et al. (2023) in their special issue reconceptualizing KE and HEIs, draw our attention to actors where attention has been lacking. Illustrating the work of Lawson and Salter (2023) and Ramos-Vielba and D'Este (2023), they highlight issues relating to gender and those participating in broader KE.

This emerging view of KE as a set of multifaceted processes and the subsequent acknowledgement that there are multiple actors outside those previously represented. We still have some way to go to understand the diverse roles and actors that contribute to KE. Lewis (2019) points out that with this changing view of KE as a non-linear process, technicians become central figures in these broader, all-encompassing activities that represent KE. For instance, the TALENT (2020) report highlights case examples of KE activities that technicians contribute directly towards, including (but not limited to):

- Involvement and creation of innovation, invention, IP (for example commercialization through spinouts)
- Working with business from Small and Medium Enterprises (SMEs) to multi-national companies
- Enabling access to facilities and/or providing analysis
- Public engagement
- Delivering training and development

Yet, the issue remains that this work appears to be 'hidden in plain sight' with little theoretical or empirical insight evident in the literature to date. To address this deficit, we now turn to micro-foundations to help build a conceptual framework of the potential contribution of technicians to KE.

1.4 Taking a micro-foundations perspective of knowledge exchange

We build upon calls to understand how a KE capability can be built through considering the multi-level interactions of specific actors within particular contexts (Barney & Felin, 2013). The micro-foundations literature considers that macro-concepts and macro-outcomes, (e.g. firm-level capabilities, performance, and strategies) needs to be understood in terms of the underlying actions, interactions, and characteristics of micro-level entities (e.g., individuals) (Contractor et al., 2019). Consequently, there has been a call to understand how these routines and capabilities are created (Felin et al., 2012). Studies adopting a micro-foundational perspective of KE have deepened our understanding of the complexity and diversity of KE activities and some of the actors involved.

Micro-foundations have been utilized to provide insights into the interactions between academics and external organizations—referred to as academic engagement, (e.g., Perkmann et al., 2013, 2021). Specific work examining aspects of these interactions examined the micro dimensions of environments supporting joint University-Industry Laboratories (Adegbile et al., 2021). Further work explored the dimensions of participating firms extending their innovation capabilities through funded research (Ryan et al., 2018). In addition, Borge and Bröring (2020) took a multi-stakeholder perspective when examining technology transfer and emerging knowledge areas such as the bioeconomy. Finally, the work of Santoro et al. (2020) sought to explain KE and open innovation, from the view of the interplay between entrepreneurs, employees and firm level factors where universities are often key partners.

In addition, micro-foundations have been used as a lens to illuminate KE capability through taking an internal university focus. Research has sought to examine the role played by key actors from within the university setting and their role in developing a KE capability. Most of the research attention has been on the role of academics, yet several perspectives have been taken. Empirical work by Cunningham (2019) examined the academic role as a principal investigator and how they contribute to value creation within the quadruple helix. The role of the academic as an entrepreneur has received much attention, with research seeking to examine the key characteristics of academic entrepreneurs (Bercovitz & Feldman, 2008; De Silva, 2016; Jain et al., 2009; Wright, 2014). Other work taking a

micro-level view is presented by Wang et al. (2022b) who sought to understand the role of academic researchers in the commercialization process.

These multiple studies illustrate the value of applying a micro-foundation perspective, enriching our understanding of the multi-level complexity of KE. Scuotto et al. (2020) argue there is a need for a more fine-grained examination of how KE unfolds at an individual level. We propose that a consideration of the role of technicians in KE could contribute to this call. Drawing on Felin et al.'s (2012) work, they established that the micro-foundations of capabilities can be clustered into three categories: (1) individuals, (2) processes and interactions, and (3) structure. We adopt these categories in two ways, firstly, we use the categories as an organizing structure for our review of the extant literature on technicians and KE. Secondly, they form the fundamental constructs of our conceptual model (Fig. 1) to guide future research towards deepening our understanding of KE and the role that technicians contribute within the university context.

It is important to note that the three categories of micro-foundations are not discrete, instead they are inter-related through internal and external interactions within and across levels of analysis (Ryan et al., 2018). They offer an approach to study collaborations at the individual-level (Bogers et al., 2018) and build an understanding of "the unique, interactional, and collective effects that are not only additive but also emergent" (Barney & Felin, 2013, p. 4), where the aggregation of individual interactions can build towards organizational level KE capability development. Within the subsequent sections, we will examine the extant literature pertaining to micro-foundations in KE and examine nascent research on technicians and their role within the framework of the micro-foundations categories. We will also highlight where there are clear gaps in research and current understanding and draw on the broader university research context to illustrate where work has been carried out and where there is potential for future research.

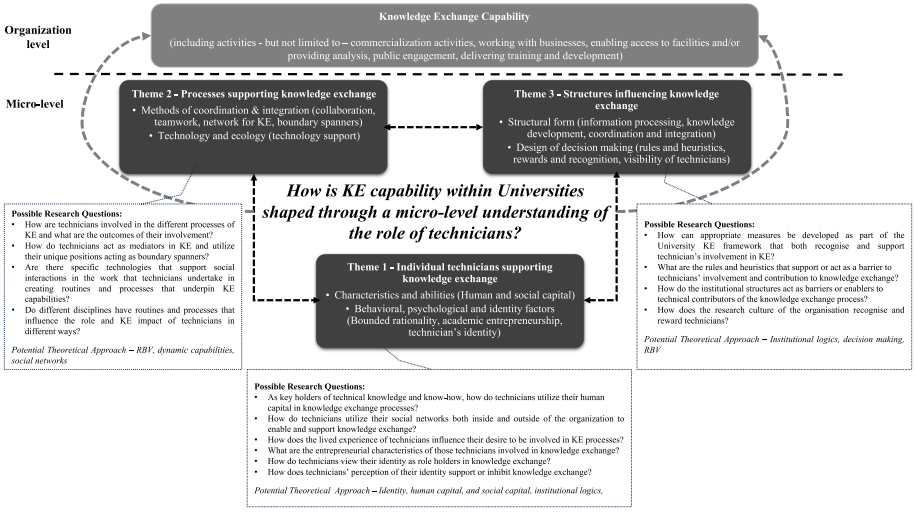

Fig. 1 A conceptual framework of technicians' potential contribution to KE capabilities and possible research questions

2 Conceptual framing

2.1 Individual: technicians supporting knowledge exchange

In its simplest form organizations are composed of an aggregation of individuals, who have the capacity to greatly affect the behavior, evolution, and performance of the organization they belong to (e.g., Felin et al., 2012). Thereby, as a central tenet of an organization, understanding individuals is crucial to recognizing how routines and capabilities are developed (Adegbile et al., 2021; Felin & Hesterly, 2007) and in turn how organizational outcomes are achieved (Felin et al., 2012). Individuals can contribute at a micro-level in various ways, with the individual category forming one of the building blocks that enable the KE phenomena to be understood. Felin et al. (2012) proposed two components for consideration that guide our literature review on KE; 1) examining the characteristics and abilities of the individual technician– here we specifically examine human capital, and social capital and 2) behavioral and psychological aspects, within this category we introduce the role of technician identity as a pertinent component that requires consideration (Felin & Foss, 2005; Grossman & McDonald, 2008).

2.1.1 Technicians' characteristics and abilities—human capital and social capital

Felin et al. (2012), states that to build a micro-level understanding of organizational outcomes we need to understand the individual characteristics of those who are fundamental to creating routines and capabilities. Acknowledging that individuals sit at the heart of the process of transferring knowledge and technological know-how, Adegbile et al. (2021) explains that the differences in the process of KE can be attributed to the variations in individuals. Understanding the characteristics, preferences, knowledge, and experience, typically conceptualized as the human capital, of these key individual champions involved in KE, is fast becoming a priority for HEIs (Adegbile et al., 2021). For instance, Wright et al. (2007), found that university employees with higher levels of technical and entrepreneurial human capital have more utility for technological entrepreneurship due to their ability to be adaptive and agile.

Evidence confirms technicians as problem solvers, with technical skills required to solve complex research and real-world problems (TALENT, 2020, 2022). Through their varied roles e.g., facilities managers, research technicians, laboratory coordinators, it is their specific human capital that converts abstract concepts into reality. Their role often involves working with external stakeholders to deliver impactful research and innovation, and ultimately delivering university KE outcomes (TALENT, 2020). However, their contribution has been likened to being a lab elf or fairy, with parallels drawn to the fairytale 'The Elves and the Shoemaker' telling the story of how leather and thread left by the shoemaker were mysterious transformed into shoes overnight (TALENT, 2020). Much the same as technicians, the output of their work is known, but how it materializes is rarely reflected upon. In sum, although it is agreed that human capital acts as a key mechanism for sharing knowledge in an organization, acting as a bridge between the individual and organizational level (Albats et al., 2022; Felin et al., 2015; Ghouri et al., 2019), how technicians' specific human capital aids (or constrains) KE remains opaque.

In conceptualizing the relationship between human and social capital, Coleman (1988) argues that social capital acts to facilitate the exchange of human capital among people. So

as important as the skills and experiences (human capital) of individuals are in supporting KE, it is equally important to understand the social mechanisms that underpin the production of knowledge (Bozeman & Mangematin, 2004). Innovation research informs us of the importance of diverse social capital in facilitating innovation and entrepreneurship (Meyer, 2022; Wu et al., 2008). This must be considered alongside the view that innovation does not comprise discrete events, rather it is the result of the interactions and exchanges of knowledge involving diverse actors in organizations (Gu et al., 2013). Thus, as KE encompasses more diverse activities (than previously recognized by technology transfer), KE is fundamental to the innovation processes within HEIs (Striukova & Rayna, 2015). As such it makes sense that we seek to enhance our understanding of the social networks present in KE (Hayter et al., 2020; Mosey & Wright, 2007) through recognizing the potential value of technicians as diverse and previously missing actors in the process.

The extant literature focusing on social networks within the context of entrepreneurial academics undertaking KE activities indicates their networks are typically constrained to a narrow scientific research network (Mosey & Wright, 2007). Academic entrepreneurs benefit from close and/or strong ties with team members in their department and can be limited by relationships that are typically characterized as being loose or weak ties with actors located outside their department (Granovetter, 1973). Yet, academics seeking to commercialize their research need to mobilize both strong and weak ties (Mosey & Wright, 2007). The indication is that not only are social networks important and how they are mobilized, but an individual's perceived status in the organization can impact their capacity to build and utilize their social capital (Packalen, 2007). Evidence from TALENT (2020) seems to support this view of status impacting an individual's social capital and their ability to leverage it. In some cases, it was apparent that technicians were limited by how they were viewed in the organization. It was often reported as technicians being viewed as extensions of the physical assets they operate, rather than being seen for the human and social connections that they possess (TALENT, 2020). It seems that the specific human and social capital of technicians contribute to routines and processes that comprise KE, yet much remains to be understood.

2.1.2 Behavioral, psychological and identity factors for technicians

In examining the process of KE, research has identified both normative behavioral and psychological factors for success (Adegbile et al., 2021). The focus of behavioral theorists has been on the experiential and learning-related aspects of rationality. Where action is driven by an individual's belief system, from which they receive feedback and gain experience, that leads them to learn about their environment (Adegbile et al., 2021; Felin et al., 2012). Here Felin et al. (2012) introduces the deterministic concept of bounded rationality. Bounded rationality is determined by the cognitive limitations of the actors and by their experiential data (Adegbile et al., 2021). With this crucial insight, understanding the bounded rationality of technicians would help to shed light on their decision making within the KE context. We have evidence from the TALENT (2022) report that technicians' lived experience are constrained by several barriers; recognition, visibility, career development and sustainability. Whilst the report presented many examples of technical staff contributing to KE, it acknowledged these occurrences were at a local level. Therefore, the lack of institutional and national recognition bounds their potential. As the initiatives seeking to support technicians in HEIs e.g., Technicians Commitment and TALENT gain traction,

and the barriers are eradicated then understanding how these changes affect technicians' bounded rationality can be empirically captured.

Behavioral studies within academe have predominantly considered academic actors (for examples see, D'Este et al., 2012; Jain et al., 2009; Wang et al., 2022a; McAdam et al., 2012; Cunningham, 2019). Drawing on the extant literature studies on academic scientists in their endeavor to be entrepreneurial agents, provides evidence that suggests academic entrepreneurs are similar in their behaviors to entrepreneurs in more general settings. Empirical association indicates they share certain characteristics, such as innovation, opportunity recognition, and risk-taking behavior (Wang et al., 2022a). This suggests that technicians acting entrepreneurially will likely exhibit analogous characteristics to their academic counterparts.

Research seeking to investigate the micro-level behavioral and psychological aspects of academic entrepreneurship have also sought to examine them from the theoretical perspective of identity (Wang et al., 2022a, Fenters et al., 2017). Jain et al. (2009) posit it is necessary for academics to build an entrepreneurial identity in addition to their academic identity. Yet, there remains ambiguity in our understanding regarding whether the initial identity as a scientist strengthens or inhibits their participation in research commercialization activities (O'Kane et al., 2020; Würmseher, 2017). In studies examining star scientists or prolific academics in the commercialization process (e.g. Lockett & Wright, 2005), very little is known about the likely conflicts inherent in having multiple identities across science and academe and the concomitant impact on their entrepreneurial behavior (Hayter et al., 2021). Wang et al. (2022a) explain that at times identities can conflict. In this vein, we argue it is essential to gain insight into technicians' perceptions of their identity and any perceived conflict with KE. Perhaps, this is of greatest significance given the documented invisibility of their role within the university environment (Noke et al., 2022; TALENT, 2020, 2022; Wragg et al., 2023). According to identity theory a person's self-concept is established through a hierarchy of role identities. An individual develops a collection of identities that reflect their role and are based upon their perceptions of their position in the social structure. Whilst the literature states that roles and identities differ (Jain et al., 2009). It appears they are certainly related, with elements that are socially defined influencing an individual's role and their own interpretation of their role (Wang et al., 2022a). Thus, it may be the case that the cognitive concepts of identity guides technicians' actual behavior (Dutton et al., 1994). Either way, we lack clarity in their perceptions of their identity and how this relates to their involvement and work in KE.

2.2 Processes supporting KE

Much like the individual category, processes are also the building blocks of micro-foundations (Felin et al., 2012). Defined as "a sequence of interdependent events" (Ibid, p. 1362) processes, inform routines which can be described as "repetitive, recognizable patterns of interdependent actions, carried out by multiple actors" (Feldman & Pentland, 2003, p.95). Both processes and routines require action in the form of individual intervention, with routines articulated as collective rather than individual-level phenomena (Liu & Pentland, 2011). To understand these processes and interactions, Felin et al. (2012) proposes consideration of (1) the methods of coordination and integration, and (2) technology and ecology. We review current literature relating to these two categories from the context of KE and where available provide examples of technician's contribution in underlying processes.

2.2.1 Methods of coordination and integration for technicians in KE

As a process KE delivers significant benefits outside the realms of the university (Ireland & Miller, 2004), it is also not a singular activity, rather it is a fluid, complex and iterative process involving many different actors (Bramwell & Wolfe, 2008). In establishing the micro-foundations of routines, interactions between the individuals that jointly represent and establish the formulation of a particular activity is necessary (Baer et al., 2013). Interactions are possible at a formal (e.g. rules, standard operating procedures) and informal level (e.g. experience, know-how) and can constrain and/or enable individual action (Baer et al., 2013). Felin et al. (2012) advocate the need to explore the role of individuals as they enact these routines, as there are still questions over what supports the development of sustainable routines and capabilities. A consensus is emerging that KE relies on collaboration and teamwork and should not be viewed as isolated individual efforts (Zaggl & Pottbäcker, 2021). As such teams have been examined in the context of university research and KE (Hall et al., 2018; Lee et al., 2015; Walsh & Lee, 2015) and networks in science (Breschi & Catalini, 2010; O'Kane et al., 2021).

In considering the membership of teams, Zaggl and Pottbacker (2021) found the importance of diversity amongst the teams, helping to provide a shared understanding, as well as leading to more effective problem solving. It was seen that through the integration of individual skill specialization, when combined and aligned led to improved outcomes (Battaglia et al., 2021; Zaggl & Pottbäcker, 2021). The TALENT (2020) report provides insight into technicians' contributions within the wider research team and how they often act as a lynchpin, coordinating and integrating work to ensure the smooth running of departments. Yet academic literature remains scarce on how they perform these roles and how the routines they enact contribute to KE. One insightful paper by Barley and Bechky (1994) that has focused on technicians characterized their role as a boundary spanner. Boundary spanners are typically individuals with a unique ability to link different parts of the organization internally and to reach externally due to their ambiguous status (Bertello et al., 2022; Crupi, 2021). It is this ability to link, integrate and coordinate knowledge that typifies the role of the technician (Lewis & Gospel, 2011).

This ability to connect is argued to be partially due to the privileged access to contextual knowledge that makes technicians indispensable for collaborations (Barley & Bechky, 1994; Shapin, 1989). It raises the question whether this is an individual trait within a technician or inherent to the role. As research is lacking in providing this insight there is still future work to be carried out in this area. However, evidence does support the view that technicians are often in possession of knowledge and skills pertaining to equipment, processes and people that are unique to their roles that other members of the research team do not possess (TALENT, 2020). As innovation and KE is built on the ability to access different sources of knowledge flows then drawing on the diverse expertise in the research team can lead to innovative outcomes (Zaggl & Pottbäcker, 2021). The TALENT (2020) report exploring the role of technicians within KE highlights a number of case studies where technicians support research and external collaborations, acting as the lynchpin between academic and industry. Specially, Case Study 1 details the role of Tim Self and illustrates how Tim and his group work within academia, as well as with external partners. The cited example highlights how Tim helped one business to visualize how the anti-microbial latex gloves they had developed

worked and how bacteria was being killed on the surface of the glove "what was great about it was that we were able to apply our expertise and technology to quite a difficult, practical problem. But also what was very pleasing, we felt that we were part of something that's important, healthcare wise" (pg 12).

Whilst we do know that there is a certain power technicians accrue from their direct knowledge of 'doing' the work (Lewis, 2019) this has not necessarily translated into higher status in the university. In their study Kaplan et al. (2014) compared the roles of technicians with students in the lab and found that whilst students suffered from status ambiguity, this was not long lasting. The students' role as apprentice meant whilst not viewed with the same status as faculty, they were viewed with the potential of eventually joining professorial ranks. For technicians such luxury of status development has not always been a reality (TALENT, 2022). However, the tide is turning in some UK Institutions e.g., The University of Liverpool, (Mitchell et al., 2023) and University of Warwick (Jarvis, 2019) where technical career pathways have been developed.

Despite technicians having access to contextual knowledge, which is valuable in developing collaborations, their status classification often remains low (Kaplan et al., 2014; Lewis & Gospel, 2011) or simply their work goes unrecognized (TALENT, 2022). Therefore, Kaplan et al.'s (2014) findings are interesting for two reasons; firstly, it supports the view that technicians hold an important position in the lab and have the contextual knowledge to enable boundary spanning and act as mediators which is fundamental to KE (de Wit-de Vries et al., 2019). Secondly, the finding highlights the issues technicians face with their role being invisible and unrecognized in the workplace (TALENT, 2022; Wragg et al., 2023). There is little documented exploration of the process and routines technicians undertake as contributors to these processes of boundary spanning, and integration. Examining the interactions relating to technicians' technical know-how and how this facilitates routines and processes that underpin KE and how this could be potentially enhanced through higher status within the organization is a contemporary research opportunity.

2.2.2 Technology and ecology for technicians in KE

Felin et al. (2012) argues that microlevel studies should be cognizant of the interface between individuals, processes, technology, and ecology, to appreciate how technologies shapes organizational outcomes. Adegbile et al. (2021) points out that specific technologies can structure social interaction among university stakeholders—the impact of which is not yet understood from a technical capability perspective. It is argued that upskilling is necessary to increase capability, and this is certainly central to the initiatives aiming to better support technicians (Lewis, 2019; TALENT, 2020). With research stressing the role of 'situated learning', it is argued that effective problem-solving hinges on more effective individual interactions with technology (Tyre & Von Hippel, 1997).

In understanding how organizational routines and capabilities develop overtime, Felin et al. (2015) advocate for a greater understanding of how material items that individuals, such as technicians, interact with inside an organization help the organization's ecology and ability to build and evolve. Adegbile et al. (2021) considered one specific aspect of KE, joint university—industry laboratories as a setting. Here they found that KE was contingent upon the interactions of several influential factors including physical workspaces, joint training and reports of successful commercialization and grant funding from industry. The physical workspace of the joint laboratory was a shared technology upon which a new set of collaborative routines were practiced. In a similar vein, when looking

at aspiring academic entrepreneurs, Bercovitz and Feldman (2008) found the influence of peers sharing the same laboratory setting to be critical to engagement for technology transfer. How such factors influence technicians, who manage and operate these very laboratories, in supporting the development of technology and routines for KE is still very much under-researched.

2.3 Structure influencing KE

The final aspect of the micro-foundation framework relates to the structures at an organizational level or within an organization. According to Barney and Felin (2013) a micro-level approach is often conceived as denying the role of structure and other macro factors such as culture, institutions, and norms—but structure should be recognized for the role it plays in organizational and social analysis (e.g. Hodgson, 2012; Winter, 2013). Related to the earlier critique that micro-foundations dictate everything be reduced to individuals is not necessarily the case. Therefore, within the work to understand KE and the role of technicians, it is important that we understand the structural forms that support or hinder their work, such as the design of decision-making activities and the environment and context in which their work takes place.

2.3.1 Structural form for technicians in KE

Structures can enable and constrain organizational outcomes whether at the organizational level or within an organization (Felin et al., 2012) not least those relating to KE. Through influencing individual and collective action, structures can enable or constrain interactions within an organization (Adegbile et al., 2021). It is noted by Felin et al. (2012) that structures have the capacity to shape key processes such as information processing, knowledge development, coordination and integration that can support collective action. Notably these are key foundations for KE. The structures associated with universities are often represented as being bureaucratic, complex and inflexible (Anderson et al., 2007) which are the opposite of those required to support innovation and entrepreneurial endeavor necessary to support KE. Interestingly, the studies that have examined organizational structure on aspects of technology transfer highlighted coordination as being a key issue (Chapple et al., 2005; McAdam et al., 2012). Some universities have found ways to bypass bureaucracy in certain circumstances. Dedicated entities, such as research centers, are an established means to overcome barriers to structural and coordination issues, as well as facilitating better engagement with external partners (Arvanitis et al., 2008; Bozeman et al., 2015). The TALENT Commission report (2022) highlighted common structural barriers to recognizing the role of technicians both within the organization and outside. A rewarding avenue for research would explore how different structural approaches undertaken by different universities may affect routines and capability development relating to KE.

2.3.2 Structure of decision making for technicians in KE

Fundamentally, Felin et al. (2012) state "the structure or design of decision-making activities within an organization may affect routines and capabilities" (p. 1364). Link and Siegel (2005) found that academic members often make choices in the face of organizational and institutional constraints, thereby decision-making is often governed by rules or heuristics. Felin et al. (2015) argue that how rules are set may affect how routines and capabilities

are created and evolve in organizations. Transparency of decision making and reporting are emphasized in the recommendations presented in the TALENT (2020) report on KE. It calls for representation of technicians on key institutional KE boards and committees to ensure their visibility and recognition. In part UKRI (2021) have sought to respond to some of these recommendations in their Technician Commitment Action Plan, where they pledge to seek consultation and inclusion in forthcoming Research Assessment Framework exercises. As UK universities seek to adopt such recommendations to working practices concerning technicians, there is an empirical opportunity to capture the impact upon the way that KE capability evolves providing theoretical insight into this potential relationship.

From the KE perspective, empirical studies have shown that traditional rewards focusing on publications, funding, and teaching activities are often at odds with KE. This does not always fit within these norms of traditional universities reward and promotional mechanisms (Miller et al., 2014). If this is the case for academics, then for technicians as a hidden community our knowledge and understanding is even further behind. Thereby, Alexander et al. (2015) suggest challenges of this nature can lead to 'decision paralysis' since decisions cannot be made without reference to a higher authority. There is little work in exploring the decision-making activities that support the role of technicians. There is an opportunity to build a greater understanding of the organizational structures and context that support or constrain the technician's role in KE, and indeed how these vary across and within university settings.

3 Future research: setting the agenda

The aim of this paper is to deepen our understanding of KE, by proposing a research agenda that seeks to understand how technicians contribute to the development of KE capabilities and routines. As part of our proposal for a future research agenda, we propose the conceptual framework illustrated in Fig. 1. The conceptual framework draws on the micro-foundation perspective and highlights the three themes for future research, the themes provide a conceptual bridge between the micro-foundational categories of (1) individual, (2) processes and (3) structure, and KE capability development at the higher level. Through our review of the extant literature on KE pertaining to the three categories, we précised the extant literature, highlighting current thinking and suggested research gaps to be addressed. Our review incorporated the somewhat limited research that has explored the role of technicians. To augment this limitation, we have drawn on contemporary policy reports regarding the technical community and its role in KE—highlighting not only the important role they take on, but also the implicit nature of the work they undertake. We now present a discussion contextualizing the three proposed research themes each with a set of potential research questions. These are not exhaustive, rather they are an attempt to provoke thought for future research. Finally, throughout our review of the literature we have noted several underlying theories that have guided previous research. The conceptual framework notes these as potential theoretical approaches that can be adopted in pending research, but here we acknowledge that there are many more possible theories on which to draw.

3.1 Theme 1: Individual—how technicians support knowledge exchange

The first of our research themes relates to the individual characteristics, abilities and identities of technicians and how these factors influence KE capability development. Mom et al.

(2012) states that to understand organizational competencies supporting technology transfer we need a similar understanding concerning the skill base of individuals who participate in this area. We can infer that the same is true for the broader, all-encompassing KE. Through a better understanding of the skills that different individuals possess we could advance our understanding about organizational competencies for KE (Morgeson & Hofmann, 1999). Typically, technicians as holders of fundamental tacit knowledge about machinery, processes and ways of working hold valuable human capital, yet their roles are not always explicitly considered as part of KE (TALENT, 2020). We argue that to understand the contribution of technician's human capital it is important that we understand how their skills, capabilities and experiences influence their engagement with KE processes and in turn support KE capability development. Future research could help reveal if and how technicians deploy their skills within KE processes and how these contribute towards a broader conceptualization of human capital. In turn, a better understanding of how human capital is utilized by technicians should help policy makers and practitioners develop better support mechanisms for the development of technicians' skills, capabilities and experiences, such as through the provision of suitable training (Mom et al., 2012).

Underpinning the development of human capital are the social mechanisms that constitute the social capital of an individual. The ability of key role holders within KE to utilize their social networks and social capital is critical to KE capability development. For university research commercialization we know there needs to be a synergistic combination of internal and external networks in bringing together industry challenges and research knowledge for breakthrough innovations (Mosey & Wright, 2007). Technicians are central to these networks due to the unique position they hold in the organization as boundary spanners between the research networks of academe and the external networks of industry, yet their role in boundary spanning and network bridging is underexplored (Barley & Bechky, 1994; Shapin, 1989).

The technical community is often referred to as a hidden workforce (TALENT, 2022), where their voice is rarely part of the organizational discourse. How such structural factors bound their decision-making and impetus to engage in KE processes poses an interesting question. Shinn (1982) posits that understanding the social and cognitive processes present will enable a deeper understanding of the unique practices that will enable in turn us to build towards understanding the macro-level interactions. The final aspect within the individual micro-level is identity and how technician's self-perception enables or acts as a barrier to their involvement in KE processes. We understand from the academic entrepreneurship literature that they share similar identity characteristics to entrepreneurs in other more traditional settings; therefore, we could presume that technicians will be similar, but this remains an opaque area (O'Kane et al., 2020; Würmseher, 2017) requiring further investigation. This leads to the following research questions:

3.1.1 Potential research questions

1. As key holders of technical knowledge and know-how how do technicians utilize their human capital in knowledge exchange processes?
2. How do technicians utilize their social networks both inside and outside of the organization to enable and support knowledge exchange?
3. How does the lived experience of technicians influence their desire to be involved in KE processes?

4. What are the entrepreneurial characteristics of those technicians involved in knowledge exchange?
5. How do technicians view their identity as role holders in knowledge exchange?
6. How does technicians' perception of their identity support or inhibit knowledge exchange?

3.2 Theme 2—Processes supporting knowledge exchange

The second research theme is concerned with processes and integration. The interactions between individuals and processes within a firm shape its routines and capabilities in critical ways, both formal and informal (Bozeman et al., 2013). A more fine-grained understanding of these different processes and how technicians deploy them or are involved, would help to provide greater recognition and visibility of technicians working in KE. In setting out a future research agenda focusing on the micro-level processes technicians engage with as part of their KE activities, we can understand the support required to better enable universities to realize their Third Mission. Drawing on the resource-based view (Barney, 1991; Wernfelt, 1984), we argue that technicians contribute towards the appropriate resources to enable experimentation and growth required to sustain an innovation capability. Dynamic capabilities theory (Makadok, 2001; Teece et al., 1997; Winter, 2003) extends this view and explains that to embrace opportunities as they arise resources need to be available to be developed and recombined. By developing a theoretical understanding of KE and the role of technicians as a key resource in the research team we can build knowledge of the enablers and barriers that support or hinder KE. In addition to theory development of KE in this area, this should help policy makers and practitioners to develop better KE processes for technicians' engagement. For instance, in the UK this could be through empirical examination of the relative efficacy of technician specific KE funding applications, career development and leadership training (TALENT, 2022).

In relation to universities pursuit of innovation and undertaking of entrepreneurial endeavor, there is much to build upon from the more general innovation and entrepreneurship literature regarding how interactions with technicians can support university integration and collaboration for sharing ideas and knowledge (Conway, 1995). For instance, the innovation literature calls for the involvement of all individuals in the process (Tidd & Bessant, 2020), reflecting the need for an individual level focus on technicians within the scope of university entrepreneurship research studies (Wright et al., 2007). Within the context of university research teams, the value of being able to share knowledge across a diverse team appears critical, yet the process of how that new knowledge is accumulated, translated and bought together requires further study (Muñoz et al., 2015). Insights into how technicians have been seen to coordinate work efforts through mediation, bridge different domains through boundary spanning and enable knowledge creation are therefore necessary (TALENT, 2022).

We propose that teams are equally relevant to the innovation process and development of new products and technologies (Salomo et al., 2010; Zaggl & Pottbäcker, 2021), not least in the university and scientific domain (Crupi, 2021; Lee et al., 2015). For universities to deliver their entrepreneurial mission, teams (and the individuals that make up those teams) are becoming increasingly important, with the emphasis being on the collective rather than solitary quests for scientific advancement. Shapin (1989) referred to the power that technicians can hold within the department, due to their knowledge and know-how of the laboratory and the relationships that they form in the process of their work. Adegbile

et al. (2021) found that the physical workspace of a joint laboratory between university and industry was a shared technology upon which a new set of collaborative routines were practiced. Clearly the technicians who manage and operate these very laboratories have a key role to play in the relationship between technology and ecology. Thereby, how they act as team members in the laboratory and beyond to enable KE can unlock some revealing insights and shed light on where technicians could act as barriers to the optimization of KE processes.

3.2.1 Potential research questions

1. How are technicians involved in the different processes of KE and what are the outcomes of their involvement?
2. How do technicians act as mediators in KE and utilize their unique positions acting as boundary spanners?
3. Are there specific technologies that support social interactions in the work that technicians undertake in creating routines and processes that underpin KE capabilities?
4. Do different disciplines have routines and processes that influence the role and KE impact of technicians in different ways?

3.3 Theme 3—Structures influencing knowledge exchange

We present our final research theme – structures. As the mechanism that influences individual and collective action, understanding how organizational structures enable or constrain the involvement of technicians in KE is essential, especially as within micro-level analysis understanding the impact of structures is often neglected (Barney & Felin, 2013). The organizational structure has profound implications in setting the culture and providing context to the activities that take place within and outside its boundaries. We propose that research is required to help clarify the influence of organizational structure and context on the role of technicians within KE. Firstly, we suggest that future research considers the decision-making structures that act as a barrier or facilitator of innovation and KE involving technicians. TALENT (2020) proposed that the establishment of appropriate measures to support technical staff involvement in KE, was necessary. Principally, TALENT (2020) argued that the institution should have increased formal recognition of the contributions of technicians in supporting KE activities. This should include KE activities integrated with technical staff career development, secondment opportunities related to KE being available for technical staff, technicians to be incentivized for participating in KE related activities and income generation activities to be possible for technical staff.

The policy work aiming to galvanize change in the technician community has been led by a desire and commitment to change the culture within organizations, and to acknowledge and support technicians in their work. Understanding the changes these initiatives have created should be central to future research, not merely as an evaluation of the work but to better understand what has changed and what remains to be addressed. There are implications from the organizational perspective as funding bodies seek to drive change by creating opportunities for technicians to apply for funding as well as stipulate their involvement in funding bids organizations need to ensure that the supporting structures (and processes) are in place. The planned changes to university culture that UK policy makers are setting will be fascinating to observe and how these unfold across quite diverse settings provides a rich natural experiment for empirical inquiry.

3.3.1 Potential research questions

1. How can appropriate measures be developed as part of the University KE framework that both recognise and support technician's involvement in KE?
2. What are the rules and heuristics that support or act as a barrier to technicians' involvement and contribution to knowledge exchange?
3. How do the institutional structures act as barriers or enablers to technical contributors of the knowledge exchange process?
4. How does the research culture of the organisation recognise and reward technicians?

3.4 Integration

The proposed research themes highlighted above demonstrate the research agenda required into the micro-level foundations of KE, it is however important that we address how these micro-level constructs integrate towards developing a KE capability. Whilst advocating that there is work to be done to understand KE and technicians within the three categories, nevertheless, this is perhaps not enough to simply understand the micro-level constructs on their own. These micro-level phenomena do not operate in isolation, as Fig 1., depicts there are significant interaction effects across the constructs, and we invite further work to understand the relationship between and across these elements. Barney and Felin (2013) state that aggregation is useful to a point in understanding organizational phenomena, that the collective is more complex than simply a sum of the parts. It is thus necessary for future research to consider this and understand the integration between the micro-level constructs. There is interesting work conducted by Shinn (1982) that aimed to highlight the unique character of research practices in different scientific fields. In doing so Shinn (1982) demonstrates the complex and multi-faceted composition of research institutions where different areas demonstrate their own set of distinct characteristics. He goes on to argue that it is important that we do not ignore this complexity in favor of a reductionist view. In other words, seeking a balance between the micro and macro levels to support our understanding is fundamental. Thereby understanding how technicians integrate and interact with the wider organizational strategies and resources will enlighten our view of their role further.

3.4.1 Potential research question:

1. How is KE capability within University's shaped through a micro-level understanding of the role of technicians?

4 Conclusions

This paper introduces a micro-level view of KE capability development among technicians. Empirical research to date has demonstrated the use of micro-foundations to explain academics involvement in KE activities (for a review see Perkmann et al., 2021). Yet scholars have been slow to recognise the wider community of contributors to KE development (Marzocchi et al., 2023; Scuotto et al., 2020). As such the literature does not provide conceptual tools to understand why and how KE capability development occurs from a more holistic perspective, in this case technicians. The micro-level

perspective enables a fuller understanding of KE at the organizational level, through mapping the micro-level entities enabling a conceptualization of their contribution to the higher-level. In doing so it provives a collective and forensic examination of those lower-level and multi-level elements: individuals, processes and structures (Foss & Pedersen, 2016). Drawing upon micro-foundations to fill this now exposed gap of how KE capability develops has allowed us to map the potential contribution of technicians to KE. Thus, we advance current thinking by conceptualizing the potential contribution of technicians to KE, integrating current policy work and extant literature.

In addressing this important area of research, we seek to contribute to the momentum of UK policy makers. Our aim is to provide a deeper and richer understanding of KE capability development contributing to the KE agenda and Third Mission of the HE sector. Certainly, understanding KE is essential given the requirement for universities to embrace their broader role within the economy and society. From a university perspective, our work provides greater insight into how technicians can be supported and encouraged to flourish, enabling a potentially significant contribution to the entrepreneurial university agenda for scholars and policy makers alike. Our work further underscores the contribution of technicians to the University KE agenda. This enhanced acknowledgement may be valuable, given the limited mapping or reporting of the activities that technicians undertake. Building upon this, as University leaders learn more about the value of supporting and encouraging technicians in the KE agenda, this will likely support the emergence of more effective University Third Mission goals.

This paper also seeks to enhance the recognition and visibility of technicians. In parallel with the policy initiatives highlighted already in this paper, the aim is to advance theory to better support policy makers and practitioners. Whilst contemporary literature highlights the enablers and barriers for KE more generally, research is still limited concerning the role that technicians play. By supplementing previous work, we argue that theory is required to support and underpin the policy imperative. Through the construction and development of theories pertaining to KE capability, not only will we gain a more rigorous understanding of how and why technicians undertake KE activities, it opens a black box regarding the hidden contribution of technicians. Armed with this advancement of knowledge and insight it will make possible more impactful policies that will assist technicians at the individual level to realize their contribution. As well as, facilitate the development of appropriate processes to support technicians involved in KE activities, and finally, assist in creating organizational structures that support technicians in their pursuit of KE. We propose that it is through the establishment of such mechanisms and support at the micro-level will lead to improved KE outcomes.

In conclusion contemporary policy work in the UK has highlighted the hidden role of technicians within university knowledge exchange. Through a critically review of the KE literature, we show that a micro-foundations approach reveals, the potential theoretical contribution of technicians to KE capability development. We build a conceptual model highlighting how the interactions between individual, process and structural contributions of technicians may integrate towards a university level capability. Given the strategic importance of such a capability for universities across the world, this provides a unique opportunity for the research community to contribute to theory and practice as new policy is deployed.

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