Enhancing technology transfer through entrepreneurial development: practices from innovation spaces

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Abstract

As the research on technology transfer and innovation continues to develop, there is still a need to determine which mechanisms can be used to develop entrepreneurial capabilities to enhance technology transfer. This study aims to show how mechanisms such as innovation spaces can be used to support entrepreneurs by enhancing their ability to seize opportunities of high value. This can be attributed to the development of new-generation technologies stemming from the Fourth Industrial Revolution (4IR). Thus, the objective of this study is to demonstrate innovation spaces' role within knowledge-rich research environments such as universities, and how they enhance entrepreneurial abilities to create ventures of high value. To enhance the understanding of this concept, the important role of technologies, especially those attributable to 4IR to create entrepreneurial ventures of high value were reviewed. This was done through the lens of entrepreneurs who originate from academic environments within the context of South African universities. In order to achieve this, a theoretical overview of innovation, entrepreneurship, technology transfer and 4IR was developed. This study followed a case study methodology which allowed for an analysis of bounded entities, which—in this research—involved universities in South Africa and the innovation spaces they utilise to support entrepreneurs. The results indicated various themes and common practices across entities in South Africa, which create an ecosystem that aims to enhance technology transfer within the region by leveraging innovation spaces. This means that innovation spaces offer an early access point to technological innovation, which can emanate from academic research to accelerate the development of entrepreneurial ventures through an array of support resources and services. As such the findings show that technology transfer continues to play a pivotal role in this emerging technological paradigm, where strategies to address disruptions of 4IR require coordinated activities. It is recommended that further research be conducted based on an institutional theory approach to expand the focus of entrepreneurship, where innovation spaces are used as a launchpad in an attempt to improve their success rate.

Keywords

Emerging economies; Entrepreneurship; Fourth Industrial Revolution; Incubators; Innovation spaces; Makerspace; South Africa; Technology transfer

1 Introduction

Enormous leaps have been made in technological innovation and adaptation with the movement into the Fourth Industrial Revolution (4IR) (Zhong et al. 2017). This has attracted major attention as the rapid integration of technology within several spheres of the world has disrupted businesses, academia and government (Park 2018). Literature continues to strive to add knowledge on how to harness innovation practices to successfully deliver high-value outcomes stemming from 4IR (Guerrero et al. 2019; Peris-Ortiz et al. 2017). Numerous studies (Langdon et al. 2014; Lasi et al. 2014; Sá and Lee 2012) have noted that technology transfer continues to play a pivotal role in this emerging technological paradigm. Technology transfer itself can be described as the process of transferring or disseminating technology from its creator or owner to someone else (Audretsch and Caiazza 2016). To achieve this, several variables and actions need to occur. This usually includes a concerted effort to share knowledge, skills, technologies or methods to a wider range of users who can further develop and exploit the technology into new applications, materials, products, processes or services (Cunningham et al. 2019a). Etzkowitz (2003) demonstrated that these activities and processes do not occur in isolation, but rather between three main actors, which include universities, government and business. Based on this, the triple helix framework was developed. In contrast, more recent studies emphasise a more holistic "smart" ecosystem, which adds a fourth dimension to the triple helix framework. This additional pillar includes the environment in which the actors operate, as it has been found to impact on the level of successful technology outputs (Campbell and Carayannis 2016; Carayannis et al. 2017).

In this context, both developing and developed economies are orientating themselves towards paradigms where actors and their innovation mechanisms contribute to each other's ability to effectively develop or apply technology, even in the rapidly changing environment that can be attributed to 4IR (Guerrero et al. 2019). Within this framework, it is notable that entrepreneurs have the potential to enhance technology transfer activities by stimulating creativity and innovation, as well as enhancing the cohesion between the actors within their respective environments (Cunningham et al. 2019a, b; Fleacă et al. 2018; Link and Audretsch 2018). In so doing, entrepreneurship has been shown to promote job creation, generate innovation, create new markets and redefine the very work of the future. This supports the idea that entrepreneurship can play a vital role in market competitiveness and efficiency (Xu et al. 2018). For this reason, many authors have discussed and introduced numerous ventures to assist entrepreneurs to create positive impacts within their respective environments (Esselaar et al. 2006; Kunene 2017; Merkofer and Murphy 2009; Oke et al. 2007; Talukder et al. 2013; Thomas et al. 2004). Several authors have noted the need for technology to actively assist entrepreneurs in value-creating initiatives (Adeniran and Johnston 2016; Merkofer and Murphy 2009; Steyn and Leonard 2012; Steyn 2018; Thomas et al. 2004). This is where technology transfer and entrepreneurial development comes to light, as 4IR has various advantages to offer in stimulating entrepreneurial ventures that take advantage of new-generation technologies (Fleeson et al. 2017; Mosey et al. 2017) to create ventures of high added value (Berger and Frey 2016; Mazzei 2018; Vendrell-Herrero et al. 2014).

Findings within current research note a lack of coverage of supportive mechanisms within universities, where universities are key actors in the triple helix framework who aid in the development of entrepreneurial skills to be innovative and create products with commercial value (Budyldina 2018; Etzkowitz 2003; Rasmussen et al. 2014). This implies that entrepreneurs, even those with lower skill sets, are not always certain of where to seek help and develop skills to understand and apply information and communications technology (ICT) effectively across multiple industries (Steyn and Leonard 2012; Sandberg 2018). This extends to the development of soft skills, such as collaboration and communication to execute tasks and strategies in hybrid systems (Mamabolo et al. 2017; Steyn et al. 2018). In this sense, previous research findings specify that access to environments where linkages and entrepreneurial processes can be effectively conveyed would play a decisive role in enhancing innovation capacity towards technology transfer (Wright 2014; Zahara and Wright 2011). Fortunately, there has been maturity in entrepreneurship and technology transfer, with mixed evidence regarding linkages on processes entrepreneurs follow (Kolympiris and Klein 2017). Furthermore, research suggests that innovation mechanisms and policy play a pivotal role in supporting entrepreneurs to create ventures of commercial value (Lukeš et al. 2018; Manyika et al. 2017; Ndemo and Weiss 2017).

This research paper aims to show how mechanisms such as innovation spaces—primarily within universities—can be used to support entrepreneurs by enhancing their ability to seize opportunities of high value addition that can be attributed to the development of new-generation technologies stemming from 4IR. This is done through the lens of entrepreneurs who originate from academic environments (Rasmussen et al. 2014) within the context of South African universities. Empirical studies in ecosystems have analysed technology transfer from scientific institutions, such as universities, to industry in varying ways. They have shown that university–industry collaborations have positive outcomes with regard to venture creation and technology development (Link et al. 2015; Maree and McKenzie 2014; Montes and Bastos 2013; Peeters et al. 2018). The internal mechanisms require further research, especially those that focus on delivering products from academic institutions quickly (Link et al. 2015; Seo-Zindy and Heeks 2017). The purpose of this study is to provide insight into innovation spaces and their practices through a proposed conceptual framework. By doing so, one of the supportive mechanisms in the larger entrepreneurial ecosystem can be optimised, enhancing the ideation, creation and refinement of products that can be attributed to capturing 4IR opportunities (Fleeson et al. 2017; Rasmussen et al. 2014; Wright 2014). The study takes place in South Africa, which is driving entrepreneurial endeavours on all fronts. This region has seen limited research (Urban and Chantson 2017). Mechanisms that enhance the entrepreneurial ecosystem and its outputs could present valuable information, especially within emerging economies. To establish practices from innovation spaces, the case study methodology was used. To collect the required data, a multi-method qualitative approach was used. This included document analysis and collaboration sessions to provide insight into innovation spaces, practices and their role in the ecosystem towards achieving technology transfer. The implications of this research affect researchers, practitioners, academics, managers and policy makers who need to consider these mechanisms' impact to effectively support entrepreneurs to leverage 4IR technologies.

The remainder of this paper is structured as follows: The next section provides a brief overview of theoretical considerations. This includes the important role of new-generation technologies, which stem from the 4IR and have created entrepreneurial opportunities, research and development (R&D) mechanisms and innovation spaces within universities, which support entrepreneurship to create high-value outcomes. This is followed by the

methods and limitations of the study. The resulting themes of the document analysis and common practices of innovation spaces that were established from the case studies are then presented. A discussion follows, where a potential conceptual framework is presented. This paper concludes with suggestions for future research.

2 Theoretical considerations

2.1 Opportunities and technologies of the 4IR

"The scale and breadth of the unfolding technological revolution will usher in economic, social and cultural changes of such phenomenal proportions that they are almost impossible to envisage" (Schwab 2017: 70). The 4IR, or technological revolution, has changed the way people interact and live. Literature shows that its impact in terms of scale, scope and complexity is extensive, and as a consequence, is changing the way people experience the world around them (Qin et al. 2016; Xing and Marwala 2017). According to Lee et al. (2018), several actors, including the public, private and academic sector, will need to change the way they engage with one another to manage the changes in power, wealth and knowledge that can be attributed to this disruption. A key aspect of this is the innovative technologies of 4IR, as they are being integrated into different scientific and technical disciplines, facilitating rapid advances in R&D (Carayannis et al. 2017). This will occur as technologies are fusing into the physical, digital and biological domains, creating new markets and growth opportunities (Xu et al. 2018). Fortunately, there has been extensive research on interactions between organisations and the external environment, with corresponding strategies developed to exploit innovations through technology transfer. However, uncertainties arise regarding the effectiveness of these established practices in addressing this disruption (Fleeson et al. 2017; Takalo and Tanayama 2010). There are indications from research that the first movers, or those who adapt quickly within this domain, expect to gain significant benefits from digital capabilities, with corresponding levels of investment (Markman et al. 2009). Predictive models that have been developed show that first movers are more likely to achieve success, with efficiency gains of 30% expected when compared to similar organisations. This, alongside an additional 30% in expected revenue, has driven the need for more efficient technology transfer practices to get products to market (PwC 2016; Ranga et al. 2016). This means that, by improving the transformation of an idea to a product or service, more innovations can be realised from inputs, especially in the 4IR realm. To address this, actors in the triple helix framework are encouraging entrepreneurial behaviour to address changes and seize new opportunities as they arise (Etzkowitz 2003; Zahra et al. 2006). The new opportunities created within the 4IR are widespread, as they include the end-to-end digitisation of all physical assets and their integration into digital ecosystems. Entrepreneurs could leverage innovation to create products and services that effectively utilise technology to achieve synergy, or even create completely new ones (Carolis et al. 2017; Schwab 2017). Results from research supports the assertion that synergies of 4IR technologies could be developed to drive efficiency and effectiveness for complete competitive supremacy (Gandhi et al. 2014). For example, half the activities people are paid for could be automated with technology, saving almost US$16 trillion in wages (Manyika et al. 2017). For this reason, the 4IR is expected to continue to realise significant investment of around US$907 billion per year through to 2020 (PwC 2016; World Bank 2016). With this level of potential, technological innovation can be exploited by

individuals through new venture creation in their academic or private capacities (Lackéus and Middleton 2015). These individuals, though, who by their nature are entrepreneurial (Mosey et al. 2017), need to be able to grasp 4IR technologies in order to innovate (Steenhuis and Pretorius 2017).

Entrepreneurs need to know what technologies exist and what synergies can be created with 4IR, but more importantly, they need to find ways to leverage them. Studies show that, within the 4IR, the technologies themselves are broad, but generally include additive manufacturing, augmented reality (AR), artificial intelligence (AI), autonomous robotics, Big Data analytics, cloud systems or the Internet of Things (IoT), which can be used separately, or integrated to deliver a complete solution (Oztemel and Gursev 2018; Wang et al. 2016). Certain examples of these technologies are noted to show their application in the creation of new technologies. Additive manufacturing is a process that is used to render a series of layers, one on top of the other, to create a physical object in varying mediums (Xu et al. 2018). There are, of course, various methods, including the depositing of mediums or lasers, to solidify it. This has seen extensive applications across industries (Steenhuis and Pretorius 2017). For example, additive manufacturing is being used extensively in the health sciences, where patients' unique profiles can be rendered, and surgeries prepared on physical models. This has reduced surgery times, improved recovery times and reduced associated risks (Hsieh et al. 2017). In other industries, such as aviation, the traditional milling of thin-walled and lightweight titanium structures generates machining waste of as much as 95%. Additive manufacturing is being used to address this issue through laser metal deposition, reducing waste, while ensuring that the aircraft remains lightweight. This addresses fuel costs, which accounts for 40–50% of operational costs, indicating massive savings potential (Kumar et al. 2019). Augmented reality refers to computer information that is integrated into the real world. This has shown potential to enhance the user experience where users must interact with information in a specific environment. An example is where human workers are being supported by AR systems. This is achieved as the users are presented with information and guides in their spatial environment to perform unfamiliar tasks such as assembling or repairing machinery (Paelke 2014). Artificial intelligence refers to a computer system with the ability to perform tasks usually associated with intelligence (Park 2017b). This means that AI can learn from past experience, generalising or even discovering meaning. The applications behind this require large data sets in order for AI to learn. However, there has been an increase in its application: from simple predictive text while writing emails, to AI that makes decisions related to building power usage to reduce costs based on human movement and work times (Park 2017a). Big Data refers to data that would typically be too expensive to store, manage and analyse using traditional database systems and software such as image recognition (Oussous et al. 2018). Another technology that has seen an uptake in usage is cloud systems. These are data-driven applications that allow real-time data processing and access to resources without requiring physical infrastructure (Kitchin 2014). Data points of IoT devices can route to cloud systems as they can manage larger sets of data to create valuable information (Oztemel and Gursev 2018; Serpanos 2018; Wortmann and Flüchter 2015). For instance, sensors can be placed along the production and distribution chain to predict performance issues at critical points. This can include components such as motors, where their failure can severely disrupt production and lead to extensive downtime (Mrugalska and Wyrwicka 2017). These sensors can send data to either a local point or cloud points for analytics to prevent issues and ensure that failures are quickly identified and repaired. This can also be set up to detect object flaws that can be attributed to faulty machinery. Within this context, the human element can also be addressed (World Economic Forum 2018a). For

example, facial recognition can be used for workers' access control, and in recent applications, it can be used to monitor the distraction levels of operators of heavy machinery. This data is then sent to either a local or cloud point and analysed for improved decisions or to create feed-back scenarios in an attempt to prevent dangers (Oztemel and Gursev 2018).

As a result of these technologies, research shows that massive disruptions are being experienced in several industries, spurring the issue of resource constraints, unpredictable market conditions and job security (Autor 2015; Manyika et al. 2017). As these breakthroughs continue, tasks performed by humans are being shifted by machines, and with 4IR, organisations are seeking to reach larger levels of automation to save on costs and expand into new markets to compete on a global scale (Cockburn et al. 2018). If this transformation is well managed, research argues that there could be improved quality of life alongside good work opportunities. Complex feedback loops need to be addressed, but if done well, technologies can be leveraged to drive business growth to stimulate further job creation (World Economic Forum 2018b). New jobs require new skills, though, which indicates that while certain roles become obsolete, others are created that require new levels of competency. Based on this premise, literature suggests that where businesses approach automation to replace certain functions, there is a need to empower staff to fulfil new roles. In so doing, they can achieve a competitive advantage and sustainable growth alongside employment opportunities (World Economic Forum 2018b). Overall, automation has substituted labour in certain environments, but has also increased output and higher demand for labour in others (Autor 2015). However, the counter-argument remains. With this level of disruption, job losses become a reality, which widens the gap of inequality and overall poverty. Automation may prevent the economy from creating enough new jobs, where a bigger production capacity requires a smaller workforce (Manyika et al. 2017; World Economic Forum 2018b). Furthermore, Autor (2015) notes that as computers and AI become more powerful, there will be a reduced need for certain kinds of workers, making skilled labourers with years of experience redundant. As an example, Netflix had 7100 employees in 2018 (Statista 2018), with a market value of nearly US$165 billion (Taylor 2018). This wiped out Blockbusters' competitive advantage by 2010, which at the time needed 25,000 employees and provided less content. This was achieved as Netflix leveraged Big Data, analytics, algorithms and digital streaming innovations to provide users with what they wanted in a convenient manner without massive needs for labour (Berger 2015; Taylor 2018).

Despite these arguments, research continues to demonstrate an opportunity for growth through innovation and technology transfer within the triple helix framework (Etzkowitz 2003; Magruk 2016). In this sense, it is important to understand the influence and characteristics of institutional factors on the creation and development of new technology ventures for job creation. One such example is the supportive mechanisms on offer and the policies that govern their development and application, as shown by Mosey et al. (2017). Empirical evidence to date has covered areas in technology transfer mechanisms towards entrepreneurial ventures, including academic involvement and corporate incentives. These studies portray universities as a critical source of knowledge, which adds value to the overall environment in which they are situated (Mosey et al. 2017; Peeters et al. 2018) as academics at universities enhance public research and embody scientific rigour. Consequently, we look to entrepreneurs' problem-solving ability to introduce novel innovations with commercial value, which can occur within the academic environment for business development and job creation (Cassiman et al. 2008; Fleeson et al. 2017).

2.2 Innovation, entrepreneurship and technology readiness

This section discusses the opportunities and integration of new-generation technologies that can be attributed to the 4IR and how it has stimulated innovation towards venture creation. Innovation is often described as being fundamental to harnessing opportunities (Lafuente and Berbegal-Mirabent 2017). Research shows that it is pertinent in the exploitation of 4IR technologies as there are correlations in developing the new with rapidly changing technologies (Heinis et al. 2018). Due to this, actors continue to strive for new products and processes through innovation. However, literature notes that this process is inherently complex and usually resource intensive. To address this, external knowledge is outsourced from actors such as universities, governments or research centres. Peeters et al. (2018) mention that there is evidence supporting university–industry collaborations to broaden and complement resources to enhance commercial product development. The effectiveness to leverage this and ensure technology transfer depends heavily on the activities of universities (Sharif and Baark 2008). Research has been conducted on variables such as university size, experience, faculty, research orientation and strategy. However, limited research has been conducted pertaining to innovation spaces and their practices to further innovation (Lafuente and Berbegal-Mirabent 2017; Wonglimpiyarat 2014). While innovation is not the only factor to foster business development and venture creation, industrialisation or inclusive development, it remains a significant and vital catalyst. If one observes the developing world, there are several impairments that stifle innovation, especially where there is a struggle to convert innovation inputs to outputs (Urban and Chantson 2017). For instance, research shows that resources and social cohesion obstruct the delivery of technologically sound products (Fleeson et al. 2017). In traditional established economies, differences are observed between states, including labour markets, educational enrolments and supporting institutional mechanisms, which produce differing qualities and quantities of innovation (Lafuente and Berbegal-Mirabent 2017). South Africa, as an emerging economy, is a good example of this. It is one of the leaders in Africa, but witnesses a low rate of start-ups or commercialisation when compared to the global market. To address this, research by the World Economic Forum (WEF) in 2017 and the South African Department of Science and Technology (DST)[1] shows that South Africa is seeking strategies to support the entrepreneurial ecosystem, with universities playing an important role in skills development, research, intellectual property (IP) protection, licensing and spin-offs (DST 2019; Urban and Chantson 2017).

Within the concept of innovation and its role in delivering commercially viable products, reference is made to an ecosystem that provides infrastructure to support ideation, creation and skills development towards innovative business endeavours. This is referred to as the entrepreneurial ecosystem (Feki and Mnif 2016). The ecosystem encompasses heterogenous elements that add to the overall success and outputs of innovation activities, usually performed by entrepreneurs (Corrente et al. 2019). Entrepreneurial ecosystems have received substantial attention to measure elements and leverage them accordingly. As an example, institutions such as the WEF have developed comprehensive diagnostic tools for ranking entrepreneurial ecosystems. These tools aim to determine the effectiveness of ecosystems, as entrepreneurship is considered to be one of the key elements in creating value-adding ventures and job opportunities

[1] Now known as the Department of Science and Innovation (DSI).

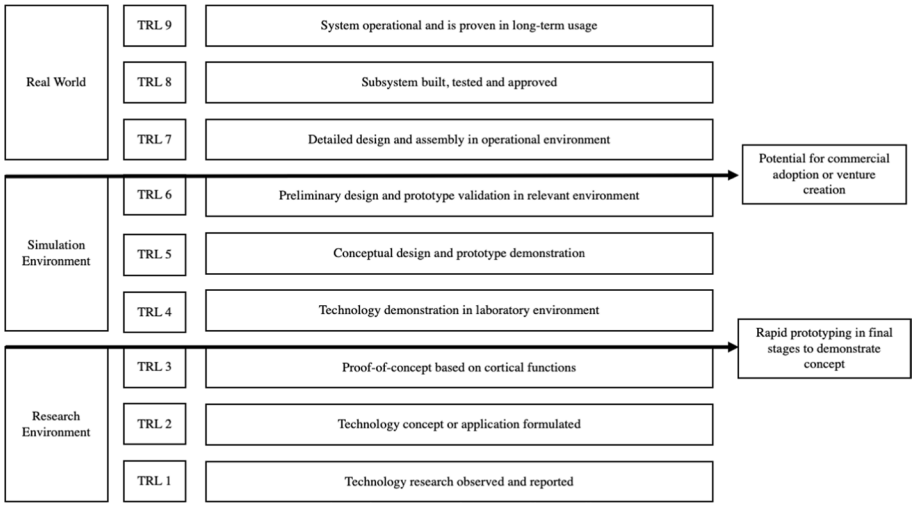

Fig. 1 Technology readiness level

(Esselaar et al. 2006; Fathian et al. 2008; Gono et al. 2016; Martínez-Fierro et al. 2016). However, failure rates to commercialise products have seriously impeded motivation, as well as continuous support (Mushonga et al. 2018). In order to improve this, skills need to be leveraged on an individual level through the amendment of policies, environments and resource support (Evers et al. 2016; Kapurubandara and Lawson 2007). In order to break through the barriers of technology development and build a conducive ecosystem, research points towards the open innovation theory (Vanhaverbeke et al. 2008). This theory proposes that innovation should be "opened" towards early university–industry spin-offs for agile uptake and not only fully-fledged technologies. Based on this premise, resource allocation and skills should be channelled in such a way that organisations receive the support needed to develop products even as early as at conceptualisation stage. To determine the stage of a product, the technology readiness level (TRL) can be used. The TRL establishes the readiness or viability of a product from the beginning of the commercialisation journey (Leitão et al. 2017). Based on the level attained, corresponding actions, support and resources can be determined and sourced. An overview of the TRL is given in Fig. 1, where the stage of product development determines the TRL. For spin-offs to be viable, a TRL of 6 and above is required to potentially deliver a commercially viable product or service in an efficient manner (Hess and Siegwart 2013). A TRL of 6 demonstrates that a product or process has been conceptually designed or prototyped (Leitão et al. 2016). As such, the open innovation theory supports the assumption that entrepreneurs and the ecosystem that supports them are vital in driving innovation, and that resource distribution should occur as required (Bruneel et al. 2012).

Thus, institutional research notes that actors are looking to find solutions to support innovation among various industries and disciplines (Roco and Bainbridge 2013). As a result, universities have been contributing to business and technology development by fostering entrepreneurial behaviour and innovation activities to receive funding (Oliver et al. 2019). For instance, George Washington University pledged to expand agreements between corporations and its faculty as a solution to federal funding in 2017.

This resulted in an investment of US$5.7 million for cancer research (Adams et al. 2018). This shows that knowledge-based economies are experiencing further investment despite economic downturns. Universities can then be used to create new knowledge, as well as to provide the required supportive mechanisms for entrepreneurs to produce outcomes beyond the academic sphere and—in so doing—enhance entrepreneurial ventures (Fleeson et al. 2017).

2.3 Technology transfer for entrepreneurs

Despite there being various drives and outcomes of entrepreneurial endeavours, Florén et al. (2017) suggest that entrepreneurs innovate towards commercially viable products or processes. These innovation activities, especially with new-generation technologies, can be delivered by technology transfer. Technology transfer has several definitions, but is usually a term used for mechanisms and processes that enable the development or creation of products or technology with commercial value (Panetti et al. 2019). To support entrepreneurs in their endeavours towards efficient technology transfer, studies on the roles and functions within entrepreneurial ecosystems have been investigated (Cunningham et al. 2019a; Nicotra et al. 2018). These ecosystems have been identified as having a set of interdependent and coordinated factors that aim to enable entrepreneurship (Fleeson et al. 2017; Lasi et al. 2014; Malecki 2018). Strategic management analytics and the assessment functions it encompasses are of interest, as it focuses more on start-ups (Corrente et al. 2019). Universities have governed and organised knowledge flow systems to enable the creation of these ecosystems (Cunningham et al. 2019a, b; Leitão et al. 2016). Several mechanisms exist within these ecosystems, with a recent focus on the technological dimension, since it adds complementary variables in ensuring innovative product creation (Panetti et al. 2019).

In this sense, there is an increasing awareness of the role universities play in shaping regional competitiveness and prosperity (Cunningham et al. 2019b). Universities themselves are organisations that have performed a key role in educating various constituents to generate valuable knowledge (Audretsch and Caiazza 2016). Governments are continuing to invest in universities and to review how they can stimulate universities and the ecosystems they support to produce innovations (Lafuente and Berbegal-Mirabent 2017), since universities continue to be a vital part of technology transfer (Etzkowitz 2003). This is further confirmed as policy makers have specifically created new legislation to enhance the flow of knowledge to generate technology transfer and research collaboration (Audretsch and Caiazza 2016). Thus, universities themselves have become hubs for fostering entrepreneurial attributes (Lee 2018). To aid these institutions, a substantial body of knowledge points towards technology transfer offices (TTOs) and their role in the entrepreneurial ecosystem. Technology transfer offices ensure close ties with research to identify innovative products that have commercial potential. Technology transfer offices, by their definition, are catalysts for innovation and—in this context—perform certain activities to manage technology transfer (Lafuente and Berbegal-Mirabent 2017). These offices are tasked to foster knowledge and ensure that high-value research is commercialised (Etzkowitz 2003), as they are knowledge brokers whose primary role is to manage the technology transfer process. Their outputs (IP, spin-offs, patents and licenses) have seen variances over time, with informal metrics adding personal contracts, industry-science networks and cooperation in education to the list of their successes (Bruneel et al. 2012; Link et al. 2015). The drive behind this is for businesses

to have the prospect of new products and services, while institutions are motivated by the potential of further income streams and greater employment opportunities with industry partners for graduates.

Despite the positive interest, there are hindrances that stifle innovation and effective technology transfer, which researchers note depends on the TRL. As such, the ability of these ecosystems to facilitate the activities needed to create commercial products, especially those of academic institutions, depends on certain variables (Campbell and Carayannis 2016; Carayannis et al. 2006). Variables that stifle this range from insufficient policy coherence and coordination to weak partnerships between actors (such as industry and academic institutions), technical skills and undersized research systems (Nicotra et al. 2018). Erol et al. (2016) show that, with the right activities, universities can develop incentives and investment to recruit skilled human capital, appropriate mechanisms and infrastructure to address potential hindrances. Accordingly, there is substantial research that assesses TTOs as central hubs to guide these activities (Berbegal-Mirabent et al. 2013; Gassmann et al. 2010; Jung and Kim 2018; Lafuente and Berbegal-Mirabent 2017; Van Stijn et al. 2018). This has led universities to create TTOs to legitimise their commercial activities (Rasmussen et al. 2014). Within the university environment, TTOs and innovation spaces can be used together to support initiatives based on the TRL. Within the entrepreneurial ecosystem, innovation spaces offer various solutions. To date, limited attention has been paid to how innovation spaces in universities have enhanced the delivery of patents and technologies. Part of this gap is the term "innovation space". Despite being broad, it includes a variety of spatial areas for technology transfer and commercialisation (Kolympiris and Klein 2017; Smith 2006; Vohora et al. 2004). Underlying practices that generally aim to promote a digital and innovative culture through training and consultancy are also part of this gap (Fleeson et al. 2017; Paper et al. 2017; Rasmussen et al. 2011; Zahara and Wright 2011). These spaces include incubators, which are often linked to universities, and makerspaces, which are found privately or within university environments (Seo-Zindy and Heeks 2017). Despite their names and functions, there are commonalities in their service offerings and practices to encourage innovation (Erol et al. 2016; Peris-Ortiz et al. 2017). For instance, incubators usually help improve the competitiveness of small- to medium-sized enterprises (SMEs) by providing supportive environments for start-up ventures to help them survive and grow (Lawal et al. 2018). Academic incubators, however, play a broader part in the university–industry relationship paradigm by offering licensing, networking, development for patenting or spin-off creation (Hess and Siegwart 2013). On the other hand, business incubators typically provide space, support and consulting services to their tenants. This would depend on their location. Business incubators have different typologies, including university business incubators, business innovation centres, independent private incubators and corporate incubators (Lukeš et al. 2018). Another example is technology incubators. Generally, technology incubators are known under various names, such as innovation centres, science parks and technology centres. A central feature of an incubator, albeit academic, business or technological, is the provision of networking opportunities to establish collaborative endeavours (Mueller et al. 2017). The types of incubators have the same objectives, but their scope differs (Tamásy 2007). In this regard, makerspaces also provide space to collaborate, empowering a new generation of creators by bringing together experts and novices from a variety of disciplines

(Adams et al. 2018; Colegrove 2017). These spaces are not limited in terms of expertise, but are a physical point for stakeholders to test and explore concepts through a hands-on approach. This allows entrepreneurs to ideate and test; and if they fail, to quickly revise until a viable concept is found. To deliver this concept, makerspaces focus on the skills needed to design, build, invent and rethink. Adams et al. (2018) show that, within this process, entrepreneurs are transforming the landscape by promoting a hands-on aspect of the learning experience, while ensuring exposure to novel tools and technologies, which can include those of the 4IR.

Despite the different names used, innovation spaces generally offer programmes and resources that facilitate the generation of high-tech outputs across varying industries (Sá and Lee 2012; Wonglimpiyarat 2014). This indicates that innovation spaces—as a holistic term—support the incubation of entrepreneurs to develop products from research in various ways and address all aspects of the TRL. This includes the screening and identification of the applicable products and technologies that are required. Researchers also consider the system of innovation spaces, and not only the space itself (Lukeš et al. 2018). However, the basic definition of technology transfer, as described by Van Stijn et al. (2018), allows for the services of these spaces to enhance efficiencies of technology transfer along the entire innovation value chain. By positioning these spaces to develop and enhance entrepreneurs to take technology to the market, based on R&D within their respective institutions, the early positioning of the technology and a potential direction for technology transfer can be defined. From the above literature, the main objectives of innovation spaces are to accelerate the development of entrepreneurial ventures through an array of support resources and services. Thus, these innovation spaces offer an early access point to technology, which can emanate from academic research (Etzkowitz 2003).

With these goals and functions, the development of these spaces has experienced an uptake around the world as a tool to accelerate venture creation (Gumede 2016; Sá and Lee 2012; Schelfhout et al. 2016). Overall, these spaces seek to provide nurturing environments in which early-stage ventures can acquire the resources, expert services and administrative support that they otherwise could not afford (Landström et al. 2015; Taylor and Hartwig 2018). In emerging economies, limited access to resources has further encouraged the creation of these spaces to provide access to equipment and infrastructure, as well as funding and soft skills training. Despite the indirect linkages, a redistribution of funds has been noted towards these supportive innovation spaces, not only for teaching and learning, but also to ensure high-value outputs through research (Worku 2015). Literature further shows that the aim behind this is to stimulate entrepreneurial endeavours within their respective environments. These spaces then aim to address and support innovation and creativity to produce products and processes through various forms of innovation in their respective environments (Paek and Lee 2017). This could include the development of leadership skills to guide entrepreneurs through different stages of development (Zahra et al. 2006). It is key to note that, despite offering a good value proposition, these spaces come with their own challenges. For instance, unique skills are required to develop innovation alongside relevant physical resources. This challenge is not limited to spaces, but applies to organisations as a whole. Furthermore, when creating an innovation space, albeit an incubator or a makerspace, there is no "one size fits all" solution. It remains the role of the institution creating it to define its purpose and evaluate the entrepreneurial needs of the environment.

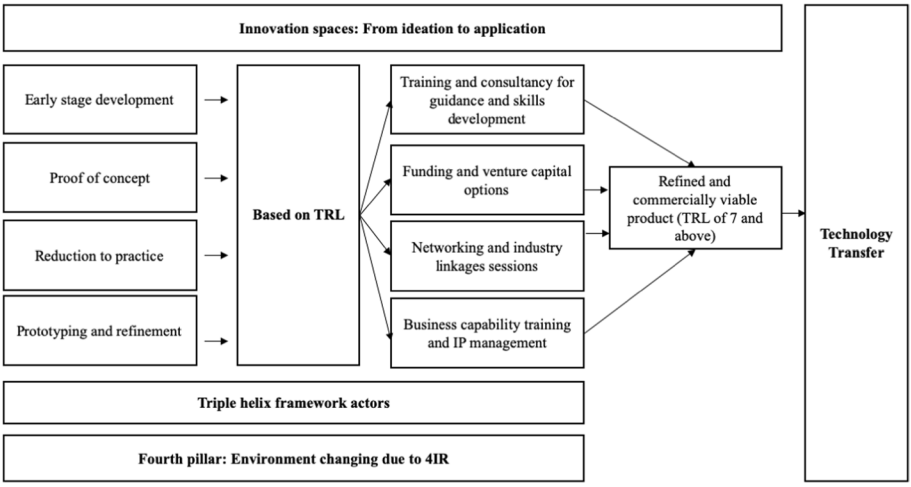

Fig. 2 Theoretical overview of the role of innovation spaces in technology transfer, derived from Markman et al. (2009), Mrkajic (2017), Sharif and Baark (2008) and Wonglimpiyarat (2014)

Fortunately, there are several theories and guides, depending on their purpose, at the disposal of institutions (Adams et al. 2018) to create these spaces with corresponding practices for technology transfer success. As an example, the competency theory of Hayton and Kelly (2006) can be amended to corporate venturing, which can explain how academic entrepreneurs develop competencies together with industrial partners. This theory, if well applied, better explains the efficacy of different support measures for academic entrepreneurs, such as incubators, accelerators, fab labs, hack labs and makerspaces (Link et al. 2015). In order to demonstrate the supportive mechanisms and journey for technology transfer based on the above literature, a theoretical framework is shown in Fig. 2.

From the literature, it can be seen that supportive mechanisms within the triple helix framework play a significant role in the innovation process for successful venture creation by entrepreneurs (Cunningham et al. 2019a; Hermann et al. 2015; Lackéus and Middleton 2015). This is achieved by creating a conducive environment that stimulates innovation towards technological product development (Ferreira et al. 2016; Guarino et al. 2007; Guerrero et al. 2019; Schmitz et al. 2017). While there is an extensive body of literature on interactions within the triple helix framework (Etzkowitz 2003; Wonglimpiyarat 2014), there are fewer studies aimed at understanding the internal mechanisms of universities. Studies have reviewed the characteristics and impacts of patents that have stemmed from university–industry relations, including the perspective of collaboration between academia and businesses, society as a whole and even industry (Cunningham et al. 2019a). The results from this have shown that inventions do not only stem from academics. However, academia has resources that are focused on R&D, which assist innovation, especially in an emerging economy (Lee 2018). Findings confirm that academic inventors are relatively present in exploratory studies, with positive outcomes and benefits (Peeters et al. 2018). As such, organisations tend to seek academic involvement in unobserved, or uncertain fields to leverage technology platforms with which they are familiar (Dijkman et al. 2015; Peeters et al. 2018). Research notes that the presence of areas that enhance and support technological development through supportive mechanisms can better drive idea generation, new product development and improved process development capacities. However, gaps remain

Table 1 Summary of themes from literature

Entrepreneurs, innovation and 4IR	Universities as actors	4IR technologies
The 4IR has created various technology development opportunities	TTOs aim to legitimise commercial activities by ensuring close ties with research to identify innovative products that have commercial potential	Additive manufacturing
Innovation practices are vital in an attempt to deliver high-value outcomes from 4IR	The triple helix framework demonstrates that three main actors are needed to address changes and to seize new opportunities as they arise	Augmented reality
The 4IR has created various opportunities in stimulating entrepreneurial ventures, which take advantage of new-generation technologies	Universities have been contributing to business and technology development by fostering entrepreneurial behaviour and innovation activities	Artificial intelligence
Innovation mechanisms and policy play a pivotal role in supporting entrepreneurs to create ventures of commercial value	Innovation spaces located at universities generally offer programmes and resources that facilitate the generation of high-tech outputs across varying industries	Autonomous robotics
Innovation is not the only factor to foster business development and venture creation, industrialisation or inclusive development, but remains a significant catalyst	Academic incubators play a broader part in the university–industry relationship paradigm	Big Data analytics
Entrepreneurs need to know how to use, apply and leverage 4IR technologies to deliver solutions and products	Innovation spaces offer an early access point to technology that emanates from academic research	Cloud systems
		Internet of Things

regarding innovation spaces, and the role they play within the TRL, from ideation to the development of a commercially viable product (Guerrero et al. 2019). Several areas have been analysed, where various 4IR technologies have created opportunities for entrepreneurs to innovate toward technology transfer. Table 1 provides a summary of these themes.

3 Method

3.1 Methodology

This study followed a case study methodology. The case study approach allowed for an analysis of bounded entities, which—in this research—involved universities in South Africa and the innovation spaces they utilise to support entrepreneurs. It is the preferred choice when information needs to be accessed that is not commonly seen (Yin 2018). Using a multi-method approach, the researchers aimed to provide an in-depth examination of the phenomenon under investigation. The case study methodology allowed for themes to be developed and integrated, based on literature, to develop a potential conceptual framework. In this way, the limited theory on innovation spaces and the role they play in higher education institutes could be addressed, especially in South Africa, to enhance entrepreneurial ventures in the rapidly changing environment due to 4IR.

For the theoretical framework to be established with regard to innovation spaces and the role they play in supporting entrepreneurial activities towards technology transfer, a literature analysis was conducted. It focused on understanding opportunities of new-generation technologies that could be attributed to 4IR, the importance of innovation, the role entrepreneurs play in leveraging these technologies and how innovation spaces could act as supportive mechanisms. Determining and obtaining the relevant existing academic literature was the first step. The next step was developing themes and presenting the research findings to establish practices. The results were integrated to develop a potential conceptual framework. For this, two qualitative data-gathering or multi-method approaches were used. This included document analysis and semi-structured collaboration sessions. This is an established application in case studies, as described by Yin (2018). The first method used was document analysis, which is designed to facilitate document research in a systematic way, allowing for secondary data to be drawn from documents. By using this method, the secondary data sources were interpreted to establish the market environment and current success rate of technology transfer to develop relevant themes (Zikmund et al. 2010).

Based on the themes that were identified, the collaboration sessions could be guided to collect data to identify practices from innovation spaces that support entrepreneurs in venture creation. This qualitative approach allowed themes to be established and variables to be discovered that provide potential explanations. The population of the study comprised two major groups of role players. The first was the managers of innovation spaces, which could provide in-depth knowledge of activities, development phases and their understanding of the innovation practices needed for entrepreneurial support. The second was the users of innovation spaces, as they engaged within the space towards ideation, prototyping and testing to achieve a certain TRL. Judgmental sampling (Saunders et al. 2009) was used as not all information was relevant, and decisions needed to be made on what to include and what to exclude. The criterium for inclusion was the capacity of the participants to

inform the research phenomenon. The data gathered was analysed using a thematic approach, where the core aspects were identified from the document analysis. Finally, the key innovation spaces within higher education were identified with practices noted from the collaboration sessions. Project reports, meetings and participation in collaboration sessions regarding innovation projects, supportive mechanisms and activities that utilise aspects of the 4IR provided valuable inputs to understand the case studies more thoroughly. By analysing this data, the researchers could add to the body of knowledge in order to further understand the practices and processes available to entrepreneurs to drive innovation and technology applications towards commercial ventures, with innovation spaces acting as supportive mechanisms.

The validity of this research is evident in the manner in which strict focus was maintained on the aim of the research project. This strict maintenance was followed by the multi-method approach. The data-collection methods were also relevant for the case study approach (Quinlan et al. 2016). The population comprised experts in relation to the phenomenon under investigation. The study is repeatable as researchers should be able to obtain the same general results if the study is applied to another environment under investigation. One factor in this regard is that the technology may rapidly change due to the nature of the 4IR.

Ethical issues are present in this research, especially due to the human aspect of collaboration and observation. However, the research was approved by an ethics committee on the basis that the research be conducted properly through a code of conduct. This meant that the engagement with the population had to be conducted in a professional manner, and the participants had to be able to opt out at any point during any collaboration session or engagement. The identities of the institutions and participants were to remain anonymous. Finally, the data itself would be held securely and safely.

3.2 Data

Based on the research methodology, a multi-method approach was used. As such, two forms of data were collected and analysed. The first comprised published documents and available statistical information based on the document analysis methodology, detailing current trends in South Africa regarding innovation and technology transfer. This included published reports from the World Bank, which compared research expenditure in terms of South Africa's overall gross domestic product (GDP), as well as patent applications and trademarks. This assisted in establishing a picture of the country's technology transfer success, correlating investment with overall activities in the region. These documents were primarily electronic reports. Furthermore, the researchers examined policy documentation to demonstrate the technology transfer successes of South Africa's top three universities, as well as information on patents and spin-offs that demonstrated value-adding ventures. The three universities that were identified from this data fell within the top 10 patent successes for 2018 in the region. They all had a TTO alongside various innovation spaces. They are referred to in this paper as University A, University B and University C. To note the challenges and entrepreneurial ecosystem, the South African White Paper on Science, Technology and Innovation (DST 2019) was used, alongside a secondary dataset that specifically considered the identification of various pilot projects and technology transfer initiatives.

This was obtained from Innovation for Inclusive Development (IID), a collaboration between DST and the Human Sciences Research Council (HSRC) in the region. The benefit of this secondary data is that it noted the challenges faced by these programmes and specifically considered interventions that effectively and efficiently supported the achievement of developments such as innovation spaces. Furthermore, it was important to associate the innovative outputs of universities and their internal mechanisms to create valuable commercial outputs. To measure this, patents and co-patents were used to showcase positive outcomes. It is assumed that intensive investment leads to a positive value outcome, such as patents and co-patents, which have a positive market value, even though there is not sole ownership in all instances. This information is used to build insights and identify themes related to the environment in which supportive mechanisms operate, where universities are key actors of innovation (Cassiman et al. 2008).

The second set of data used comprised observations and collaborations conducted within the South African context, which noted interactions in the overall entrepreneurial ecosystem. This data helped inform practices in line with themes within the respective environments. These interactions included practices of innovation spaces that were identified as being key mechanisms to deliver outputs for the three universities that were studied. The outputs that were measured included spin-offs, ventures, contracts, IP and patenting. To warrant this, the case study method was selected to allow for a detailed investigation and analysis of university–industry linkages to build practices of innovation spaces that are used in developing entrepreneurs to leverage 4IR. This was done as the researchers had access to the environment and management of activities in the entrepreneurship and technology field. For the purposes of this study, the researchers investigated cases from 2016 to 2018. The reason for the shortened period is due to the growth of innovation spaces over the last few years. There is also a movement towards the support of innovations in both the short and the long term. This includes radical to incremental innovations. The aim was to ensure that new opportunities had actual outputs and assigned value. A challenge that arose from the case studies was the need for a holistic system to guide funding into the collective that effectively stimulates human capital development, incentives and impact monitoring.

The study focused on the emerging economy of South Africa, which is labelled a strong innovator in Africa, with specific strengths in trade and research outputs. Overall, this evidence warrants further analysis into mechanisms that support entrepreneurs. By using a multi-method technique, the research draws on documentary evidence and data attained from engagement sessions to provide a triangulated perspective, which was necessary for case study research.

3.3 Limitations

The data sources used for this study imposed several limitations. Data availability did not contain certain variables within the time frame of 2016–2018, which could lead to determining the impact and effectiveness of known R&D outputs. As noted in literature, there is no generic framework for innovation spaces based on their mandate, and studies have focused more on developed than on emerging economies (Corrente et al. 2019). The way in which they are managed, or if they missed their respective mandate, was not included in this study. Furthermore, performance metrics within each innovation space were assumed to differ, based on the required outputs. Several of the advances in patents and trademarks may be attributed to the ecosystem as a whole, and not specifically to the innovation spaces within the region. Not all variables could be addressed, including the technology and

resource availability within the region, or micro practices and subtle private relations that could not be observed. Another limitation related to the location of innovation spaces and their significance to entrepreneurs.

4 Results

4.1 Theme development from document analysis

The South African environment provides a useful context for this study. With a population of approximately 57.7 million people at the end of 2018, distributed across nine provinces, the region offers diverse opportunities and challenges. It has a diverse set of cultures and backgrounds, and 11 official languages. Entrepreneurial challenges and initiatives continue to take centre stage to stimulate job creation. This is relevant as the country has a staggering 27.6% unemployment rate (Statistics South Africa 2019). Initiatives to address this include innovation centres such as those run by the Council for Scientific and Industrial Research (CSIR), Entrepreneurship Development in Higher Education (EDHE) and 26 public universities, which literature notes are vital actors in innovation. These institutes exist alongside other initiatives that are accountable to drive innovation and other outputs to reduce unemployment rates. The South African government offers an R&D tax incentive under section 11D of the Income Tax Act, Act No. 58 of 1962, to promote private sector R&D investment in the country. This directly supports R&D. This incentive allows any company that undertakes scientific and/or technological R&D in the country to deduct 150% of its R&D spending when determining its taxable income. The incentive is available to businesses of all sizes and in all sectors of the economy. This supports innovation as one of the keys to taking the South African economy to a new level (DST 2019). With this level of focused investment, key statistics—especially those relevant to innovation outcomes—are noted in Table 2.

Technology transfer in South Africa has been another specific focal point of government. This can be seen in the presentation of new legislation in the form of the Technology Innovation Agency Act, Act No. 26 of 2008, and the Intellectual Property Rights from Publicly Financed Research and Development Act, Act No. 51 of 2008. These acts have

Table 2 Key findings from document analysis for South Africa

	2015	2016	2017	2018
Patent cooperation applications [World Intellectual Property Organisation (WIPO)]	6999	7014	7337	6602
Trademark applications	37,974	36,057	30,115	34,028
Patent applications abroad	1188	1314	1461	1204
Patent grants broad	773	674	835	992
Unemployment rate (Percentage of population)	25.5	26.5	27.4	27.6
Population (in million)	55.29	56.02	56.72	57.73
WIPO (per 10,000)	1266	1252	1294	1144

provided a Technology Innovation Agency (TIA) to support government in stimulating and intensifying technological innovation and invention (DST 2019).

Despite its high unemployment rate, the country was fourth in Africa in terms of the fastest growing number of mobile devices, 11th in terms of internet bandwidth in kb per user, and 25th in terms of financing through local and extensive angel funding mechanisms with access to 49,000 US$ millionaires in 2018. South Africa has experienced a large focus on innovation and entrepreneurship through investment in its higher education institutes and—by extension—their support mechanisms.

Part of this is due to the 4IR, where technological innovation and application have received investment based on their TRL. This technology has certain novelty levels, which impact on its patent progress. The International Patent Classification (IPC) system provides a classification of patents into at least one technological field, which is used to establish the needs and viability of applications. In terms of the TRL, this represents a TRL of 7. Since researchers are the creators of IP, it is crucial that their IP is managed and properly protected. In so doing their findings can be translated into useful and innovative products and services (Arafeh 2016). This provides industry access to IP to further develop and use it commercially or otherwise. To support TTOs, centres of competence and excellence are available as collaborative entities with the necessary resources to affect market-focused strategic research and technology development for the benefit of industry and the economy at large (HSRC 2019). In so doing, they provide physical or virtual platforms upon which to establish collaborative technology innovation and commercialisation partnerships between government, industry and universities for commercialisation (Corrente et al. 2019; Verbano and Venturini 2012). Within this context, TTOs and innovation spaces are part of the mechanisms used to achieve these goals, since they have an important role to play in bringing together resources to enhance the identification and protection of new technologies. South Africa is channelling funding to universities through existing instruments to develop capacity in this regard, and—over time—aims to increase the quantity and quality of outputs (DST 2019). The investment goal in question is 1.5% of GDP in the next decade, which is directed towards R&D.

However, with regard to the higher education environment, several changes have been experienced that impact on their activities and focus points internally. In recent years, massive movements towards open access education have been published, and political unrest has impacted on the way in which funding is received. A key element of this was the “Fees must Fall” movement, where students damaged several universities across the country in protests for free education. Higher education institutions also experience extensive pressure as they are viewed as key mechanisms in not only educating the population for employment, but also developing entrepreneurial endeavours in various spheres. Fortunately, significant investment has been noted, where 75% of R&D is publicly financed. A White Paper, published by the government (DST 2019), reviewed institutions’ overall patents. Within the top ten were the three universities that form part of this study, which had achieved significant patent cooperation treaties (PCTs). In this regard, University A had 66 PCTs, University B had 84 and University C had 36 in 2018. All three these institutions have TTOs, as well as innovation spaces within their environments. There are also national priorities in which South Africa has a competitive advantage to support R&D-led industry development to encourage high-technology exports, such as high-tech technology incubators. As a result, entrepreneurs and venture capital start-ups have experienced an exponential growth across South Africa as they benefit from these priorities (Cunningham et al. 2019a). To ensure access to this market, higher education institutions have developed

TTOs alongside supportive mechanisms, including those of innovation challenges and spaces to leverage 4IR technologies.

Several policies are aimed at supporting the improvement of innovation outputs. This includes mechanisms to strengthen support to business with a focus on SMEs, as well as revitalising the role of state-owned entities (SOEs) in innovation through programmes to build an innovation mindset from primary school level. This commends entrepreneurs and innovation role models to adopt innovative approaches (DST 2019). As a result, more stakeholders have access to resources and expertise. This ensures that the market environment, even though subsidised, has access to innovations. However, evidence also suggests that universities have long-standing relationships and offices to drive these outputs beyond government funding (Vanhaverbeke et al. 2008). Governments around the globe have created incentivised programmes towards innovations (Borge and Bröring 2017). This has included emerging economies where university partnerships and funded innovation spaces have been developed to stimulate local economic development (Vanhaverbeke et al. 2008). South Africa is no different, as indicated by the support of the Department of Science and Technology, the Department of Higher Education and the Small Enterprises Development Agency (SEDA).

4.2 Case study review

From the document analysis, the main themes and practices of innovation spaces were identified for further investigation, as well as the institutions involved in technology transfer. Data was gathered through collaboration sessions with representatives of the three top universities that had been identified for further investigation as they fall within the larger research context. The results that were obtained were used to develop a conceptual framework to provide the South African context. During the collaboration sessions, theoretical approaches and linkages to the literature review were discussed to guide the sessions so that appropriate data could be gathered. Although the processes within each innovation space differ, several of the themes supporting the processes within these institutions were discussed to verify their accuracy, and the outcome was found to be favourable. The outputs are summarised Table 3.

Most of the applied research conducted between academia and established industry involves strong R&D collaboration. In this regard, university–industry relations are based on the premise of a need, where the industry partner can absorb the technology know-how. Although technology transfer is complex, especially with breakthrough technologies, consistent interest remains in acquiring products within markets. With this in mind, universities are striving to deliver outputs to address business needs for the market. With the 4IR, the pace has exceeded the ability to deliver, especially in emerging economies. The support mechanisms within these institutions and the need to deliver are apparent. This includes the establishment of innovation spaces, outputs and practices in the region. It emerged that the higher education institutions that were selected for investigation had several internal mechanisms within the entrepreneurial ecosystem, which could integrate with research activities in the larger community. They also had patent outputs directly associated with their TTOs. As indicated in the literature, TTOs perform specific roles and functions. For this research, however, the focus was on the practices of the innovation spaces and not of the TTOs themselves. As such, it is assumed that the TTOs in these institutions fulfil the roles and functions as described in the literature. Innovation spaces positioned around the universities were also observed,

Table 3 Themes and practices of innovation spaces. *Source*: Adapted from Barbero et al. (2012), Mrkajic (2017), Mushonga et al. (2018), Peris-Ortiz et al. (2017) and Wonglimpiyarat (2014)

Environmental impacts in South Africa	Themes from document analysis	Support mechanisms	Practices identified from cases through collaboration sessions
South Africa is seeking strategies to support the entrepreneurial ecosystem, with universities playing an important role in skills development, research, IP protection, licensing and spin-offs	There is a focus on support mechanisms to drive innovation outputs and value-adding ventures	TTO	Assess and provide guidance based on the TRL
Unemployment rates have increased alongside diminished job security	Top institutions that produced high levels of patents and spin-offs had TTOs and innovation spaces	Entrepreneurship Development in Higher Education across 26 universities	Enhance networking mechanisms and create industry linkages
Insufficient policy coherence and coordination, weak partnerships between actors and a lack of technical and soft skills continue to impede technology transfer.	Early-stage support for software and hardware development, as well as configuration, is needed	Innovation centres	Provide access and guidance on new-generation technologies
The region is driving entrepreneurship to stimulate job creation for high unemployment rates	Need to support start-ups and guides on forming start-ups	New legislation and TIA to improve technology innovation	Provide support and guidance through a rapid prototyping process and available technologies
Diverse culture and languages add unique barriers to be overcome	Various forms of venture creation support are required based on the type of technology	Hackathons and challenges	Present industry collaboration sessions and hackathons
Lack of necessary skills: both technical (ICT) and soft skills	Several notes on the importance of a network with industry partners and support areas	Small Enterprises Development Agency	Provide access to on-site expertise and resources
Access to education has been raised as a major challenge	Innovation spaces are in universities, but also around the institution	Incubators, accelerators and makerspaces	Provide advisory services on technology applications and advancements

Environmental impacts in South Africa	Themes from document analysis	Support mechanisms	Practices identified from cases through collaboration sessions
There are unpredictable market conditions, not only in South Africa, but globally	Skills deficits are noted in terms of ICT and soft skills	Council for Scientific and Industrial Research	Provide research project support and guidance to obtain commercial output
There is continued investment into R&D and areas to harness 4IR	Universities strive to deliver valuable outputs	R&D tax incentive under section 11D of the Income Tax Act, Act No. 58 of 1962	Provide know-how, training and skills development
	Technology transfer situations are highly complex		Support IP management

as they have direct ties with the universities, and integrate and channel knowledge through human capital within their entrepreneurial ecosystem.

The first South African university in the study, University A, is situated in the Western Cape. At this university, an innovation space was observed that enhances networking mechanisms for its stakeholders to discuss products on TRL 3 and above in a small café-styled space. This environment is used to stimulate discussions around science, engineering and innovation, and encourages broader interaction with society to continue building on the university–industry relationship. The aim of this environment is to provide a sociable space to connect industry with academia in a non-formal setting. It was even noted that wine was encouraged to encourage the creation of linkages through informal discussion. In so doing, key aspects of the relevant research could be highlighted in easily understood concepts. The results were commercial opportunities and partnerships.

University A had set up its TTO alongside this space to showcase research with commercial potential, thereby enhancing the University's portfolio and empowering non-scientists to assess innovative products more comfortably. As a result, University A has seen varying technologies across different fields at different TRLs being identified for commercial application. The ultimate goal, as noted by the University, is to create employment opportunities. An example of one of its successes relates to cancer research. A recent study published in *The Lancet* (Plummer et al. 2016) predicts that South Africa could see an increase in cancer cases of 78% by 2030. Early diagnosis is key to successful cancer treatment, and the University's innovators have pushed novel ideas forward that are tailored to South Africa; hence, University A's focus for 2018 was on health technology, with 13 successful related technology transfer success cases. In 2017, it registered 37 IP license agreements, and signed 2363 research contracts with 41 invention disclosures. Their mix of IP is interesting, as it is split at 5% for spin-offs, 9% for third-party leads, 23% for licensed IP with 12% for assignment to a corporate partner. Ultimately, spaces are used to showcase products and drive viability or uptake through varying mechanisms, alongside their dedicated TTO at University A.

In the larger entrepreneurship ecosystem of Cape Town, and through access to the general public, an open workshop was founded as one of the mechanisms within the region, known as Silicon Cape. This is to support entrepreneurial activities, as well as technology transfer through start-ups, irrespective of their background. The drive behind this is to provide businesses who have left the research environment with the opportunity to still produce economically viable projects, especially technology innovations, to the private sector, both locally and globally. This has supported over 2000 business start-ups and supports 3000 entrepreneurs, including access to over 20 other incubators internationally. Despite this being a public area, alumni and entrepreneurial programmes have extensive collaborations within this community, where graduate talent is used and channelled to start-ups that originate from University A.

The second university, University B, is situated in Gauteng. Innovation spaces at this university work together with its TTO across faculties, and include its library's makerspace, a high-tech business incubator and the University's business incubator. These are in place to ensure technology transfer through IP or business ventures.

The makerspace was the first of its kind in South Africa. The goal was to provide a creative laboratory where people with ideas could get together and collaborate with those with technical abilities to make ideas become a reality. The space is open to all students and staff, whether it is for research or technology development. It also provides students access to some of the latest and most current technology trends, such as

additive manufacturing, 3D scanning, electronics and 3D design software in an attempt to address 4IR technologies. The makerspace environment allows students the opportunity to ideate and establish products that are ideal for larger markets, enhancing the University's technology transfer successes. This provides the foundation for innovation through ideation. One such product involving technology transfer was the Kli-Pi project. Facilitated by the Department of Civil Engineering, this project aimed to develop a robust sensor to measure vibrations along train tracks. This product would address one of many functionalities that remain limited in South African railways. With the help of rapid prototyping technologies, and an open collaboration space, the student inventor was able to design a prototype using an Arduino microprocessor and sensor attachments. As time progressed, the prototype was enhanced to ensure that it could deliver on the proposed functionalities. It is being commercialised through the University's TTO.

The high-tech business incubator is a space within the University that provides specialised product and business development support to start-ups. Its focus is mainly on the commercialisation of technologies through the creation of spin-off companies, which is one of the mechanisms of technology transfer. The University's TTO works closely with this space to enable technology transfer where relevant. The business incubator then focuses on creating start-up spin-off companies to commercialise the technology and scale-up production where applicable.

The University's business incubator programme provides worthy applicants access to an array of start-up support services, which includes specialised mentorship and coaching, access to hot-desking, 3D prototyping facilities and business model development support. It has not yet disclosed any start-ups; however, it is directly funded by the Small Enterprises Development Agency and forms part of the larger entrepreneurial ecosystem through direct government funding. This channel exists to address the larger student population that has not yet developed research to a required TRL. Ideas and concepts are channelled to relevant innovation spaces based on their TRL. The business incubator also develops the soft skills required of entrepreneurs.

Strategically, University B notes the drive for new products and services for the public good and benefit to promote regional economic growth and job creation. This is further aligned to create the bridge between industry and academia, and to obtain funding for relevant opportunities. There is also active support of the venture labs and other campus endeavours to form new connected ventures.

Several events took place between 2015 and 2016, including patent sessions in the library to educate researchers on options to commercialise their research. Competitions were also held to this end, where six large-scale commercial projects were completed, while another six were in the process. One technology that was registered was a Rhinoceros Index System: a project that involves the microchipping of rhinos and the testing of their deoxyribonucleic acid (DNA) by the University's Veterinary Genetics Laboratory with the aim of establishing a DNA database of South African rhinos. This project was located on one of University B's campuses, but made use of several funding mechanisms across the University to achieve its desired outcome.

An innovation hub was developed in the area surrounding the capital city, which is associated with the CSIR. It ensures product development and research in the science environment with both institutions and the general public. To ensure access to the public, the Innovation Hub created an online platform that aims to create linkages and networks between regional, national and international innovators, industry, and public and private technology developers, commercialisation funding partners, and other relevant innovation players (Innovus 2019). A direct technology that stemmed from this was a biofiltration system that

offers a simplified clean water treatment system, with the researchers originating from University B. Overall, there are numerous mechanisms in this province that form part of the overall entrepreneurship ecosystem.

The third university, University C, is also situated in the Western Cape. It has a dedicated TTO alongside other innovation mechanisms. This institution is one of the leaders in technology transfer success in South Africa for 2018. Its innovation hub is responsible for technology transfer, entrepreneurial support and development, and innovation at the University. It manages the commercialisation of the University's innovation and IP portfolio through patenting, licensing and the formation of spin-off companies through its business incubator. University C has recently begun an in-house makerspace as well for research development support, and has a business incubator to enhance spin-offs and connect innovation directly to industry for both in-house stakeholders and the general public. Its Department of Mechanical and Industrial Engineering has launched a new technology centre that focuses on industrial relevance. The facility focuses on the identification, acquisition, mastering, multiplication and transfer of advanced technologies to industry through the training, demonstration and dissemination of acquired and accumulated knowledge via a specialised innovation area for skills development with access to the required resources.

To link all these disciplines together, University C has a technology centre that was established to ensure that industry is brought closer to a state-of-the-art technology base for manufacturing engineering research, while offering the centre as an attractive and reliable partner for collaborative projects. Interestingly, the business incubator has been a key focal point, since its inception has assisted various start-ups and spin-offs of local students and community members. It has varying levels of support and initiatives for skills development, as well as industry partnerships. It has raised about ZAR110 million since 2016. This demonstrates that it has achieved several successes with specific innovation spaces, which adds to the entrepreneurial development that is needed in South Africa.

Based on the above information, collaboration sessions were guided to identify what these universities do to achieve the various themes that were identified. This is presented in Table 3.

5 Discussion

Overall, the research aimed to provide insight into the importance of innovation spaces within the entrepreneurial ecosystem, how they support technology transfer and innovation, and the practices they engage into achieve this. From the above, it can be seen that the institutions that have successfully been driving technology transfer have common themes. They all note that entrepreneurship is vital for innovation, and that the identification and protection of IP, including patenting, is needed to raise funds for technology development and commercialisation. They have clear strategies for financial and non-financial support, with linkages to entrepreneurial development programmes, and have innovations spaces that facilitate research and innovation (HSRC 2019; DST 2019; Maree and McKenzie 2014; University of Pretoria 2015).

The importance of innovation spaces was revealed in the observations obtained in the research, as these spaces provide conducive environments for innovation to deliver commercially viable products (Carayannis et al. 2017; Taylor and Hartwig 2018). Based on the observations within South Africa, it can be seen that these spaces are no longer limited to more elite areas or academic institutions. This could be attributed to the larger policy drive

for entrepreneurial support. However, the transfer of skills and knowledge may be problematic for mid-range universities located in the more peripheral regions of the country, such as the Northern Cape, where there is not a wealth of research or strong commercial networks (Rasmussen et al. 2014).

It was shown that innovation spaces drive innovation directly by offering guidance on the following aspects: Firstly, these spaces focus on research to develop better products for technology transfer success. It was found that spaces that create viable ventures, especially in the early phases of the TRL lifecycle, ensure that there is an opportunity for recognition and development by providing the required resources. From here, development and networking come into play regarding the timing of when to provide and request further financial investment. In order to do so, networking is needed throughout the life cycle. Innovation spaces can provide access to this through challenges and events (Wright 2014). Research has been conducted to assist government to support venture capital in this regard, as well as to develop selection criteria for the most viable options. There has also been some debate surrounding this topic, especially due to resource scarcity and the associated return on investment (Takalo and Tanayama 2010). Fortunately, in the pursuit of developing entrepreneurship and technology transfer capacity, there is advocacy to create an objectifiable model that will ensure that growth potential is achieved. In this capacity, financial resource allocation in specific stages of the technological development life cycle have been promoted; one of which is local support mechanisms (Mosey et al. 2017).

Based on the above practices, innovation spaces offer the opportunity for technology innovation and refinement by providing an area for research, exposure to learn about technology integration and methods to refine and produce products of commercial value (Wyness et al. 2015). By hosting collaboration sessions, entrepreneurs can identify market needs and relevant distribution channels and build the required networks (Vohora et al. 2004). The ability to adapt and amend the product as needed will drive an improved trajectory of a potentially viable product (Schelfhout et al. 2016). The practices and guidance act as supportive mechanisms in the overall entrepreneurship ecosystem. Despite having access to innovation spaces with their ability to create refined products, with defined

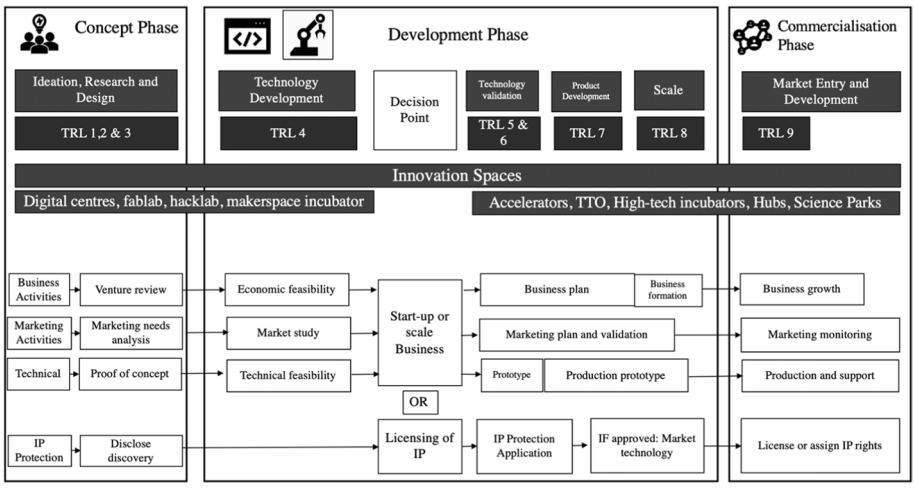

Fig. 3 Proposed overview of the role of innovation spaces in entrepreneurial support based on their TRL

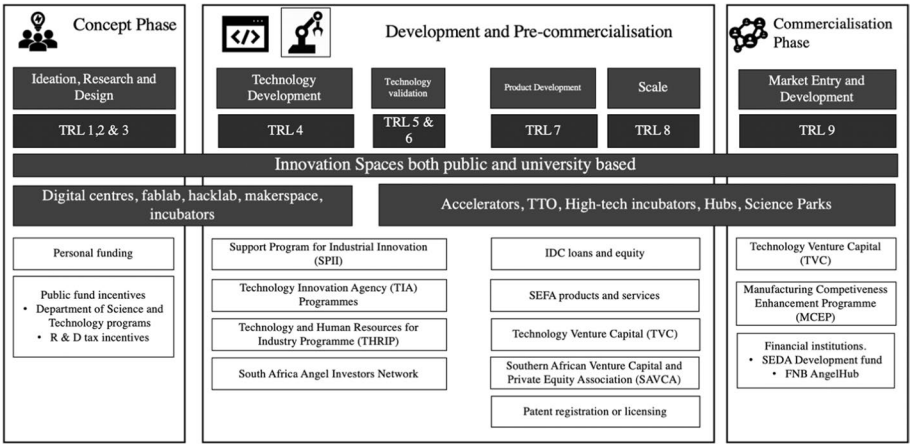

Fig. 4 Proposed overview of funding options that innovation spaces can use based on their TRL

markets and true value add, there remains a need to be in spatial proximity to financial resources as they affect investment behaviour, especially in terms of venture capital or spin-offs (Harrison and Leitch 2009). However, these practices do not stand in isolation. Since innovation spaces are supportive mechanisms within a larger ecosystem, an overview is proposed of the role of innovation spaces in entrepreneurial support based on their TRL (see Fig. 3). This aims to guide universities as actors as to which practices are required.

Table 4 Key findings and obstacles from the study

Key findings	Obstacles
The 4IR has brought about various technologies and opportunities for increased venture creation	Skills shortages hamper the ability of entrepreneurs to identify technology application potential and effectively develop prototypes towards viable ventures
Practical guidance is not readily accessible to entrepreneurial ventures, although they welcome timely interventions from both academics and support agencies	Inefficient processes within institutions negatively impact on internal collaboration and resource assignment
There are several commonalities regarding innovation practices across the region	Innovation spaces need to constantly adapt to changing needs, meaning that their staff require constant upskilling and a willingness to learn
Continuous communication with industrial partners and supporting organisations are crucial to guide supportive actions, as well as funding	Industry linkages and networking remain difficult to access
The TRL is a useful tool to guide the decisions, actions and requirements of ventures	Ideation in terms of R&D appears to be difficult to motivate when it comes to resource assignment, especially where the TRL is not always straightforward to determine
An awareness of relevant business ecosystems could help the commercialisation process and help make the available support networks more visible	Funding mechanisms in terms of grants and information regarding supportive mechanisms appeared to be low, since awareness beyond the innovation spaces was lower than expected

Fig. 5 Proposed conceptual framework

Funding forms a vital part of the ecosystem, where innovation spaces offer guidance and support in terms of funding. As such, an overview of funding options in South Africa is provided based on their TRL, which forms part of the ecosystem illustrated in Fig. 4.

With these outcomes, the key findings and obstacles observed in this study are noted in Table 4.

Despite these obstacles, there are numerous opportunities to examine the nexus between using different theoretical approaches to enable entrepreneurship (Mosey et al. 2017). One of these is the type of spaces that can be developed across faculties with relevant industry linkages to offer expertise and begin to transform research outputs into business ventures where possible (Gilsing et al. 2011). These need to overcome institutional barriers, where policies have often failed as they focused on funding only major innovative technologies, and not smaller incremental units (Rasmussen et al. 2011, 2014). The research has shown that practices conducted in these spaces is one of the mechanisms to support technology transfer, and if these innovation spaces are leveraged successfully, they can promote indigenous development through SMEs, improve commercialisation from research findings, ease avenues for patenting and offer alternative options such as spin-offs to ensure diversified offerings (especially with automation causing job losses). In order to do so effectively, a conceptual framework is proposed in Fig. 5, which ties together the literature, as well as the findings.

6 Conclusion

This paper aimed to provide insights into what innovation practices are conducted to support technology transfer, especially with the movement into 4IR, where technological advances have led to increasing opportunities for high-value outputs. Attention was paid to the South African environment as an emerging economy, and how universities act as key actors of the triple helix framework. Cases were reviewed to establish practices of innovation spaces based on established themes, where they have been adopted in institutions

that have experienced high-value outputs. To establish a theoretical framework, literature was reviewed on how the 4IR has created opportunities for entrepreneurs, the various forms of innovation spaces and the services they offer. It was seen that innovation has varying stages, where the role of a university is to support skills across all TRLs. Despite the limitations noted, there is a strong case for positive outcomes from innovation spaces, which implies that, for stakeholders, it is a mechanism to enhance leveraging 4IR technologies. The entrepreneurial ecosystem does not stand alone, and this study adds insight into how adding to these practices can enhance entrepreneurship towards commercially viable outcomes. In the innovation landscape, the commercial exploitation of inventions is one of the goals of practical research, and by stimulating TTOs alongside innovation spaces, universities have seen an enhanced identification of opportunities and the ability to seize them. In South Africa, the government has introduced various entrepreneurship policies and programmes. However, further coordinated activities and resources are required (Wonglimpiyarat 2014). To address this issue, further research can be conducted regarding policy to assist individual entrepreneurs in their drive to create, make and innovate. As a basis, an institutional theory approach could be used to expand the focus of entrepreneurship by using innovation spaces as a launchpad. For example, new theories could be built by considering reconceptualised aspects of entrepreneurship, such as student and alumni entrepreneurship engagement, hackathons or innovation challenges (Link et al. 2015; Rasmussen et al. 2014). Overall, it was observed that South Africa has made efforts towards a high-level response to opportunities and risks stemming from the 4IR. By adopting this conceptual model, universities have the opportunity to increase their 4IR outputs by assisting entrepreneurs' value creation activities focusing on 4IR.

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