A conceptual model of entrepreneurial competencies needed to utilise technologies of Industry 4.0

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Abstract
The Fourth Industrial Revolution, also known as Industry 4.0 (I4), has provided an unprecedented platform for innovation in various spheres. For entrepreneurs then, who are known to drive innovation and progress in various fields, I4 offers a wide scope of opportunities. The purpose of this paper is to provide a conceptual model of needed entrepreneurial competencies to effectively utilise novel technologies I4 has to offer. To develop the model, this exploratory study adopts an action research approach. Using predefined questions developed from previous literature, a representative sample was obtained from 17 in-depth interviews with entrepreneurs. From the data analyses, where machine learning technologies were used, it was found that to respond and navigate the layers of I4 technologies and enable new possibilities, entrepreneurs require certain competencies in this globally connected and technology-fuelled world. This paper advances entrepreneurial research as it provides a platform to guide and support their development, which has been a key focus area both internationally as well as in South Africa, to address one of the key Sustainable Development Goals, economic growth. Despite this contribution, further investigation is required on how to develop these competencies through supportive mechanisms and corresponding education relating to I4.
Keywords: economic growth, entrepreneurship, fourth industrial revolution, industry 4.0, innovation, skills development, sustainable development goals

Introduction

Automation, Big Data, digitisation, Internet of Things (IoT), networking and smart manufacturing have disrupted industries, impacted productivity, changed service delivery outputs and altered customer expectations (Gaub, 2016; Hermann et al., 2015; Lasi et al., 2014; Leitão et al., 2016). The main triggers behind this has been shorter product development periods, improved resource effectiveness, easier access to information and overall efficiency in areas not before possible due to technology (Vendrell-Herrero et al., 2014). It has been noted that this movement is due to the shift towards Industry 4.0 (I4), also known as the Fourth Industrial Revolution (Lasi et al., 2014). I4 itself is said to focus on the end-to-end digitisation of all physical assets and integration into digital ecosystems. This is to create products and services by effectively leveraging technology to achieve synergy (Carolis et al., 2017; Schwab, 2017). This synergy has been sustained through emerging technologies such as additive manufacturing (AM), augmented reality (AR), artificial intelligence (AI), autonomous robotics, Big Data analytics, cloud systems and the Internet of Things (IoT) which have the potential for integration within the value chain, irrespective of industries (Wang et al., 2016). At the core of this connectivity- which ensures a level of interconnectedness like never before- is cyber-physical systems (CPS) (Bagheri et al., 2015). The concept of I4 then is the fusion of technologies, allowing a bridge between the physical, digital, and biological spheres at an unprecedented pace, changing the very way people live and interact (Kruger and Steyn, 2019; Leitão et al., 2016; Schwab, 2017).

Due to the influence of the I4 phenomenon, there has been extensive expansion and interconnection across industries. The interconnection provides a link between customers, employees, systems and suppliers to accelerate business performance and create new opportunities through shared collaboration platforms (Cunningham et al., 2019). This is happening in real-time, across multiple geographic locations, where cloud systems are used as a common platform to store, manage and distribute data for informed decision making (Lasi et al., 2014). How then, does a country ensure it is taking advantage of what I4 has to offer (Ferreira et al., 2016)? This is where entrepreneurs are seen as a key instrument, as they are link innovation and opportunity seeking to ensure competitive advantage is gained (Mazzei, 2018; Vendrell-Herrero et al., 2014). With the technological improvements of I4, entrepreneurs have the potential to create entirely new ways of providing goods and services through technological innovation (Feki and Mnif, 2016; van der Westhuizen and Goyayi, 2019). However, this requires a certain level of comprehension to enhance products and services with digital capabilities (Ndemo and Weiss, 2017; Zivdar et al., 2017).

Therefore, this paper seeks to study entrepreneurial competencies required to leverage I4 technologies. To establish this, the paper is divided into 4 sections. The first section is a brief literature review. It starts by defining entrepreneurship and its importance, the need for innovation and entrepreneurship to leverage I4, the three main layers of I4, the business value potential of I4 and a South African context (Qin et al., 2016). In the following section, the methodology and qualitative data analysis is presented, followed by a review of the findings. Based on these findings the conceptual model is presented, with conclusions drawn and directions for future research presented.

Literature review

Entrepreneurship is considered to be a key objective, amongst nations, in terms of stimulating economic growth and creating job opportunities (Jones et al., 2018). Thus, it is of vital importance with regard to the development

of new business, innovation and opportunity seeking to achieve a competitive advantage (Feki and Mnif, 2016; Schmitz et al., 2017). One key activity behind this is effective technology and knowledge transfer (Jones et al., 2019; Kruger and Steyn, 2019). From this it can be noted that "*An entrepreneur is an innovator. More precisely, someone who constantly seeks the opportunity to introduce new products and new procedures, to invade new markets, and to create new organizational forms*" (Baumol 2002:57).

The most indispensable skill for entrepreneurs to drive economic growth and ensure sustainability, is said to be the capacity to adapt with change and to innovate (Devezas et al., 2017). This necessitates entrepreneurs, even those with lower skill sets, to understand and apply Information and Communications Technology (ICT) skills (Sandberg, 2018). They also need to have soft-skills, such as collaboration and communication to execute tasks in hybrid systems (Mamabolo et al., 2017). This implies that they will require continuous learning across multiple disciplines to adapt an entire business, enable effective coordination between components and innovate in rapidly changing environments (Hermann et al., 2015; Vendrell-Herrero et al., 2014).

Innovation, entrepreneurship and I4

Innovation is more than invention. It is the commercialisation of concepts, modification of ideas and implementation of existing products, systems and resources to stimulate positive outcomes (Kruger and Steyn, 2019; Smith, 2006). The majority of literature in entrepreneurship is devoted to the entrepreneur's ability to innovate (González-Cruz and Devece, 2018; Mazzei, 2018; Schmitz et al., 2017). South Africa (SA), as one of the developing markets, aims to improve the economy and create employment through entrepreneurship (Mamabolo et al., 2017). Innovation and entrepreneurship in this sense are noted to be of vital importance for economic development in the era of I4, which has become more prevalent with the increased opportunity to innovate (Ibarra et al., 2018). Lu (2017) implies that there needs to be an innovation process to address competition and survive the ever-changing economic environment. As innovation cycles become faster, a need for more enterprises emerges, calling entrepreneurs to seek business opportunities (Arafeh, 2016; Wilson and Martin, 2015). Within I4, entrepreneurs can look to two categories of innovation. The first is evolutionary innovations, which are continuous and incremental advances in technology or processes that attempts to improve efficiency. The second is revolutionary innovations, which are entirely new and disruptive changes in technology and processes which can lead to additional areas of revenue (Lu, 2017; Maree and McKenzie, 2014).

If competencies which drives entrepreneurs to bring about creation of new sectors can be endorsed, economic growth can be stimulated through new business development (Sandberg, 2018; van der Westhuizen and Goyayi, 2019). One such area which has seen such development is data science, where new types of companies such as cloud computing providers have been created (Schwab, 2017). Value propositions which arise includes 1) Novelty, 2) Efficiency, 3) Lock-in and 4) Complimentary (Guo et al., 2017). The drive behind this is to enhance the supply chain by reducing cycles and testing times whilst improving quality, flexibility and efficiency. These need to be incorporated within the value proposition. Entrepreneurs then need to define products or service enhancements whilst reviewing the business model to guarantee effective integration between activities. A key component of this will include the human capital aspect (Zivdar et al., 2017). With the advancement of I4, connected business models can be used to enhance competitive advantage and leverage innovation (Dijkman et al., 2015). The challenge that arises is how to connect devices to business value, maintain standards and ensure information security within this smart industry. By being able to optimise the value proposition and improve the revenue stream through smart technologies, entrepreneurs are increasingly able to build astounding new business models (Mazzei, 2018). This however, requires innovation and creativity as well as a defined identify (Jones et al., 2019; Smith, 2006). A key consideration in developing these skills and competencies is the mechanisms available to support the ideation and business side of innovative products. These include incubators, makerspaces, hackathons and relevant educational training (Edoho, 2015; Fisk, 2017; Kruger and Steyn, 2019).

Layers of I4 technologies

Entrepreneurship and innovation are certain aspects that can address the proliferation of technology which can be exploited for business development and competitive advantage across sectors to drive economic growth. To better understand several of these technologies and adapt business models accordingly and control new value creating opportunities across sections, they have been divided into three logical layers. It is noteworthy, that despite a technology being in a certain layer, it does not mean that they are separate and not interconnected (Wirtz et al., 2016).

The first layer of I4 technologies is the physical layer. The technologies within this layer are associated with hardware to detect changes in an object or environment to capture data. The hardware would include sensors to detect physical changes in temperature, light, pressure, sound or motion. It could also be used for detection of logical relationships of one object to another in terms of its location or activity. Finally, it can also act as the feedback mechanism or technology which carries out the physical task (Holler et al., 2014).

The second layer of I4 technologies is the connectivity layer, which connects smart things such as the IoT using various technical communication models and technologies such as 3G, 4G, Bluetooth, internet protocol (IP)

networks, WiFi, Radio-Frequency Identifiers (RFID) or Near-Field Communication (NFC). It is the platform used to enhance and connect devices for interactions between humans and technology (Sethi and Sarangi, 2017). There are management protocols and best practices behind these technologies ensuring cohesion between one another. These were established by the International Organisation for Standardisation (ISO) which defines the Open Systems Interconnection (OSI) Model. This model reviews the process of communication between technologies. In the architecture that has been designed, there are seven layers which govern communication on a strategic level, ensuring that the data travelling between endpoints over related functions achieves its destination to fulfil a relevant function. With I4 producing vast quantities of data, there has also been advancements in optimally managing data transfer based on these practices to reduce congestion and drive efficiency based on optimal performance configurations (Obiora, 2016; Yemini, 1993).

The final layer, which includes technologies such as AI, cloud systems and Big Data is the digital layer. The digital layer stores, analyses and processes the data that comes from the physical layer through the connectivity layer. This allows systems and technology to provide valuable information to automate decisions and changes to achieve efficiency (Sethi and Sarangi, 2017; Streetline, 2018).

How I4 delivers business value

With US$493 billion in digital revenue, US$421 billion in cost efficiencies and US$907 billion in digital investments estimated for 2016, there are areas of cost efficiencies and additional revenue where I4 technologies have already created business value-add (PwC, 2016; Sung, 2018). Table 1 provides insight into efficiencies and additional revenue I4 facilitates. It demonstrates the vast scope of revenue and business development areas available to entrepreneurs to take advantage of and innovate to stimulate economic growth (Feki and Mnif, 2016; Vendrell-Herrero et al., 2014). This does however require a certain skill set, which drives the need for further research.

Table 1 Value adding activities from I4 technologies

Cost efficiency areas	**Additional revenue areas**
Automation of processes for smarter use of human resources	Capture profitable business avenues through customer insights based on data analytics
Economies of scale from increased market share	Digitisation of products and services within existing value proposition
End-to-end planning based on real-time data with horizontal collaboration on cloud systems	Increase market share in new areas
Optimisation of activities with AR and data analytics	New digital products or services
Predictive maintenance and improved asset utilisation	Offering of I4 technologies such as cloud services or Big Data analytics
Real-time quality and business controls from Big Data	Personalised product offerings and mass customisation

Source: → (Feki and Mnif 2016; Lee, et al. 2015; PwC 2016a; Sung 2018).

South African context

The entrepreneurs interviewed were primarily based in SA, as the environment is striving to address various issues, including economic growth and employment. This is because the South African economy slipped into recession during the second quarter of 2018 as a result of a fall-off in activity in the agriculture, transport, trade, government and manufacturing industries (Statistics South Africa, 2019). This coupled with high unemployment among unskilled and the younger generation in particular, has brought about an immense challenge. The official unemployment rate fell from 27.7 percent in the third quarter of 2017 to 26.7 percent in the fourth quarter (National Treasury of South Africa, 2017). However, this decrease conceals a large exit in the labour force, with a staggering 21,000 people losing their jobs. Consequently, an additional 503,000 people were deemed economically inactive, with 102,000 categorized as discouraged job seekers. Although the unemployment rate among the age group 15 to 24 years has declined since the second quarter of 2017, more than half of South Africans in this age category participating in the labour market are without jobs (World Economic Forum, 2017). As such SA's long-term economic growth prospects are weak given the current policy mix and foreseeable external circumstances (Ndemo and Weiss, 2017).

At the core of this problem is education and skills (Dlodlo and Mafini, 2014; Fisk, 2017; van der Westhuizen and Goyayi, 2019). The economy continues to create opportunities for semi-skilled and skilled workers in an attempt to shed unskilled jobs (Arafeh, 2016). To address this and stimulate inclusive growth, technological innovation across a range of industries through business development is required for new jobs (Chen et al., 2014). This will be for skilled as well as semi-skilled workers (Beechler and Woodward, 2009; Sandberg, 2018). As SA builds its skills base, there is also a need to increase employment in sectors that have historically absorbed large numbers of less skilled workers, such as mining and agriculture. This can be developed with the increase in

efficiency and production levels with technology. It is key to note that "Policy certainty is required to support growth and employment in these sectors" (National Treasury of South Africa 2017:23; Ndemo and Weiss 2017). In SA, entrepreneurship has been identified as a key area to develop these particular economies (Martínez-Fierro et al., 2016).

Summary

One of the multiple challenges that arises from I4 is the process and corresponding competencies required to automate, coordinate and connect complex distributed systems with emerging technologies (Wilson and Martin, 2015). The benefit of which is to increase value adding activities to the economy (Vendrell-Herrero et al., 2014). In certain instances, predictive methods can be instituted with intelligent algorithms to drive infrastructure towards positive outcomes and achieve efficiencies noted in Table 1 above (Lee, Bagheri, et al., 2015). In addition to this, an ability to derive patterns from data at any time can ensure more precise predictions of system behaviour that provides autonomous control or artificially intelligent responses to reduce workloads. As seen from the improvements in production and service delivery, I4 focuses on the establishment of intelligent and communicative systems including machine-to-machine communication and human-machine interaction (Holler et al., 2014). From all this integration and interconnectedness, there is not only a need now, but will be in the future with a way to effectively manage data. This pertains to acquisition and assessment of data extracted from the intelligent and distributed systems interactions. One of the benefits of data acquisition and processing is the installation of self-control systems. These systems for example can enable taking precautions before systems operations suffer, or areas of improvement can be exploited (Waal et al., 2014). The aim behind this investigation, is to establish the entrepreneurial competencies and functional business areas (Zivdar et al., 2017) needed to enhance the adoption of I4. Thus, in this paper, a conceptual model is presented consisting of a multi-layered approach based on the literature and data gathered, which is the main contribution of this study.

Methodology

Sustainable Development Goals (SDGs) aim to address various global challenges, including the alleviation of poverty through economic growth. A household in SA is 21 percent more likely to move out of poverty if they are employed (WorldBank, 2017). If entrepreneurs can be developed with the required competencies in managing aspects of I4, they can address the growing need for increased job creation and business development to drive economic growth, as entrepreneurship has the potential to create new businesses and employment opportunities. As entrepreneurship can contribute to economic growth, it is important that they have the skills needed to be successful in business venturing (Mamabolo et al., 2017). Furthermore, with I4, business avenues that do not yet exist can be created, especially within a South African context, where there are various resources at the disposal of entrepreneurs. The research aims to demonstrate a conceptual model for the competencies needed and associated business functions to address this SDG, and help entrepreneurs identify mechanisms needed to become successful in adopting I4 with its associated opportunities (United Nations, 2017).

Qualitative data analysis

This study was based on the interpretivism philosophy to establish the cause-effect relationship between I4 and the required competencies of entrepreneurs. The inductive approach within this philosophy allowed review of I4 technologies, supported by qualitative data collection, where the researcher was part of the process in the support field of entrepreneurial development and ideation (Saunders et al., 2009). This exploratory study then aimed to gain valuable insights in the field of entrepreneurial competencies and associated technologies of I4. Based on this involvement, action research as a strategy was used. Action research emphasises the iterative nature of diagnosing, planning and taking action as data units can be coded (Brannick and Coghlan, 2007). It also argues that the findings of research results is of genuine concern to the researcher who is engaged in the field in question (Cassell and Johnson, 2006). In other words, the results should clearly inform others and allow relatable outputs. To create these outputs, axial coding was used to recognise relationships between categories and selective coding for the integration of categories to produce a model. In order to accurately transcribe the data and apply aspects of I4 in the process of the research, the GCP based machine learning platform was utilised. To transform the data from audio to text, Google Cloud Speech-to-Text was used, which enabled the researcher to convert audio to text by applying powerful neural network models with the use of an application programming interface (API). The API can recognize 120 languages and variants to support various audio inputs. The voice command-and-control tool was used to process recordings after the interviews were completed using Google's machine learning technology. The majority of the interviews were in English; however, Afrikaans was used in certain instances between participants. Each render specifies the confidence level of the output, which was approximately 91% according to the API. Each transcript was then word-processed and imported into computer aided qualitative data analysis software (CAQDAS) known as ATLAS.ti™ version 8 and Voyant Tools. Open codes were applied to each transcript using the ATLAS.ti™ package and inserted into Voyant Tools to identify linkages for theoretical development. As relationships between categories were recognised, they were rearranged into a hierarchical form,

with the emergence of subcategories. This allowed the identification of core categories, in order to relate the other categories to and develop the model. The recordings were then reviewed again to ensure accuracy of coded content. This interpretive process allowed for the formulation and identification of the level of understanding and skills needed for I4. Semi-structured interviews were used, following themes and allowing for organisational context to be followed. Participants were able to demonstrate their level of I4 understanding and competencies associated to derive business value from I4 technologies.

The non-probability, representative sampling approach was used for this study, to identify an appropriate sample size with suitable characteristics. This also ensured the sample was recent, included relevant cases and was precise to answer the required questions. The entire population could not be interviewed as it would be impractical and unfeasible. The data also needed to be collected quickly to address this rapidly encroaching field. From the approach the validity, understanding and insights could be gained from the data. The homogeneous nature of the sampling focused on a particular group, being entrepreneurs with assumed similar behaviours. This enabled the group to be studied in great depth and the required competencies to be established. Patton (2002) argues that although the sample size is small, it is in fact a strength to obtain the required data relevant to the specialised study. The benefit as well is any patterns that do emerge are likely to be of interest and value to represent key themes. With regards to the amount required, it is recommended that 12 in-depth interviews would suffice (Guest et al., 2006). Thus, to ensure accuracy and sufficient data was obtained, a total of 17 in depth interviews were conducted and recorded. Of the 17 interviews conducted, 14 were face to face, 3 were through electronic mediums, primarily Skype™. All participants in the study allowed the researcher to explore aspects and probe characteristics of skills and experiences to identify the required data. The study is cross-sectional relating to the third quarter of 2018 (Saunders et al., 2009). The assumptions within this study is that the results can differ between participants interviewed, based on their experiences, understanding and overall exposure to technology in SA. This is also true for levels of education, cultural background and overall access to opportunities and resources. For this reason, the transcribed data was sorted into logical areas and linked to categories, based on standard entrepreneurial behaviours described in literature, and the technological components of I4 which have the potential for value-adding activities as defined above. The choice of strategy ensured that participants provided true insights into what drives entrepreneurs, despite these differences, and how this can be used to innovate in I4 which is relevant to the researcher. These assumptions assisted in demonstrating what competencies are required to leverage this revolution and drive business outputs, even in a diverse climate such as SA.

For this study an entrepreneur is an individual or a group of individuals (team) responsible for the process of creating new value or new ventures through value creating activities. They are assumed to have certain behavioural attributes as defined in literature and have a level of drive and expertise in their respective field. All participants were interviewed individually and were unaware of who other participants were before, during and after the study.

Ethics

In pursuit of this information, all participants were informed and confirmed their consent. Areas of sensitivity were reduced to complete anonymity of participants. The nature of the investigation pertained to levels of competencies; however, the participants were not assessed in this regard, rather asked questions to provide their insights to determine what is required. The researcher in question noted qualifications obtained, institution being represented and presented ethical clearance obtained from the institution's ethics board, which was reviewed by peers in order to conduct the research. As such all procedures performed in this study were in accordance with the ethical standards of the institutional research committee and aligns with the 1964 Helsinki declaration. Based on this, participants allowed physical access to them and allowed cognitive access to obtain the required data. Data collected was recorded for review by the interviewer. Only the interviewer and supervisor have access to this, which is stored securely on an institutional cloud repository.

Data analysis

From the data obtained from the interviews, dimensions for competencies were identified using ATLAS.ti™ and Voyant Tools. The output of this is revised in Table 2, which reviews findings which have been placed into relevant dimensions. Within this analysis review, 4 major areas arise. The first of which is business skills, also known as business acumen. This would allow entrepreneurs to identify opportunities of I4 and use them for business development. The sub-dimensions that stemmed from this included the level of their experience, qualifications, educational background and ability to adapt to change. These dimensions supported by their strategy and customer focus would enable them to sense the environment and seize the relevant opportunity. The opportunities in question which I4 brings are reviewed in the technology layers, where cost optimisation or business value-adding activities can be strategically unpacked to ensure new value adding activities are achieved (Paek and Lee, 2017). These dimensions then describe the components of the findings and associated technological layers for better understanding. However, these dimensions and technologies require certain actions and linkages to be established to obtain valuable insights into aspects of I4, as well as institute corrective actions. For this reason, the linkages dimension is displayed.

Table 2 Data analysis overview

	Dimension	Sub-dimension	Findings
Business skills	Experience		Knowledge allows for sustainable business
			Perseverance
	Qualifications		Allows personal branding and access to market
	Adapt to change	Innovation	Allows updated business models
		Creativity	Facilitates ideation for new products and services
			Identify new business areas
			Integration areas both horizontal, vertical or end-to-end
	Strategy	Review business rescue viability	Know when to abandon failing or outdated area or methods
	Customer focus	Communication	Optimise internal business processes and relations
		Networking	Access distribution channels
			Outsource expertise, but on case by case basis
		Product design and MVP	Ensure business success and customer needs addressed
	Training	Multi-discipline approach	Needs to be business skills taught across industries
		Self-learning	Supported by MOOC
	Law and policies		To protect business, must remain relevant as well
Physical layer	Adaptive robotics	Cyber physical systems	Usages of sensors and data to enable AI
	Additive manufacturing	3D Printing	Produce customised solutions
		CAD Software	Design and simulate
	Automation	Data collection	Automate tasks where possible for better human resources
	IoT	Hardware	GPS, Mobile devices, heart rate monitors, RFID, RTLS
		Software	SAP and Oracle systems
Connectivity layer	AR and VR	Headsets and mobile devices	Training mechanism
	Human robot interactions		SA has trust issues with technology, limited user knowledge
	Internet access	Communications and networking	Expensive and requires development
Digital layer	AI and Cloud	Real-time data collection, storage and analytics	Storage mechanism and easy access
		Usage of data to enable decision models	AI for chat bots
	Big Data driven decisions	Product and service enhancement	Newness
			Customisation
			Flexibility
			Economies of scale
		Customer relations	Personal assistance
			Self-service
			Automated service offerings
			Targeted focused marketing
		Costing efficiencies	Research and development
			IT and infrastructure
			Personnel costs
			Logistics and procurement
		Integrated business processes	Agility
	Cyber security		Several examples of breaches
Linkages	Determine ROI of data driven services		Invest wisely in technology
	Data analytics	Access is key	Social media platforms
		Customer focus	Mining for data or purchase of databases
	Innovate towards smart products and services	Smart costing	Adapt business models
	Drive smart production and operations	Production, logistics and procurement	Drive strategic partnerships
		Research and development	Innovation and ideation key
		Smart marketing and sales	Connect to the right people
	Leadership	Drive agile and willing workforce	Job roles are changing
	Mechanisms to facilitate	Incubators or Makerspaces	Need follow through for business sustainability
	Access to specialist expertise or consultants		This includes implementation and involvement of IT experts and developers

Findings and model

From the data analysis and literature, I4 is a complex concept, where technology and business unite. It disrupts several industries with the capacity to change the way business is conducted and the business itself. It is vast and rapid; and due to its expanse, has a large impact with a potential for great opportunity, or failure (Ganzarain et al., 2016). Entrepreneurs need to be able to respond accordingly and navigate these integrated technologies, since man and machine are aligning to enable new possibilities (Sandberg, 2018). Thus, entrepreneurs require a holistic view of I4 to harness the potential of digital technologies by leveraging data in this globally connected and technology-fuelled world. This can be achieved through competencies which empower them to develop new business models, integrate value-chain components, optimise business processes whilst inspiring an agile workforce (Dijkman et al., 2015; Schmitz et al., 2017). From these findings, a conceptual model is proposed which reviews competencies and associated business functionalities to enable entrepreneurs to address these changes.

Conceptual model

The design principles behind the proposed model were based on key advantages of existing models found in current literature. This included critical success factors and characteristics of other models to ensure there was a continuous and discrete approach, that will allow for it to be expanded into a potential maturity model. It also ensured that it has the ability to be tailored, is simple to understand and the concepts proposed are presented in a logical fashion (Nikkhou et al., 2016). This meant that the content used also needed to be based on existing literature that was created on solid research principles. As such, entrepreneurship and I4 research was used and then tied together with findings from the data analysis to deliver a coherent set of outputs. By approaching the model design with critical success factors and requirements grounded on this design principle, the proposed conceptual model has distinguishing characteristics when compared to other models, whilst being based on sound theoretical principles. The aim behind this design is to showcase this studies information and highlight forces that shape the emergence and subsequent evolution of dynamic capabilities and relating dimensions required of entrepreneurs to address I4 (Zahra et al., 2006). The model integrates prior findings on the various activities associated with the evolution of I4 alongside business functions to provide some clarity on these requirements. When designing it, the core competencies were defined first. To make this relevant and not just basic information (Wilson and Martin, 2015). The selection criteria were based on the corresponding business functions which were considered from the data analysis. These functions considered aspects such as the value chain, smart factories, strategy, smart operations, smart products, data-driven decisions as well as the human capital aspect that need to be addressed within I4. These core functions were selected as they can be used to enhance value creating business ventures, or can be incorporated to optimise efficiencies, demonstrating the utilities of I4 technologies (Ganzarain et al., 2016). Entrepreneurs then would need to allocate resources to comprehend smart technologies and processes which impact current systems and where value opportunities can be leveraged. This implies that an understanding of the physical, connectivity and digital layer will enhance entrepreneurs aptitude for this rapid and inevitable change (Schumacher et al., 2016).

The conceptual model, based on these principles, with a specific purpose in mind, is presented in Fig.1. It aims to assist entrepreneurial development by showing what competencies are required to successfully adopt aspects of I4, with corresponding dimensions of expertise and understanding. As can be seen, there are 7 core competencies which have been identified. From this, 59 corresponding business functions were recognised. These have stemmed from literature as well as the data analysis of the entrepreneurial sample within SA. The model basis its validity on previous research, empirical data analysis and is formulated on the assumptions made for the scope of this paper. This model can form the foundation for a readiness toolkit for I4 (Lichtblau et al., 2015).

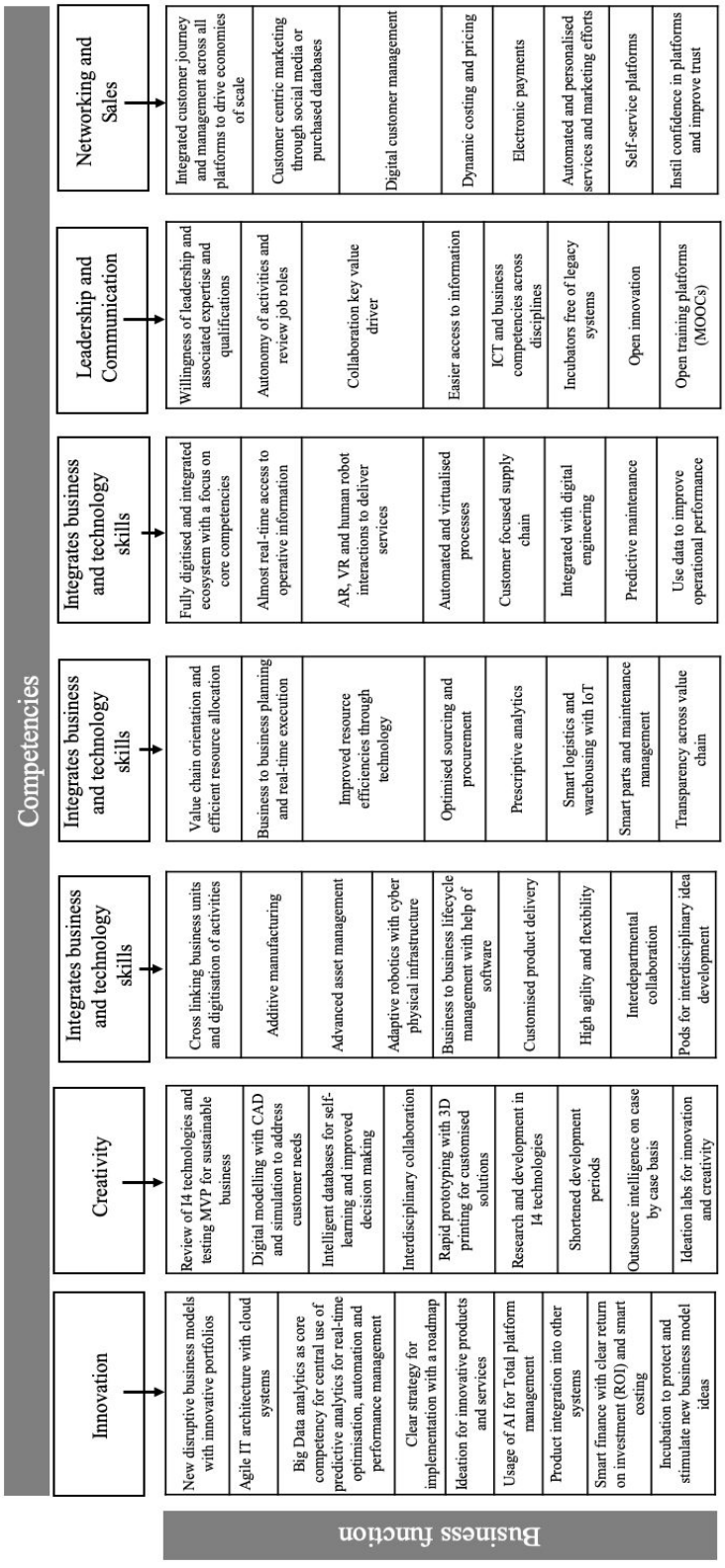

Fig. 1 Proposed model of entrepreneurial competencies for I4

Implications

From the data analysis and model, the results show that there is a wide scope of I4 that can be leveraged. This can be used to ensure further mechanisms are invested in, including the higher education institutions (HEI) and incubators, where a selection platform tool could be developed (Adams et al., 2018; Kruger and Steyn, 2019; Peris-Ortiz et al., 2017; PwC, 2016a). The main motivation as seen from I4 is the connection and integration with

systems which provide a platform for efficiency, adaptability, coordination and effectiveness. In order to achieve this from an entrepreneurial perspective, cyber systems and communication need to be leveraged with an ability to make better business decisions to derive efficiencies supported by data. Although the data can be managed, it was noted there was a need of experts to translate this data into valuable info. One participant hired an information specialist in this regard to make sense of data and identify value adding areas. Ultimately, technology is an enabler of the human mind, and the focus on the customer journey should not be overlooked. A further implication is the requirement for laws, policies and protection of IP to be updated (IDC, 2017; WorldBank, 2017).

Conclusion

With interconnectedness, synergy and coordination between the physical and digital sphere, I4 surmises that we are on the brink of a change that will ultimately alter the fundamentals of how we live through technology. This will occur through the adoption of technology in almost every aspect of human life (Schwab, 2017). The difference between this and other industry revolutions, is the pace at which this will occur, and the interconnected impact this will have on systems (Vendrell-Herrero et al., 2014). By impacting the way people work, live and relate to one another, entrepreneurs will have an opportunity to automate and innovate new business ventures (Paek and Lee, 2017), but will also be threatened by these technological disruptions if they are not skilled in managing them (Bodrow, 2017). This change then, albeit daunting, has provided an unprecedented platform for innovation in various spheres. This study investigated the importance of entrepreneurship as it is at the basis of innovation and opportunity seeking to build an economy (Schmitz et al., 2017). In developing countries such as SA, entrepreneurship should be promoted at all levels of the formal system to ensure access to needed information, skills and knowledge (Sandberg, 2018). Thus, this paper contributes to the broader knowledge by providing insights into which entrepreneurial competencies and associated business functions need to be developed to adopt aspects of I4.

Limitations and future research

There are limitations to this study. Certain industries were not included such as agriculture, forestry and fishing, mining and quarrying, electricity, gas and water as well as construction. It only considers a South African perspective, and participants viewpoints can differ as the environment changes. Furthermore, not all technologies pertaining to I4 were included in this study. Despite these limitations the model offers a novel starting point to investigate the needed supportive mechanisms to cultivate entrepreneur's competence to leverage on business opportunities in this paradigm shift. This could include education 4.0 and the development of a maturity model on how strategic work planning, changes to organisational structures, job roles, and sharing technologies can be leveraged to advance society and push economic growth. Furthermore, an implementation tool and roadmap require further research. A soft-computing model can be used as the platform for this to link entrepreneurial competencies and relate certain behaviours. This method can address the multi-disciplinary facet I4 has, through several computing fields such as fuzzy logic, neural networks and generic algorithms. Based on this inference can be made to solve problems of relatability and assist in building an overall model applicable to not only SA, but various other countries. The benefit of which is to drive economic growth across industries to achieve SDGs.

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