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NEMISA SUMMIT AND COLLOQUIUM 2022

The Future of Work and Digital Skills

Radisson Blue Hotel, Granger Road, Waterfront, Cape Town

Cape Peninsula University of Technology

Centre for Communication Studies
in the Faculty of Informatics and Design

NEMISA Summit and Colloquium 2022

The Future of Work and Digital Skills

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Preface

The NEMISA Summit and Colloquium 2022, and the associated Postgraduate Symposium, was held on 15-17 March 2022 at the Radisson Blu Hotel, Granger Bay, Cape Town. It was hosted by the Cape Peninsula University of Technology (CPUT) in collaboration with the Knowledge for Innovation unit (K4I) at the University of South Africa (UNISA) and the National Electronic Media Institute of South Africa (NEMISA).

A total of 697 delegates (102 physically, 217 virtually using Zoom and 378 streaming on Facebook) attended the three collocated events (Summit, Colloquium and Postgraduate), bringing together thought leaders and experts from the international community, government, industry and academia to address the future of work and digital skills in South Africa. The virtual delegates joined from 3 continents and 13 countries (excluding South Africa): Belgium, Côte d'Ivoire, Eswatini, Ethiopia, Germany, Ghana, Kenya, Malawi, Namibia, Spain, Switzerland, United States and Zimbabwe. 11 of the 26 universities in South Africa participated.

The theme for the events was "*The Future of Work and Digital Skills*". The 4IR caused a hollowing out of middle-income jobs (Frey & Osborne, 2017) but COVID-19 exposed the digital gap as survival depended mainly on digital infrastructure and connectivity. Almost overnight, organizations that had not invested in a digital strategy suddenly realized the need for such a strategy and the associated digital skills. The effects have been profound for those who struggled to adapt, while those who stepped up have reaped quite the reward.

Therefore, there are no longer certainties about what the world will look like in a few years from now. However, there are certain ways to anticipate the changes that are occurring and plan on how to continually adapt to an increasingly changing world. Certain jobs will soon be lost and will not come back; other new jobs will however be created. Using data science and other predictive sciences, it is possible to anticipate, to the extent possible, the rate at which certain jobs will be replaced and new jobs created in different industries.

Accordingly, the collocated events sought to bring together government, international organizations, academia, industry, organized labour and civil society to deliberate on how these changes are occurring in South Africa, how fast they are occurring and what needs to change in order to prepare society for the changes.

The Honourable Deputy Minister of the Department of Communications and Digital Technologies (DCDT), Mr Philly Mapulane, delivered the opening keynote where he lamented on the worrying employment rates, especially among the youth. He noted the importance of digital skills to advance South Africa in the digital economy and identified how the changes that digital technologies are causing at the social and economic levels have had a ripple effect on other sectors such as health and education. The Deputy Minister also announced the partnership between the ministry and the ITU, ILO, and UNDP to develop digital skills for decent jobs for youth and people not in employment, education, or training (NEET).

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The host and Vice-Chancellor of the Cape Peninsula University of Technology (CPUT), Prof Chris Nhlapo, welcomed everyone to the Smart CPUT 3.0. This 2030 vision aims for smart people in a smart community – *umunye* – oneness – where individuals embrace community amid times of volatility, uncertainty, complexity and ambiguity. He prided in CPUT's recent satellite constellation launched at SpaceX in California, whose data is being harvested at the their Belville ground station.

The representative of the British High Commissioner, Mr Anthony Phillipson, delivered a message of support for the events. He described the need for concerted efforts to ensure that the digital economy's growth in South Africa also needs to be inclusive of women, youth, and underserved communities and meet the growing demands of employment. He indicated that the work of the UK government in South Africa has grown with a focus on six areas in the digital economy: promoting digital literacy and skills, developing community networks and locally relevant content, enhancing policy and regulation to support the growth of the digital ecosystem, strengthening cybersecurity and resilience, innovating scalable solutions to improve business connectivity, and training and business development for SMEs and entrepreneurs.

Prof Chris Adendorff, the celebrated futurist, Presidential 4IR Commissioner and Board Member of NEMISA, gave the keynote highlighting predicted future changes that have happened faster than expected. He also offered what the futuristic models predict for the near future and the impact of new technological innovations on life and existing social and business models. Some of these include the end of what we understand as education and offices; these are predicted to be robot-human influenced. The digital skills needed to adapt to such a world depend more on dynamic judgement and decision making and the fluency of ideas.

Full Research Papers

The Colloquium accepted eight full research papers for their theoretical and practical contribution towards advancing digital skills and impact of technological innovations on future of work.

Billy Kalema's paper, *Developing Countries' Continuance Usage of E-Services after Covid-19 in the 4IR era* identified factors that influence the continuance usage of e-services in a post-Covid-19 context. Data from SARS e-filing users found that exerted pressure and the perceived usefulness of the system are the main contributors to the continuance usage of e-services. The model informed by the Expectation Confirmation Theory and the Self-Determination theories is a useful guide for the continuance usage of e-services post-COVID.

Priscilla Maliwichi and Wallace Chigona investigated how maternal clients use infomediaries to access maternal mHealth interventions. In their study *Factors Affecting the use of Infomediaries in MHealth Interventions: Case of Maternal Healthcare in Rural Malawi*, they found that users of an MHealth intervention project in the Chipatala Cha Pa Foni project in Malawi, that do not own

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mobile phones, rather use mHealth infomediaries to access maternal health services. They developed a theoretical framework of m-Health infomediary use. Their key results reveal important factors that influence maternal clients use of mHealth infomediaries; the characteristics of the maternal client, characteristics of the mHealth infomediary, the perceived value of the mHealth intervention and socio-environmental factors. The study further shows the extent to which many people still lack access to technology yet satisfice through infomediaries.

Colin Chibaya's review article sought to establish the actions of robotic devices in swarms which contribute to emergent behaviour at swarm level with the hope of prescribing the component knowledge domains of generic SIOs. *Swarm Control Mechanisms for Modelling Generic Swarm Intelligence Ontologies* offers categorization of robotic devices which forms the basis for the design of generic SIO knowledge domains. These generic SIOs will likely capture the different knowledge spaces towards expanding the scope of application of swarm intelligence systems. Colin highlights that the properties and quantifiers of emergency connoted in each case are also important components of generic SIOs that inspire the choices and features of the SIO parameters.

In an increasingly unpredictable post-Covid19 world there are various shifts in the political, economic, social and technical environments that are reshaping work, how work will be done, and employment opportunities. In their paper Naomi Isabirye, Hossana Twinomurinzi and Trevor Rammitlwa, offer a model and instrument that may help measure job susceptibility as a result of the Future of Work in any sector. The study: *Operationalizing the Future Of Work to Measure Job Susceptibility* is based on the abductive methodology and made use of a critical literature review supported by an extant bibliometric review of the Future of Work. The model and instrument which operationalise the concept of the Future of Work also provide an overview of the risks and opportunities available for skills development. The paper highlights that while the primary trigger for the Future of Work is innovative technological advancement, practitioners and researchers should not ignore the equally important and complementary political, social and economic forces that accompany any industrial revolution.

Through a systematic literature review, Ntombiyokusa Nyoni, Patrick Ndayizigamiye and Stella Bvuma explored the current challenges and motivations for adopting digital work, the technology acceptance models that scholars have relied on to research the notion of digital work as well as the benefits of adopting digital work. The paper: *Systematic Mapping Of Studies On The Adoption Of Digital Work In Developing Countries* highlights that digital work has the potential to contribute to developing country economies. The results of the systematic mapping which included 31 primary studies, outlined a number of challenges with digital work including: lack of resources due to high data costs and lack of devices used to conduct digital work, lack of infrastructure and negative perceptions of digital work. Some of the drivers behind digital work are: need for income, social value and an entrepreneurial spirit within digital workers. The paper calls for theoretical frameworks that may inform the adoption of digital work to benefit digital workers and private companies within developing countries.

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Towards the Conceptual Digital Skills Framework in the South African Public and Private Sector by Elias Tabane proposed a conceptual framework for digital skills for the South African private and public sector. The study analysed extant literature to understand the definitions and concepts of digital skills required by the modern workforce. He highlights the type and category of current and future digital skills required by the South African government and private sector workforce to fully harness the opportunities offered by the digital era.

Nosipho Mavuso and Olutoyin Olaitan adopted a structured literature review method to compare the current school curriculum, vis-a –vis the literature on what the 4IR economy requires of its workforce. The paper: *Skilling and Reskilling Students for Relevance in a 4IR Economy*, indicates that the current curriculum for Science, Technology, Engineering and Mathematics (STEM) courses at most South African universities do not align with skills requirements for a 4IR economy. This disjuncture leads to a state of unpreparedness of students in handling the fast-approaching revolution in skills demand. The study proposes four critical success factors that government can adopt to formulate strategic and sustainable plans to ensure that students are appropriately skilled and positioned to operate in a competitive 4IR economy once they enter the workforce. These critical success factors include: a curriculum revisit, funding, equipment and support of vocational education and training, global collaborations to support student skilling and reskilling as well as educational safe spaces for the development of soft skills.

In the paper entitled: *Creativity in the 4IR Curricula with Artificially Intelligent Technologies*, Norwell Zhakata, proposed a framework for reconceptualising creativity in the 4IR skills development era dominated by artificially intelligent devices. The framework is informed by a literature review which focused on the concept of creativity and furthermore relied on the Actor Network Theory to design the framework which may support understanding of creativity in the 4IR skills development context. The paper highlights that creative learning in the 4IR should be driven by thought processes, human beings' inherent crafting capabilities and the computing power of artificial intelligence. It is recommended that skills development and consequently learning programme design in the 4IR should occur in a framework that appreciates the fact that creative abilities have moved past capabilities confined to mental acts but should include both human beings' manipulative abilities as well as the computing power of artificially intelligent systems.

Short Papers and Abstracts

Olayemi S Falope and Colin Thakur shared on *Data Analytics for South Africa's Sexual Crime Landscape* to motivate the need to address sexual crimes through predicting sexual crimes trends using data analytics algorithms. The goal is to help the police and law enforcement agencies prevent or reduce violence against women and children, specifically sexual crimes, in South Africa. The study provides a motivation and proposal for law enforcement, police, and the

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government of South Africa to use a data analytics tool capable of predicting sexual crimes in South Africa to prevent or reduce violence against women and children in South Africa.

Ilse Kariem in her paper *Digital skills development for digitally maturing South African Higher Education Institutions* investigated the challenges faced by Higher Education campuses in South Africa as they transition from traditional campuses to digital campuses using “smart technologies”, the digital skills required on the journey, and to identify the different stakeholder groups/individuals who will be able to solve these smart campus related challenges. Based on the findings of the study, Ilse suggests that the creation of a digital skills development framework can be beneficial to university management and user-groups to address the lack of basic digital skills by delineating the digital skills shortages and by identifying key stakeholders in the community in order to solve campus related challenges effectively.

Postgraduate Symposium

There were seven PhD posters at the postgraduate symposium from four Universities.

Emil van der Poll (University of South Africa) in his poster *Social Exclusion in AI-Infused Gamification,* discussed how action research was deployed to identify and draw attention to the potential drawbacks of AI-infused gamification in education.

Emmanuel Udekwe, Chux Gervase Iwu, Andre Charles de la Harpe, Justine Olawande Daramola (Cape Peninsula University of Technology) presented on the *Effective Utilisation of Human Resource Information Systems in the South African Health Sector*. Their key findings on the impact of Human Resource Information Systems (HRIS) assist healthcare organisations to achieve a competitive advantage.

Lucas Gumbi (University of Johannesburg) presented an *SMME Readiness Framework for Smart Manufacturing Adoption in South Africa*. He described the development of the framework and how it supports the digital transformation of the South African manufacturing sector, the national efforts in the re-industrialization of the manufacturing sector and the development of South Africa specific SMME smart manufacturing national policies and strategies.

Khensani Xivuri (University of Johannesburg) in her poster *Towards AI algorithmic fairness* discussed a Habermasian approach that can be applied as a process framework to reduce bias in Al algorithms.

Bongisizwe E Buthelezi, Patrick Ndayizigamiye, Hossana Twinomurinzi and Shopee Dube (University of Johannesburg) presented *A blockchain solution to drugs counterfeiting in the South African pharmaceutical supply chain*. The goal of the study is to develop a blockchain solution to address drugs counterfeiting within the South African pharmaceutical supply chain.

Nkosikhona Msweli (University of Johannesburg) illustrated the importance of *Democratizing Data Science Education for the Non-Sciences.* She is investigating how micro-credentials may support data science education for non-sciences to close the skills gap that currently exist.

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Sarel Havenga, Izak van Zyl and Daniela Gachago (Cape Peninsula University of Technology) are going *Beyond Touch: An Educational Design Intervention to Investigate the Affordances of Embedded Tactile And Sensory Technology*. This study aims to co-design an intervention for Embedded Tactile Sensory Technology (ETaST) from within an UoT, across different disciplines to better prepare learners for 4IR. The study also aims to investigate to what extent can HEI curricula and pedagogical practices respond to the implementation of ETaSTs.

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RESEARCH PAPERS

DEVELOPING COUNTRIES' CONTINUANCE USAGE OF E-SERVICES AFTER COVID-19 IN THE 4IR ERA

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ABSTRACT:

Aim/Purpose	This study sought to develop a model for the unprecedented and unforeseen growth continuance usage of e-services after the Covid-19 pandemic coupled with the exponential growth of 4IR.
Background	New trends in technology have advanced products and services that increase the efficiency of work within organizations. These advancements have seen governments and businesses leveraging e-services for their day to day operations. Additionally, the Corona virus (Covid-19) pandemic highlighted the need for many enterprises to digitize their services leading to a good number of the world's population moving into the online realm to minimize the virus spread. However the use of e-services has been slow in many developing countries as compared to the developed nations hence it is not clear whether this e-services usage will continue after the Covid-19 pandemic.
Methodology	Data for the study was collected from the South African revenue services (SARs) customers that use e-filling and was analyzed quantitatively. The model was validated by the use of confirmatory factor analysis and structural equation modelling.
Contribution	This study contributes theoretically to the literature of continuance usage of technology, e-services and in the explanation of the shift from simple digitization to innovative use of combined technologies that are changing the way organization do their businesses
Findings	Results indicated that perceived usefulness and exerted pressure are good antecedents of continuance usage of e-services.
Recommendations for Practitioners	The 4IR path indicates that the future will have to embrace telecommuting that will require upskilling. Governments and businesses should therefore consider extending benefits and protections to independent workers and to all other employees needing to develop their skills and knowledge mid-career.
Recommendations for Researchers	Future research should include the analysis of moderating factors suggested by this study as such will assist in equipping skills and expertise to citizens needed for effective usage.
Impact on Society	E-services usage is the future of businesses as 4IR find its center stage worldwide. Its continuance usage is paramount for the future businesses and service delivery.
Future Research	Future research should consider the triangulation of methods to have a more understanding of users perception towards mandatory usage of e-services.
Keywords	Fourth industrial revolution, E-services usage, digital transformation, technology use during Covid-19 era, continuance usage of technology

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INTRODUCTION

The fourth industrial revolution (4IR) caused disruptions in almost every industry in both developed and developing countries. The breadth and depth of 4IR changes foreshadowed the transformation of production, management, and governance of all activities Worldwide. The advent of the Fourth Industrial Revolution (4IR) has changed people's daily lives and has reshaped the way government and non-government sectors do business be in education, healthcare or commerce. This increasing leverage on information technology (IT) has given birth to the use of electronic services (e-services) that has exponentially expanded the provision of services and products. The increasing convergence of e-service platforms has enabled citizens to remain in contact with governments and other business entities regardless of geographical location and beyond time limits. This increasing use of e-services was heightened by the wide spread of Covid-19 pandemic that saw many organizations closing abruptly and remained to provide products and services virtually (Vargo et al., 2021). Electronic services became the centre of every organizations as each entity tried its best to reduce face to face contacts and increase social distancing. Citizens on the other hand, remained with no choice apart from joining the virtual environment.

Electronic service (e-service) can broadly be defined as services provided via the internet with the most dominant application areas being e-business and e-government (Kvasnicova et al., 2016). According to Taherdoost et al. (2015), e-services embrace e-commerce transaction services such as online buying and selling of products and services, application hosting by service providers as well as processing capabilities done on the Web. They further indicated that, e-services may also be looked at from its characteristics that include but not limited to process nature, self-service, homogeneity, intangibility, inseparability, inter action, non-ownership, and non-rival. Both government and businesses worldwide have been developing smarter online services for citizens so as to improve service delivery by providing just on-time solutions through online transactions. Much as this has been so, the use of e-service optimally in many developing countries especially those in Africa has hardly reached the stage of integration (Bakunzibake et al., 2019). This has been a centre of research for many years calling for an attention to balance social and technical factors in developing countries to improve e-service usage.

The fall of 2019, saw the advent of the Covid-19 pandemic crisis that led to many businesses to come to a standstill. However, for the sake of business continuity and service delivery organizations revisited their digitization strategies and intensified the campaign of using e-services (Vargo et al., 2021). This intensified use of e-services saw governments and businesses including those in developing countries where the use of e-services has been low to start building online portals and mobile apps, using social media and relying on instant messaging. In South Africa for example, government departments, parastatals and higher institutions of learning closed most of their branches and depended mainly on electronic means to register new businesses, file tax returns and court applications, renewing driving licenses and in offering classes to learners using blended learning (Al-Samarrai et al., 2020; Sirimanne, 2021).

Since the Covid-19 pandemic was abrupt and the use of e-services in many organizations was mandatory for survival, this leaves a big question of the sustainability of continuance usage of e-services after the Covid-19 era even in the awake of the 4IR. According to Venkatesh et al. (2003); Kalema et al. (2014) in mandatory usage users may use technology as there might not be another option but such usage may fade away as the crisis decreases. They argue that some factors like exerted pressure due to customers' demands, competitiveness and economic survival may influence usage at the peak of the crisis like in the case of Covid-19 but such cease to be significant with time and might negatively impact on continuance usage. Nevertheless, with the increasing digital transformation and 4IR, mandatory usage could later change into voluntary use, if the benefits of the technology become clear and other factors like competitive advantages become salient (Mkansi & Landman, 2021). Though Azizi et al. (2020) argue that jumping into the technology implementation and use bandwagon may hinder the transformation of technology from mandatory to voluntary

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usage. Hence this calls for adequate address of all factors needed to inform continuance usage in order to sustain e-services continuance usage after Covid-19 pandemic.

This study therefore sought to develop a model for continuance usage of e-services after the Covid-19 pandemic era. The study used the South African Revenue Services e-filing system as a case for data collection to evaluate the model for continuance usage of e-services. According to the South African Government News Agency (2020), when Covid-19 pandemic struck South Africa, the South African Revenue Service (SARS) closed most of its branches and urged taxpayers to remain compliant by making use of its online services. In the effort to support social distancing measures, the tax collecting body redesigned its website to include the online appointment system that enabled taxpayers and practitioners to make appointments so that the tax body could solve their problems either through telephone or video interaction or go to office for issues that required face –to-face interaction.

THEORETICAL PERSPECTIVES OF E-SERVICES CONTINUANCE USAGE

The implementation of e-government service-oriented initiatives is a continuous process that requires change of activities, way of doing things and human behaviour. More so, this also requires the organization in which the technological innovation is implemented to go through an institutional transformation process that leads to total organizational change. Bakunzibake et al. (2019) allude that, the organization that goes through this transformation is seen as a socio-technical system and such is comprised of two sub-systems namely social and technical subsystem. They indicate that the technical sub-system relates to the tasks, processes, and the technology needed to transform inputs to outputs whereas the social sub-system deals with the individuals' characteristics, perceptions, relationships and anxiety that leads them to use the implemented technology. As Kwon and Zmud (1987) noted, understanding these socio-technical systems has been the core of research of technology acceptance, adoption and use that led to the many fragmented models trying to explain influencing factors of these aspects.

Researchers such as Venkatesh et al. (2003); Kalema et al. (2014) and Tarhini et al. (2015) who carried out comprehensive critical review of factors influencing acceptance and use of technological innovations concur that many factors of use ceases to be significant for continuance usage. These arguments are in support of previous researchers such as Oliver (1980); Bhattacherjee (2001) who alluded that customer's post-participation behaviour leading to satisfaction or dissatisfaction after a technological innovation adoption and use, are paramount for continuance usage. Additionally, Bhattacherjee (2001); Rahi and Ghani (2019) indicate that post-participation affections are as a result of cognitive appraisal of disconfirmations of need expectations and is essential for customers' decisions of whether to continue or discontinue using a technological innovation.

According to Rahi and Ghani (2019), continuance use of technology is more to do with post-acceptance and post-consumption expectation factors as explained in the Expectation Confirmation Theory (ECT) Bhattacherjee (2001) and in the Self-Determination Theory (SDT) Ryan and Deci (2000). Both theories ECT and SDT indicate that for individual to continue performing given tasks, they need to have had their behaviour reinforced with rewards, satisfied or enjoyed the act of doing. This also implies that change in ex-post expectations is highly influenced by perceived usefulness rather than perceived performance unless perceived performance resulted in satisfaction and confirmation. Additionally, Rahi and Ghani (2019) further indicate that, playfulness and word of mouth are other good antecedents of intention to reuse or continue to use a technological innovation. These factors can be boosted by other external factors such as exerted pressure, customers' increased demands, competitiveness, cognitive closure and time monitoring and deadlines as well as moderating factors such as enjoyment, habit, experience and skills (Bhattacherjee, 2000; Rahi & Ghani, 2019).

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Holistically, the e-services usage during the Covid-19 pandemic can be synthesized into four aspects namely; technology characteristics, users' characteristics and perceptions towards technology, activities that needed to be accomplished, and effects that rose from external factors. By the fact that developing countries have been facing a challenge of scarcity of resources, sustainability of e-services usage so as to provide services with accountability, transparency and efficiency may become over constrained after the Covid-19 pandemic when the pressure to work from home has been relieved. In their systematic review of 15 years literature ranging from 2000 to 2014, Shaikh and Karjaluoto (2015) found no study explaining users' continuous behavior to use technology in non-mandatory usage. Other researchers Rahi and Ghani (2019) echoed the same concern that, there are limited studies that have investigated the factors influencing continuance usage of e-services. They further alluded to the need more research that could develop an apposite model to bridge this gap.

This paper developed a model for e-services continuance usage by leveraging the Expectation Confirmation Theory (ECT) Bhattacherjee (2001) and the Self-Determination Theory (SDT) Ryan and Deci (2000) as the underpinning theories. In addition, exerted pressure was introduced to signify the mandatory usage of technology as well as the continuance intention to behavior that elicits the actual continuance usage. The model design also considered the use of moderating factors of habit, experience, skill and enjoyment. The conceptual model is as demonstrated in Figure 1.

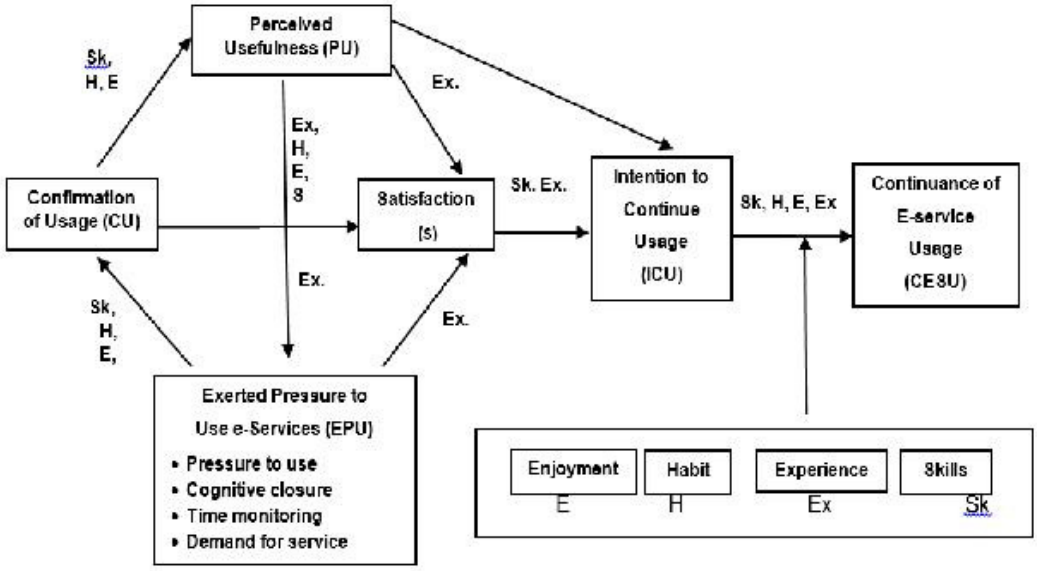

Figure 1. The conceptual model

OPERATIONALIZATION OF THE CONSTRUCTS

Based on the constructs of the conceptual model, relationships were hypothesized.

Confirmation of use refers to a situation whereby users approve and consent of using the technology either after being satisfied, found usefulness or being pressurized to use the technology. From this understanding three hypotheses namely H1, H2 and H3 were derived.

H1: Exerted pressure to use e-services influence confirmation for continuance usage
H2: Satisfaction of e-services influence confirmation for continuance usage
H3: Perceived usefulness influence confirmation for continuance usage

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Exerted pressure refers to sources of stress when users want to meet deadlines in accomplishing their tasks. During Covid-19 peak many organizations abruptly closed and remained to work virtually leaving employees and customers with no other option but to use e-services. From this construct, the forth and fifth hypotheses were derived.

H4: Exerted pressure to use e-services influence satisfaction for its continuance usage

H5: Exerted pressure to use e-services influence perceived usefulness for its continuance usage

Perceived usefulness also known as performance expectancy could be looked at as the users salient beliefs that using e-services will enhance their job performance or completion of tasks. From this construct H6 and H7 were derived.

H6: Perceived usefulness of e-services influence satisfaction for its continuance usage

H7: Users' perceived usefulness of e-services influences their intention for continuance usage

On the other hand, satisfaction refers to the judgment that a service provided a pleasurable level of consumption-related fulfilment by meeting the desired needs of the user. From this construct, the eighth hypothesis (H8) was theorized.

H8: Satisfaction influences intention for continuance usage of e-services

The last independent construct used in the conceptual model is the intention to use e-services. Intention to use refers to the users' option or choice for continuing using the technology after getting satisfied that it will help them when doing their work. From this understanding hypothesis H9 was developed.

H9: Intention for continuance usage influences actual usage of e-services

RESEARCH METHODOLOGY

The population for this study was the people using SARs e-filling system. By the fact that all government and established private entities' employees in South Africa mandatorily do file for tax returns, the population of the study was therefore employees in government departments and parastatals in Tshwane municipality, Gauteng province. Statistically the number of employees who were falling along this category were 4000 to 5000. Hence, by using the Krejcie and Morgan (1970) tool to determine the sample size (s) for finite population the sample size for the study remained 350 to 380 participants. Due to Covid-19 restrictions of movement, the study leveraged the online questionnaires uploaded on survey monkey for data collection. Organizations for data collections were purposively selected based on available contacts in that organizations and the participants were randomly selected.

Participants were only sent a link that could lead them to the questionnaire. Overall, 450 links were sent out to the probable participants and of these 366 were answered and returned making a response rate of 81.3%. Out of the answered questionnaires, 354 were usable as the rest had incomplete data and were discarded. After capturing all the answered questionnaires, the filled survey monkey forms were exported to the Statistical package for Social Scientists (SPSS vs 25) for data analysis. Structural Equation Modeling (SEM) was employed for data analysis and testing of the hypothesis.

Before analysis the constructs as demonstrated in Figure 1 were coded as follows; exerted pressure to use e-services (EPU), cognitive closure (CC), time monitoring and deadlines (TMD), demand for service delivery (DSD), satisfaction (S), confirmation of use (CU), perceived usefulness (PU), intention for continuance usage (ICU), and the continuance e-service usage (CESU).

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ANALYSIS AND PRESENTATION OF RESULTS

This section presents the findings of the study.

DESCRIPTIVE ANALYSIS

Descriptive analysis was used to indicate how respondents answered the questions relating to e-filing continuance usage after COVID-19. Results are as demonstrated in Table 1. The range values represents how far the respondents' answers vary from the mean and from the results, the range statistics gave an indication of the possible existence of outliers in the dataset. On the other hand, a high standard deviation shows a high diversion from the mean whereas a low standard deviation shows the closeness to the mean.

Table 1.Descriptive statistics: the central tendency and Distribution of the dataset for each construct

	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
EPU	3.40	1.60	5.00	2.790	.045	.847	.717
CC	3.80	1.20	5.00	2.503	.047	.893	.798
TMD	3.25	1.75	5.00	2.918	.037	.693	.480
DSD	3.60	1.40	5.00	2.369	.046	.857	.735
S	3.20	1.80	5.00	3.257	.026	.482	.232
CU	3.40	1.60	5.00	2.277	.039	.744	.553
PU	3.00	2.00	5.00	3.203	.019	.376	.141
ICU	3.40	1.60	5.00	2.698	.040	.756	.571
CESU	2.80	2.20	5.00	3.199	.018	.347	.121
Valid N (listwise)							

As demonstrated in Table 1, satisfaction of users (S) has the highest mean value of 3.257 and a relatively low standard deviation of .482 whereas the demand for services had the lowest mean value of 2.369 and a higher standard deviation of .857. These findings are agreement with those of researchers (Bhattacherjee, 2001; Rahi & Ghani, 2019) who noted that users will continue to use a technological innovation if they are satisfied with its performance. In this case it implies for users to find e-services as useful, they have to be satisfied with the nature of the services provided. These are also demonstrated graphically by a box whisker plot as illustrated by Figure 2.

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Figure 2. Box whisker plot for the constructs

The boxes of the whisker plots signifies the perceptions of the participants. As demonstrated in Figure 2, taller boxes like in the case of plots for CC, TMD, ICU and EPU implies that participants had varying perceptions and opinions about e-services continuance usage when measure on these parameters against cognitive closure (CC), time monitoring and deadlines (TMD), intention to continue use e-services (ICU) and exerted pressure to use e-services (EPU). On the other hand, constructs DSD, S, PU and CESU shows relatively short box whisker plots which implies that participants had a good level of agreement on the asked questions about continuance usage of e-service.

STRUCTURAL EQUATION MODELLING

Structural equation modelling (SEM) and confirmatory factor analysis (CFA) were used to test the model's fitness to the data. Fit indices including chi square ($\chi 2$), comparative fit index (CFI), Root mean square error of approximation (RMSEA), and goodness of fit index (GFI) were used for model modification before the final structural model was deduced from the measurement model to test the hypotheses. The testing of the hypotheses is as illustrated in Table 2 which indicates that of the nine tested hypotheses, seven were accepted while the two were rejected.

Table 2. Extracted summary of the standardized significance levels of constructs

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Hypothesis	Path			Estimate	S.E.	C.R.	P	Comment
H1	CU	<---	EPU	.668	.080	8.395	***	Hypothesis accepted
H2	PU	<---	CU	.312	.107	2.914	.004	Hypothesis accepted
H3	S	<---	CU	-.074	.052	-1.416	.157	Hypothesis rejected
H4	EPU	<---	PU	1.183	.436	2.710	.007	Hypothesis accepted
H5	S	<---	EPU	.086	.054	1.585	.113	Hypothesis rejected
H6	S	<---	PU	.099	.061	3.637	.002	Hypothesis accepted
H7	ICU	<---	PU	.182	.260	1.987	.045	Hypothesis accepted
H8	ICU	<---	S	1.530	1.499	2.021	.030	Hypothesis accepted
H9	CESU	<---	ICU	.240	.044	5.484	***	Hypothesis accepted

From the results demonstrated in Table 2 those relationships whose critical ration CR is greater or equal to ± 1.96 have their hypotheses (H1, H2, H4, H6, H7, H8, and H9) accepted. On the other hand, H3 and H5 were rejected. Among the accepted hypotheses, the influence of exerted pressure to use e-services on confirmation of use was found to be the most significant with a critical ratio of 8.395 followed by that of intention to continue usage of e-services with a critical ration of 5.484. As also indicated by previous researchers Bhattacherjee (2001); Rahi and Ghani (2019) perceived usefulness leads to satisfaction.

DISCUSSION AND CONCLUSIONS

The Covid-19 crisis accelerated the use of e-services in both public and private enterprises implying for continuance usage of e-services employees from both sectors need to be kept abreast with the changes. The pandemic renewed and anchored the role of e-government as at the height of the pandemic, organizations reduced the number of their employees and argued their customers to use solutions with limited or no human interaction. By so doing both the organizations and their customers stretched to use the digital services amidst all challenges though at the safety of their homes. Organizations on the other hand, continued to operate in spite of contact restrictions and other confinement measures. This study sought to answer the question whether this stretch of use of e-services will continue after the end of the Covid-19 pandemic and if so how best can organizations be prepared and how can they be guided to equip their employees with the needed skills for their betterment and to those of their nations. The developed model for e-services continuance usage will act as a guideline for organizations and their employees on the continuance usage of e-services after the Covid-19 pandemic.

The onset of Covid-19 pandemic triggered a global political, economic and social re-calibration with many organizations worldwide opting to retain employees through online work for critical activities. The pandemic also triggered a need to decongest the work spaces. The reality across organizations and industries is for innovative ways of working remotely, outside traditional workspaces for their customers to receive products and services online. The need for e-services usage has been accelerated and the trend is more likely to continue rather than taking the return curve. The pandemic may cease to cause potential medical threats with time but the increasing changes in technology leading to the 4IR may still keep the technology usage bar high. The combination of these two phenomena will come with social and economic disruptions including loss of jobs especially the repetitive and non-skilled ones, collapse of businesses that may fail to cope up with changes, poverty and diseases,

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illnesses and starvation for those whose jobs will be replaced and/or considered to be non-essential, fear in the population, decongestion and death, among others. Much as some organizations will boost from these changes due to reduced overheads, they are at the same time obliged to prepare their employees for these eventualities as unemployment and/or underemployment are considered to be among the major antecedents of poverty, inequality, high crime rates as well as political instability. This implies that the leverage of this study's model for continuance usage of e-services and other technologies is paramount for the 4IR preparedness that is expected "disrupt" markets, particularly labor.

CONTRIBUTION OF THE STUDY

As alluded by researchers Rahi and Ghani (2019); Shaikh and Karjaluoto (2015) fewer studies have been conducted to inform continuance usage of e-services. This study is a step forward towards the contribution to the scarce literature of continuance usage of not only e-services but for all other technological innovations. Future researchers will replicate the model developed by this study to extend research of continuance usage. By so doing, this study will be making a significant theoretical contribution to the computing body of knowledge.

Worldwide the Covid-19 pandemic brought a sudden shift away from face-face-face interaction while conducting business and providing services including in the education domain. The fact is that many countries and organizations were not ready for this shift and the point to wonder is whether this dramatic adoption and use of e-services will continue to persist post-pandemic without causing digital divides among individuals, organizations and countries. This implies that, those governments and organizations that are ready to sustain this drive will need to leverage better models like the one developed in this study to ensure continuance usage. By leveraging this model, this study will be making a significant practical contribution to practice and management towards the use of technological innovations.

RECOMMENDATIONS

Many developing countries are faced with a challenge of poor infrastructure, in addition to lacks unreliable slow and intermittent internet. E-services usage requires faster internet especially for those organizations that use oracle-based databases. Slowness of the internet may frustrate users and hinders the smooth continuance usage. Hence, government has to support the citizens by setting up good infrastructure and reliable networks.

The advent of Covid-19 and the evolution of the 4IR has changed mankind in respect to what they do and how they do them including the time they will devote to work and leisure. This implies that employees at work will have to equip themselves with new skills in order to cope with new innovations. Governments and other private enterprises need support skills development in order to prepare for these new paradigms of work and to cope up with the disruption and uncertainty caused by the need to decongest work spaces, support business continuity and afford continuance of e-services usage.

Covid-19 pandemic and like any other major world events could mark an inflection point for rapid innovation in technology. Such could propel faster adoption of automation and AI brought up by the 4IR especially in work domains with high physical proximity. This implies that knowledge dissemination within and across countries as well as among communities is paramount in order to reduce the digital divide. Hence, future research should therefore include the analysis of moderating factors suggested by this study as such will assist in equipping skills and expertise to citizens needed for effective usage. More so, moderating effects are essential for determining effective usage especially with change in time.

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Another point to note is that this study only used online survey questionnaires to collect quantitative dat. For ease of analysis this method eliminated unstructured questions where respondents could get a chance to expound on their answers or explain their feeling and perceptions of the mandatory usage of e-services. This study therefore recommends that, future research should triangulate the methods and allow the use of qualitative questions to allow users a chance to explain their feeling towards the abrupt mandatory use of e-services .

Much as it is anticipated that a time will come when Covid-19 will be no more but the 4IR is here to stay and probably lead the world to higher level revolutions. This implies that government and policymakers need to support businesses by expanding and enhancing the digital infrastructure. Anecdote, even in advanced economies, a good number of citizens especially those in rural settings lack access to the internet. The 4IR path indicates that the future will have to embrace telecommuting that will require upskilling. This implies that there is a projected high growth in the share of working age population and such presents major policy and social challenges as the demand for labour will continue to lag behind the supply. Governments and businesses should therefore consider extending benefits and protections to independent workers and to all other employees needing to develop their skills and knowledge mid-career and also to support all endevours intended to create jobs and small businesses that favour the less skilled personnel.

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FACTORS AFFECTING THE USE OF INFOMEDIARIES IN MHEALTH INTERVENTIONS: CASE OF MATERNAL HEALTHCARE IN RURAL MALAWI

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ABSTRACT

Aim/Purpose	[The aim of the study is explore how maternal clients use infomediaries in maternal mHealth interventions. The study focuses on maternal clients who do not own mobile phones but use the mHealth intervention.]
Background	[Maternal mHealth interventions in poor-resource settings are bedeviled by inequalities in mobile phone ownership. Some maternal mHealth providers facilitate the access of the mobile phones to those who do not own mobile phones using "infomediaries". Infomediaries, in this case, i.e people who have custodian of mobile phones which other potential beneficiaries may use. However, use of infomediaries to offer access to the "have nots" may be influenced by a number of factors]
Methodology	[The study used a case of a maternal mHealth intervention project in Malawi. The study used qualitative research method and interpretive paradigm. Data was collected using secondary data from the implementing agency, semi-structured interviews, and focus group discussions. Empirical data was collected from maternal clients who do not own mobile phones and infomediaries. Data was analyzed inductively using thematic analysis.]
Contribution	[The study contributes to the knowledge and practice of mHealth designers and implementers on how they can include all potential beneficiaries of an intervention. The study also proposed a conceptual framework for studying infomediaries in ICT4D.]
Findings	[Characteristic of the maternal client, characteristics of the mHealth infomediary, perceived value of mHealth intervention and socio-environmental factors affect maternal clients' use of mHealth infomediaries.]
Recommendations for Practitioners	[Implementers of interventions should leverage traditional systems instead of reinventing the wheel. Traditional systems may offer a good starting point for designing a system which would work for communities]
Recommendations for Researchers	[NA]
Impact on Society	[People are still lacking access. The lack of ownership of technology may still exclude them from participating in information society. Understanding the use

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	of infomediary may help to bridge the digital divide gap]
Future Research	[We are proposing that the traditional systems may offer a good starting point for designing a system which would work for communities. We, therefore, recommend that future research may explore these possibilities]
Keywords	Infomediaries, mHealth, maternal mHealth interventions, mHealth infomediary use

INTRODUCTION

An infomediary is a liaison or broker between an individual or group of people, on the one hand, and a group or source of information, on the other hand (Gould & Gomez, 2010). In Information and Communication Technologies (ICT) for Development (ICT4D), the use of infomediaries has been considered as an option to provide access to technology and information to those who do not have their own access and, therefore, help to bridge the digital divide. In essence, infomediaries have the potential to enable people who could be excluded from the information society to be included. Infomediaries could be setup as part of the interventions or could be people who volunteer to serve in that role independent of the intervention. Infomediaries have been used to provide information in communities, as well as access to ICTs for communities to access and use mHealth and e-government services (Maliwichi, et al., 2021b). Some mHealth interventions use infomediaries to give mobile phone access to clients who do not own a mobile phone (Larsen-cooper et al., 2015). In this study, we are interested in how maternal clients who do not own mobile phones use infomediaries to access an mHealth intervention.

Despite the growth in mobile phone penetration globally, mobile phone ownership still remains far from universal (GSMA, 2019). Women in low- and middle-income countries are 10% less likely than their male counterparts to own a mobile phone (Barboni et al., 2018). South Asia and Sub-Saharan Africa are the most affected regions with women 28% and 15% less likely to own a mobile phone (Barboni et al., 2018). It is likely, therefore, that maternal clients, especially in rural areas, may not own a mobile phone which they would use to access maternal mHealth interventions. mHealth infomediaries may enable such maternal clients to use mHealth interventions.

Most of the studies in mHealth so far focus on the feasibility, implementation, adoption, use, and acceptability of mHealth technologies (Chib, 2010; Lim et al., 2011). A few studies have assessed patient outcomes, as well as business outcomes of mHealth interventions (Ngabo et al., 2012). Furthermore, other studies have assessed the use of online health infomediaries (Khuntia, Yim, Tanniru, & Lim, 2017; Song & Zahedi, 2007). However, there is still dearth of studies on the use of infomediaries in mHealth interventions for clients who do not own mobile phones (Maliwichi, et al., 2021a). In addition, little is known about factors that affect the use of mHealth infomediaries (Khuntia et al., 2017; Song & Zahedi, 2007). Our focus in maternal health is driven by its significance as noted in Sustainable Development Goal 3.1. Furthermore, maternal health is surrounded with cultural beliefs which can affect the use of technology and infomediaries.

We posit that a range of factors affect the use of infomediaries, and consequently, affect the use of the maternal mHealth intervention. The aim of this study is to contribute to IS research, specifically on the use of mHealth infomediaries in maternal health (Larsen-cooper et al., 2015; Ramachandran et al., 2010) by addressing the following research question.

What factors affect rural-based maternal clients' use of mHealth infomediaries in maternal health?

To answer the research question, we used a case of Chipatala Cha Pa Foni (CCPF) – (translates to Health Centre by Phone) project, a maternal and child health intervention in Malawi. The intervention provided maternal clients with pregnancy tips and reminders, and in addition, the maternal clients could call a hotline for health information and advice. The intervention allowed maternal clients who did not have mobile phones to use mobile phones of family members, community members and community volunteers. The community volunteers, who served as mHealth agents of the intervention in their

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communities, were provided mobile phones by the intervention. In this study mHealth infomediaries were community volunteers, family members, and community members who provide a connection between the mHealth intervention and health information consumers (maternal clients) who do not have their own mobile phones to access the intervention.

LITERATURE REVIEW

INFOMEDIARIES

The term infomediary is formed from the combination of the words: information and intermediary (Brown & Hussain, 2016). In low-income countries, community services using Information and Communication Technologies (ICTs) are sometimes centered on infomediaries (Ngabo et al., 2012; Ramachandran et al., 2010). In most mHealth projects, health infomediaries have been Community Health Workers (CHWs) or community volunteers (Brown & Hussain, 2016). For example, "Info Ladies" were used as infomediaries to provide health information to villagers (Brown & Hussain, 2016). Large-scale adoption and deployment of mobile phone interventions using CHWs offer promising approaches to improving health care delivery (Ngabo et al., 2012). However, using CHW in mHealth has its own challenges.

MATERNAL HEALTHCARE AND MHEALTH INTERVENTIONS IN LOW-INCOME COUNTRIES

Maternal health refers to the health of women during pregnancy, childbirth, and the postpartum period, which includes family planning, preconception, prenatal, and postnatal care (WHO, 2012). Due to inequalities in access to quality health services, there is a high number of maternal deaths in some parts of the world (WHO, 2019). Maternal Mortality Rate (MMR) in low-income countries in 2017 was 462 per 100 000 live births compared to 11 per 100 000 live births in high income countries (WHO, 2019). 94% of these deaths occurred in rural settings and sub-Saharan Africa had 196 000 deaths (WHO, 2019).

To reduce MMR in low-income countries, maternal mHealth interventions are used to relay health information to pregnant women especially those who live far away from the health facility. Maternal mHealth interventions are used to unlock access to reproduction health information and improved access to health facilities during pregnancy and delivery (Nyemba-Mudenda & Chigona, 2018). Tips and reminders through voice messages and SMS are the most widely used method to communicate to maternal clients (Nyemba-Mudenda & Chigona, 2018). Voice messages and SMS are commonly used since they are readily available even on a basic mobile phone, and prove to be affordable and convenient, compared with other applications (Ngabo et al., 2012). Mobile phones used to access health information and health care services can generate opportunities for women health but also for their informational wellbeing (Ngabo et al., 2012; Nyemba-Mudenda & Chigona, 2018).

WOMEN MOBILE PHONE OWNERSHIP IN LOW-INCOME SETTINGS

Ownership is a complex phenomenon. Ownership of mobile phones can be categorized as legal ownership and psychological ownership. Legal mobile phone ownership can constitute the right to use and sale the mobile phone (Pierce et al., 2004). In other settings such as in developed countries, legal ownership also means sole ownership of the mobile phone, and consequently, sole usage of the mobile phone (Chipchase, 2009). However, psychological ownership is a feeling of possession of an object that it is *mine* (Pierce et al., 2004). Women in rural setting in sub-Saharan Africa who do not own mobile phones may have a psychological ownership of a mobile phone which belongs to family members and community members in their settings (Pierce et al., 2004). Psychological ownership of mobile phones is important since it makes access of mobile phones to marginalized groups of people possible. In maternal mHealth, sense of ownership of mobile phones is vital since it unlocks the barrier of reaching non-mobile phone owners and consequently, enhances inclusivity of non-mobile phone owners in maternal mHealth interventions.

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MOBILE PHONE OWNERSHIP OF MHEALTH INFOMEDIARIES IN MATERNAL HEALTHCARE

In low-income countries people can have different types of mobile phone ownership. Studies have found that mobile phones of mHealth infomediaries can be categorized as: 1) personal property, 2) family property and 3) project property.

Personal mobile phones are regarded as personal property if the owner has sole ownership of the mobile phone. In a developed country context, personal mobile phones are used solely by the owner (Chipchase, 2009). However, in a developing country context personal mobile phone, which is a personal property, can be used by other people (Blauvelt et al., 2018). This is attributed to the sharing culture in such a context (Zamani & Sbaffi, 2020). Thus, if a personal mobile phone is used by other people for health purposes, the personal mobile phone owner may become a mHealth infomediary. In contexts where a sharing culture exists, sharing of personal property is a norm (Zamani & Sbaffi, 2020). Hence, mHealth intervention may succeed in such a context.

In a rural setting, ownership of property may be regarded as family property (Chipchase, 2009). In this setting, a mobile phone owned by one family member may become a home or family mobile phone (Chipchase, 2009). This could be attributed to the fact the not all family members can own personal mobile phones. This means that, if the family mobile phone is used for health purposes by family members, the owner of the mobile phone may become an mHealth infomediary.

Due to low mobile phone ownership among rural women, the mHealth Intervention provide mobile phones to designated infomediaries to serve as the link between maternal clients and the project. The informediaries can be community volunteers or CHWs (Nyemba-Mudenda & Chigona, 2018). Maternal clients who do not own mobile phones prefer using project mobile phones over mobile phones owned by other people (Nyemba-Mudenda & Chigona, 2018).

CHIPATALA CHA PA FONI (CCPF): MALAWI CASE STUDY

CCPF is an mHealth interventions running in Malawi since 2011. It was piloted in Balaka district; Balaka has low performance in maternal and child health issues.

MALAWI CONTEXT

Malawi is a country in southern Africa with a population of about 17.5 million people. About 85.6% of this population resides in rural areas (NSO, 2020a). The country has a Gross Domestic Product (GDP) per capita of US$411 (NSO, 2020a). The literacy rate for women is lower than that for men. About 12% female and 5% male has no education (NSO, 2020a). In rural areas of Malawi, girls are five times more likely than boys to drop out of school (Sunny, 2018). The maternal mortality rate in Malawi is at 349 per 100000 live births (NSO, 2019).

Mobile phone ownership in Malawi

Malawi has two dominant mobile operators: (i) Airtel Malawi (52.2% market share) and (ii) Telekom Networks Malawi (TNM) (48.6%) (NSO, 2020). Over the years, ownership of mobile phones has increased rapidly. Approximately, 43.2% of the population owns a mobile phone (72.3% urban, 37.3% rural) (NSO, 2020). Mobile phone ownership by male is at 44.9% while female is at 37.7% (NSO, 2020). "Mobile phones are commonly shared within families and communities, making Malawi an ideal setting for mHealth interventions" (Blauvelt et al., 2018, p.1).

CCPF CASE STUDY

The underlying ideas for CCPF were:

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- A two-way communication between clients and health personnel via a hotline for timely access to health information and advice
- Use of mobile phone technology for tips and reminders on maternal health issues, together with a booking system and databases at health facilities to improve documentation

The main objective of the CCPF project was to maximise healthcare access and utilisation by remote maternal clients who were facing so many challenges such as walking long distances to access a health facility, resulting in delays in seeking care and unnecessary expenditures.

Components of the CCPF system

At first, CCPF had two main components: 1) toll-free case management hotline (which is available on an Airtel line) and 2) tips and reminders. These components were designed to work on a basic mobile phone which is common in poor-resource settings.

Case management hotline: The toll-free case management hotline was stationed at the district hospital and was managed by qualified hotline workers (HLWs). The HLWs were trained on maternal and child health community case management; this is a training which is also provided to CHWs. The hotline was available for 12 hrs per day (7:00AM to 7:00PM). On their first call, the clients were registered (their personal details captured) and oriented on how the system works. The women were told about their expected date of delivery (EDD) and the current stage of pregnancy.

Tips and reminders: Tips were personalized messages according to the stage of the pregnancy. Reminders were messages for antenatal appointments, medication and supplements during pregnancy. The messages were in two vernacular languages of the district. The voice messages were retrieved on any Airtel line upon authentication, using the EDD and password (voice messages were common for non-mobile phone owners). Text messages were sent direct to the personal mobile phone.

After the pilot phase, CCPF was scaled-up and handed over to the Malawi Government in 2018 (VillageReach, 2018). CCPF is now available in all districts of Malawi 24/7. The tips and reminders component has been replaced with pre-recorded voice messages and everyone can access them using an Interactive Voice Response (IVR) system when they call the toll-free number. The callers choose whether they want to talk to a hotline worker or listen to the voice messages.

mHealth infomediaries for CCPF

The implementing agency recruited about 400 community volunteers across the four catchment areas and each village was assigned a community volunteer. Community volunteers were people within the community; the minimum qualification for the volunteers that that they should have basic literacy and could use a mobile phone. The volunteers were not Health Surveillance Assistants (HSAs) (in Malawi HSAs are CHWs employed by the government). Their role was to provide maternal clients with access to a mobile phone for the intervention and demonstrate how to use the system. In addition, community volunteers were visiting maternal clients in their homes for registration and follow up on tips and reminders so that women could listen to their messages. The project provided volunteers with mobile phones to be used for CCPF for maternal clients in their communities. Some infomediaries were not appointed by the intervention; they were either community members or family members who provided mobile phone access to maternal clients. Therefore, maternal clients who did not own mobile phones could call the hotline using the mobile phone of community volunteers, community members or family members. Some took on the role of infomediary because of their roles in the community; an example was a wife of a village headman.

METHODOLOGY

The study used qualitative research method and interpretive paradigm. Qualitative research was appropriate since it is subjective in the sense that it points to the role of human subjectivity in the research process and provided new meaning to knowledge (Creswell, 2014). The study employed a single

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holistic case study. Single case studies are appropriate for studies focusing on individuals in one environment because they are unique or extreme (Yin, 2003) This study is looking at a group of women within the same environment or context who do not own a mobile phone but access the mHealth intervention using infomediaries. These women represent a minority of the population of maternal clients who used the mHealth intervention. The study used a case of CCPF and data was collected in Balaka district in Malawi where the initiative was piloted.

DATA COLLECTION METHODS

Data was obtained using documents on CCPF, semi-structured interviews with maternal clients, family members, community volunteers and Focus Group Discussions (FGDs) with the maternal client. Data was collected in three phases as presented in Table 1.

Table 1. Phases of data collection

PHASE	DATA TYPES AND METHOD	DATES
First phase	Secondary data collection using project website and peer-review journals	January 2019
Second Phase	Semi-structured interviews	June 2019
Third Phase	FGDs	August 2020

Documents relating to the project were collected from the internet and peer review research outputs, as well as accessed directly from the project. For project documents from the internet and the peer-review articles we used Google, Google Scholar and Web of Science databases to search for articles using relevant search terms. Appendix A summarizes these documents. We used documents to develop the context of the study and to triangulate with empirical data. Project reports provided a good window to the background and the main objectives of the intervention, and highlighted some activities and processes involved in the maternal clients' use of the intervention.

We conducted semi-structured interviews with the maternal clients as well as the infomediaries (refer to Table 3). The sample comprised of maternal clients with low parity (number of live births less than five) and high parity (the number of live births equals 5 or more). The sample had 20 maternal clients. All the maternal clients had attended the minimum required antenatal visits and they all delivered at the health facility. The demographic profile of the maternal clients in this study are summarised in Appendix B. We used the following procedure to access the respondents:

- The project team queried the Caller Database for CCPF for the period of August 2017 to December 2018 to obtain mobile numbers for maternal clients who indicated that they were using a mobile phone which was not theirs. We chose this period to find more active mobile numbers. We identified "hotspots" (areas which made more calls from the caller's database) in Balaka district.
- We obtained mobile numbers of mobile phone owners from Callers' Database of CCPF. We asked the mobile phone owners to identify maternal clients who used their mobile phone for the initiative. We interviewed both the maternal clients and the owner of the phone.

We interviewed two community volunteers and a community member, and asked them to identify maternal clients who were using their mobile phones. We asked the community volunteers and community member to invite these women to participate in the FGDs. We had two FGDs with maternal clients who were using community volunteer and community member mobile phones. Table 3 summarizes the sample of mobile phone owners and maternal clients who used their mobile phones.

TABLE 3. Mobile phone owners and maternal clients who used their mobile phones

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Mobile phone owners	Maternal client
Husband 1	Client 1
Husband 2	Client 2
Husband 3	Client 3
Husband 4	Client 4, Neighbours (other maternal clients in his community)
Mother-in-law 1	Client 5
Community Volunteer 1	Client 6 – Client 13
Community Member 1	Client 14 – Client 20

The interviews took 45 to 60 minutes each. The interviews were conducted in Chichewa; Chichewa is a national local language of Malawi, so all respondents understood the language. For each interview, the researcher took notes and recorded the calls using CallX mobile application.

We used the community volunteer and community member as facilitators of the FGDs in two catchment areas; the researchers could not travel to the interview site due to Covid-19 travel restrictions. The facilitators identified a quiet place where they could conduct the FGDs. We used an interview guide to ask focused questions and facilitated the discussions by encouraging participation and points of view. The discussions were audio-recorded using CallX mobile application, and an assistant took notes of the discussions as well. During the FGDs, the researchers, the community volunteer and a community member put the mobile phone on the loudspeaker for all the participants to hear the discussion at each end of the call. The maternal clients and the facilitators were compensated for the transport used to attend the FGDs. The discussions lasted two hours on average each.

DATA ANALYSIS

We conducted data analysis in two phases. The first phase focused on document analysis. The second phase of data analysis triangulated data from secondary sources and empirical data collected using semi-structured interviews and FGDs. The audio-recordings were transcribed and coded using Nvivo 12. We employed an inductive thematic analysis to analyze the data. Several phases, as stipulated by Braun & Clarke (2006), guided the analysis process.

ETHICAL CONSIDERATIONS

Before data collection, we obtained permission to use CCPF as a case study from the implementing agency of CCPF, Malawi Ministry of Health and Balaka District Health Office. Further, we obtained ethical clearance from the National Health Sciences Research Committee (Malawi).

During the interview sessions, the researchers introduced themselves as researchers studying CCPF Project. Consent was sought before interviews started and issues of privacy and confidentiality of the data collected were discussed. For FGDs the participants were told that privacy and confidentiality of the things discussed was difficult since the discussion involved the group. We were aware of the risks of interviewing pregnant women: there could be an emergency during interviews or women could recall traumatic experiences related to the pregnancy. To mitigate against this risk, our sample was limited to mothers who were not pregnant at the time of data collection; they were all women who had previously used the system. Further, we informed the respondents that participation of the study was voluntary and they could withdraw from the study any time. For the analysis, we anonymized the maternal clients as Client x.

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FINDINGS AND DISCUSSION

The study found that several factors affected how maternal clients used mHealth infomediaries in maternal healthcare. As summarized in Figure 2, these factors include (i) perceived value of the mHealth intervention, (ii) characteristics of the health client, (iii) infomediary characteristics, and (iv) socio-environmental factors.

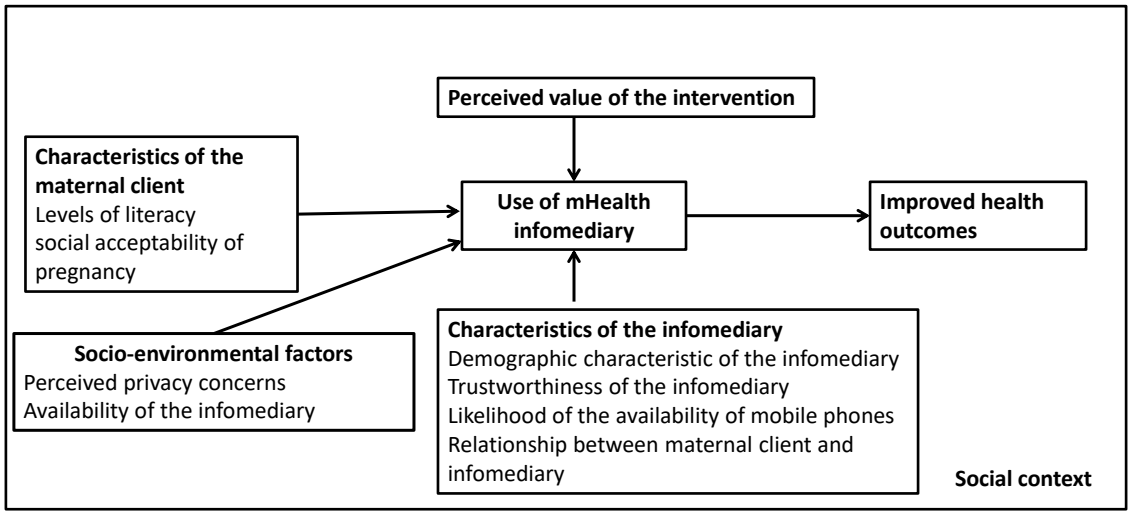

FIGURE 1. Theoretical framework of mHealth infomediary use

PERCEIVED VALUE OF THE MHEALTH INTERVENTION

Maternal clients in this study sought to use infomediaries since they perceived the mHealth intervention as valuable. The use of infomediaries involves social costs such as negotiation and, in some cases, being obligated to gift back to the infomediary. The healthcare client is likely to use the intervention and the infomediary if they perceive the service being offered by the intervention to be valuable. The maternal clients perceived the mHealth intervention as useful and the information received from the intervention as quality information. The maternal clients felt that they learnt new information and practices on safe motherhood through CCPF.

> *"CCPF information is very helpful. We were just staying and we were ignorant. We didn't know what to do. Most women were dying because they did not know when to go to the hospital when problems arise, because of lack of proper advice …"* [Client 17].

The women perceived the information as valuable partly because they believed that it was provided by the ministry of health. Maternal clients are likely to trust the information from an intervention which is affiliated to the national health framework (Blauvelt et al., 2018). Willcox et al (2019) noted that maternal clients in Ghana perceived the information from an mHealth intervention as quality information because it was originating from health professionals. . In light of this discussion, the study suggests the following proposition:

> ***Proposition 1:*** *When healthcare clients without own mobile phones perceive the intervention as valuable, they are more willing to use mHealth infomediaries.*

CHARACTERISTICS OF THE MATERNAL CLIENT

Characteristics of the maternal client which affected how maternal clients used the infomediaries include levels of literacy and social acceptability of the pregnancy.

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Levels of Literacy

Levels of literacy of maternal clients affected how maternal clients who needed to use mHealth technologies actually used them (Maliwichi et al., 2021a; Nyemba-Mudenda & Chigona, 2018). On one hand, maternal clients with low literacy levels depended on mHealth infomediaries to operate the mobile phone on their behalf to use mHealth interventions (Larsen-cooper et al., 2015), on the other hand, the clients with high literacy level used the infomediary just to access the mobile phone. The latter group tended to use the interventions with ease since they might have had technology self-efficacy (Venkatesh & Bala, 2008).

Most maternal clients in this study, like women in most rural parts of Malawi, had low literacy; most of them were lower primary school dropouts. These maternal clients depended on the infomediary to operate the mobile phone on their behalf.

> *"The method that was used to access CCPF was difficult at first. It depended on the level of education to use it comfortably. But now it is easy, they have simplified everything ..."* [Community Volunteer 1].

Some studies in maternal mHealth have found that low literacy not only affects the ability to use the mobile phone, but also level of comprehension of the messages (Larsen-cooper et al., 2015).

Social acceptability of pregnancy

Social acceptability of a pregnancy affected how maternal clients used mHealth infomediaries. Many societies have norms which define the conditions for a pregnancy to be acceptable, who can get pregnant and when can they get pregnant (Omoloso et al., 2017). Women who get pregnant at the wrong time may be shunned off (Hamal et al., 2020). Malawi, especially the rural parts, is a conservative society and as such being pregnant out of wedlock is a taboo (Nyemba-Mudenda & Chigona, 2018). Women, especially, teenagers who get pregnant out of wedlock are stigmatized and may even be cast out of their families (Levandowski et al., 2012). As such, young unmarried women who fall pregnant, struggle to inform other women about their pregnancy (Hackett et al., 2019). This may have negative consequences for the health of the pregnancy. A study in India found that even married under-age maternal clients find it difficult to use maternal healthcare services (Hamal et al., 2020).

An mHealth intervention offers opportunity for such women to obtain medical information without dealing with the shame. However, when the women do not have their own phone, they still would have to go through an infomediary within their society (Larsen-cooper et al., 2015). This was a barrier for the women to access the service.

> *"I remember starting to attend antenatal care when I was six months pregnant and registered for CCPF ... it was shameful to approach people on anything"* [Client 1].

The society's perception of what is an acceptable pregnancy may affect the use of mHealth infomediaries. Thus, in a society which frowns upon teenage pregnancy and pregnancies out of wedlock, teen maternal clients could find it challenging to use maternal mHealth infomediaries. In light of this discussion, the study suggests the following propositions:

> ***Proposition 2:*** *When a society does not accept circumstances surrounding maternal client pregnancy, the maternal client may not be comfortable to use infomediaries in that society.*

To mitigate against this challenge, interventions should make deliberate efforts to reach out to women who may be excluded from accessing the infomediaries.

CHARACTERISTICS OF THE INFOMEDIARY

Characteristics of the infomediary affected how maternal clients used the mHealth infomediary. These characteristics include demographic characteristics (such as gender, age and technical skills to support the maternal client), trustworthiness of the infomediary and likelihood of the availability of the mobile phone.

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Demographic characteristics of the infomediary

The gender and age of the infomediary affected how comfortable the maternal clients were to use the services. The maternal clients were more comfortable using a mobile phone owned by a woman than those owned by a man. Due to the cultural beliefs around pregnancy, maternal clients found it challenging to visit and negotiate use of a mobile phone from a man who was not their husband. It would be socially unacceptable for a maternal client to make this agreement with a man other than her husband. Furthermore, the maternal clients were not comfortable using a community volunteer who was younger than themselves.

The implication of this was that the women could delay in accessing the services from the intervention. Other studies in maternal mHealth have also found that the gender of an infomediary could affect the use of mHealth infomediaries (Duclos et al., 2017; Nyemba-Mudenda & Chigona, 2018).

Due to cultural reasons, women prefer seeking assistance and advice on pregnancy related matters from other women, especially older women. In most cases old women are perceived as custodians of maternal health matters in their communities. However, the design and implementation of the initiative did not involve older women. As it would have been beneficial for the project to involve them as custodians of the mobile phones for the project

When the infomediary struggled to use the mobile phones on behalf of the maternal client, the maternal clients were discouraged from continuing to use the infomediary. This was common during the pilot phase because the step that maternal clients had to follow to retrieve their personal messages was long. *"Sometimes, even some community volunteers were finding it difficult to use the intervention"* [Project Document 5]. Probably the clients felt they were burdening the informediary.

Trustworthiness of the infomediary

In Malawi, like in most developing countries, cultural believes dictate that women do not disclose their pregnancy to anyone except to their husbands and mother. Pregnancy is secretive and women find it easier to discuss pregnancy-related issues amongst women than with men. Moreover, maternal clients would prefer to discuss their pregnancy with someone whom they trust that would keep their pregnancy a secret.

"*Normally, I receive maternal related advice from my older aunt or grandmother because they take my pregnancy serious and they cannot disclose my pregnancy to anyone*" [Client 1].

A study in South Africa found that maternal clients accept interventions at the community level if they trust the CHWs in their community (Grant et al., 2017). Trustworthiness at an individual level for CHWs, community volunteers and community members who are involved in maternal health is important for maternal health interventions to succeed (Grant et al., 2017). Trustworthiness of infomediaries in maternal mHealth interventions is fragile, since maternal clients could stop using infomediaries if the maternal clients encounter a bad experience with the mHealth infomediary (Zahedi & Song, 2008).

Likelihood of the availability of mobile phones

The likelihood of the availability of mobile phones at the infomediaries affected the experience of the maternal clients. Factors contributed to the phones at the infomediaries not being available for use include battery challenges, faulty mobile phones as well as just the mobile phones being not easy to use. The area where the study was conducted, like most rural parts of Malawi, do not have grid power and this results in difficulties in charging mobile phones (Taulo et al., 2015). Most users had to pay for charging their phones. It is, therefore, foreseeable that mobile phones may not be charged.

> *"Most of the times the problem is with the volunteers mobile phone… sometimes the phone is not charged… so she tell us to come again …"* [Client 15].

Furthermore, the maternal clients walked a long distance to the community volunteer to use the mobile phone. Therefore, they felt discouraged when they found that the mobile phone was not working for

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whatever reason. Hence, the likelihood of the availability of technologies has the potential to exacerbate inequalities in poor-resource setting.

Relationship between maternal client and infomediary

The maternal clients choose infomediaries where there was a high likelihood of being granted permission to use the mobile phone as well as where the interaction with the infomediary would be perceived to be within acceptable social norms. Maternal clients noted that *"other people sometimes do not allow us to use their mobile phones.* Consequently, *most of the times, we used our relative's mobile phones ..."* [Client 17]. Due to social norms surrounding pregnancy, the negotiations for phone use were not always like other "*standard personal calls*".

The study noted that most maternal clients were using a particular mobile phone for CCPF after creating a relationship with the mobile phone owner. This was particularly true for non-emergency maternal issues. During an emergency, maternal clients could use mobile phones from anybody. Therefore, family members and relatives are crucial in providing mobile phone access to maternal clients on maternal health issues.

Studies in maternal mHealth have found that maternal clients prefer to use project mobile phone for maternal related issues since there is guaranteed access for the mobile phone from the infomediary (Duclos et al., 2017; Larsen-cooper et al., 2015). Other studies have stated that maternal clients prefer mobile phones of family members since they cannot deny them access to their mobile phones (Nyemba-Mudenda & Chigona, 2018). These findings suggest that even though mobile phone sharing is common in poor-resource communities, long-term sharing of mobile phones is still a challenge in maternal-related issues (Duclos et al., 2017). This could be attributed to the sensitivity of maternal–related issues to both parties (maternal client and mobile phone owner). Based on this discussion, the study suggests the following propositions:

> ***Proposition 3:*** *When a maternal client finds the characteristics of maternal mHealth infomediary not appropriate, maternal client may not use that infomediary.*
>
> ***Proposition 3a:*** *The demographic characteristics of the infomediaries may affect maternal client use of infomediaries.*
>
> ***Proposition 3b:*** *When the infomediary is trustworthy and more likely to be available for maternal clients, maternal clients may use those infomediaries.*

SOCIO-ENVIRONMENTAL FACTORS

Socio-environmental factors that affected how maternal clients used infomediaries include: i) choice of infomediary to provide mobile phone access, ii) perceived privacy concerns and iii) availability of the infomediary. Therefore, the study suggests the following proposition.

> ***Proposition 4:*** *When maternal clients are affected by socio-environmental factors, maternal clients may find it difficult to use mHealth infomediaries.*

Perceived privacy concerns

The privacy concerns relating to their pregnancy information affected the use of the infomediaries. Privacy is the "individual's ability to control what information is disclosed, to whom, when and under what circumstances" (Song et al., 2018, p.295). Individual privacy concerns include who is authorized to view their health information and if that information should be shared (Ambrose & Basu, 2012). This is particularly concerning where the information is perceived to be sensitive such as pregnancy related information in the context of rural Malawi. Similarly, a study in Pakistan found that maternal clients would not visit a health facility because they do not want the secret of them being pregnant being disclosed (Ullah et al., 2019).

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In this study maternal client perceived privacy concerns affected the use of mHealth infomediaries. Maternal clients were more comfortable using mHealth infomediaries whom they believed that their privacy would not be compromised.

The maternal clients in this study perceived the use of a Personal Identification Number (PIN) to retrieve voice messages as a way of securing messages which they considered personal. Even though the PIN was meant for identification in CCPF, it was perceived as a privacy and security feature by the women using shared phones: "… *once I key in the secret number; they know it's me and give me my messages... and only me can listen to them* …." [Client 8]. The majority of the maternal clients using infomediaries preferred voice messages to text messages because anyone could read text messages and some women felt that their privacy would be invaded.

> *"I used to get messages on my mother's phone ... what was happening was that she could open my message, read it first and then give it to me. Sometimes she could tell me that I received a message from CCPF but someone was playing with her phone and it got deleted"* [Client 8].

Availability of the infomediary

Availability of the mHealth infomediary affected maternal clients' use of the mHealth infomediary, and consequently, the use of the mHealth intervention. When maternal clients live far away from the infomediary, they find it difficult to access the infomediary and the mobile phone. Furthermore, if the maternal client experienced a maternal health-related problem at night, it was not easy to visit the mobile phone owner and access the mobile phone before planning to go to the hospital [Project Document 5].

> *"You know in a village setup, houses are far apart, so to travel to the mobile phone owner who lives far away and find that the mobile phone owner is not at home is disappointing"* [Client 11].

Maternal clients who reside in poor-resource settings may struggle to find access to a mobile phone since mobile phone ownership in these areas is low (Larsen-cooper et al., 2015). Studies in maternal mHealth have found that distance to the infomediary may inhibit maternal clients access of mobile phone for maternal health-related issues (Duclos et al., 2017; Nyemba-Mudenda & Chigona, 2018). This is evident especially when the maternal client is in her third trimester of her pregnancy and cannot travel long distances (Larsen-cooper et al., 2015; Nyemba-Mudenda & Chigona, 2018). Furthermore, when the infomediary travels, it means that the maternal client may not have access to the mobile phone.

The study also noted that there was volunteer fatigue; this affected the level of motivation and, consequently, the availability of the volunteers. This could have been attributed to volunteers not compensated for their work and they had to look for financial resources to support their families. This affected their work. Proper volunteer management would contribute towards mitigating against this.

CONCLUSION

Despite the increase in mobile phone ownership, there are still inequalities in mobile phone ownership in rural settings. The poorest among the poor still face challenges in accessing mobile-phone mediated interventions that are meant to serve them. Use of shared mobile phones has the potential to mitigate against those challenges. This study focused on the use of infomediaries in maternal mHealth interventions in a rural setting. The study concludes that the characteristics of the maternal client, the characteristics of the informediary as well as the social context affects how maternal clients use and benefit from infomediaries. This study points to the need for managing infomediary systems to ensure that people at the bottom of the pyramid are able to benefit from the interventions.

Interventions should acknowledge that there are already people who serve as infomediaries for other purposes in communities. A number of women in the study used mobile phones of family members and other members of the community as well as traditional leaders. Such systems already define who may be acceptable infomediaries in a community. Interventions should leverage such systems instead of

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reinventing the wheel. We acknowledge that the existing systems may still be fraught with challenges that may exclude other potential beneficiaries. For example, a system based on a traditional system may still be punitive to young women falling pregnant out of wedlock. However, we are proposing that the traditional systems may offer a good starting point for designing a system which would work for communities. For example, one of the limitations of the study was the use of male infomediaries instead of the use of elderly women as infomediaries in the communities. We, therefore, recommend that future research may explore these possibilities.

One challenge noted in the study was volunteer fatigue. Managing the volunteer system in a way that would reduce the burden on volunteers would ensure sustainability of the volunteers. Further, the intervention should be designed in a way to minimize the burden on the infomediaries. For instance, the use of frugal technologies, such as basic mobile phones, could ensure that there are more infomediaries since the mobile phone would be readily available. Furthermore, there would be little effort on the infomediaries to train potential beneficiaries. In addition, the provision of power banks and durable portable solar panels to volunteers to ensure that mobile phones are charged all the time. This could address the limitation of mobile phone battery not charged when the beneficiaries want to use the mobile phone. At the same time reduce the burden on volunteers, of walking long distances to the trading centre to charge the mobile phone.

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APPENDICES

Appendix A. Summary of documents used in the study

DOCUMENT TITLE	DOCUMENT TYPE	AUTHORS	DOCUMENT NAME
Impact Evaluation of Malawi's Maternal Child Health and Nutrition Hotline: Chipatala Cha Pa Foni (CCPF) - Preliminary Report	Project information and CCPF use	(JIMAT, 2018)	Project document 1
Chipatala Cha Pa Foni: Healthcare through mobile phone	Project Information	(IWG, 2016)	Project document 2
Evaluation of the Information and Communication Technology for Maternal, Newborn and Child Health Project: Improving Access to Reproduction, Maternal and Newborn Health Information and Services in Malawi	CCPF use Report	(Watkins et al., 2013)	Project document 3
Evaluation of the Information and Communications Technology for Maternal Newborn and Child Health Project (Chipatala cha pa Foni)	CCPF evaluation report	(VillageReach, 2014)	Project document 4
Where there is no phone: The benefits and limitations of using intermediaries to extend the reach of mHealth to individuals without personal phones in Malawi	Published article	(Larsen-cooper et al., 2015)	Project document 5
Scaling up a health and nutrition hotline in Malawi: The benefits of multi-sectoral collaboration	Published article	(Blauvelt et al., 2018)	Project document 6
SMS versus voice messaging to deliver MNCH communication in rural Malawi: Assessment of delivery success and user experience	Published article	(Crawford et al., 2014)	Project document 7
Strengthening the home-to-facility continuum of newborn and child health care through mHealth : Evidence from an	Published article	(Fotso et al., 2015)	Project document 8

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intervention in rural Malawi			

Appendix B. Summary of demographic characteristics of the maternal clients in the study

CHARACTERISTICS	NO OF CLIENTS		CHARACTERISTICS	NO OF CLIENTS
Age range: 15-19	2		Months started ANC	
20-25	6		2	7
26-35	8		3	13
36-45	4			
Educational level			No of ANC visits	
Primary	17		4	9
Junior Secondary	3		5	11
No of pregnancy used CCPF				
1	13			
2	4			
3	3			

Appendix C: Summary of activities done in data analysis

PHASES OF INDUCTIVE THEMATIC ANALYSIS	ACTIVITIES DONE
Familiarisation	We translated and transcribed the audio interviews from Chichewa into English. The raw transcribed data (including the notes) was then imported into Nvivo 12 for analysis.
Theme development and coding	We used the concepts that we identified to create themes and subthemes (nodes and sub-nodes) in Nvivo 12. Data from secondary sources and empirical data was then coded in Nvivo 12. Using the whole data set, the researcher finalised coding the data
Reviewing themes	We reviewed the coded data extracts, where collated data extract of each theme were read to see if the current theme make a coherent pattern. If the data extract does not fit, they were moved to themes where they fit. The validity of individual themes in relation to the entire data set was also checked. Using Nvivo 12, the researchers developed a thematic map (*see Figure 2*) to see if it accurately reflects the whole data set's meaning compared to the conceptual framework.
Defining and naming	This phase involves defining and refining the themes that are going to be present in the finding chapter. The researcher identifies what is of interest in the data set

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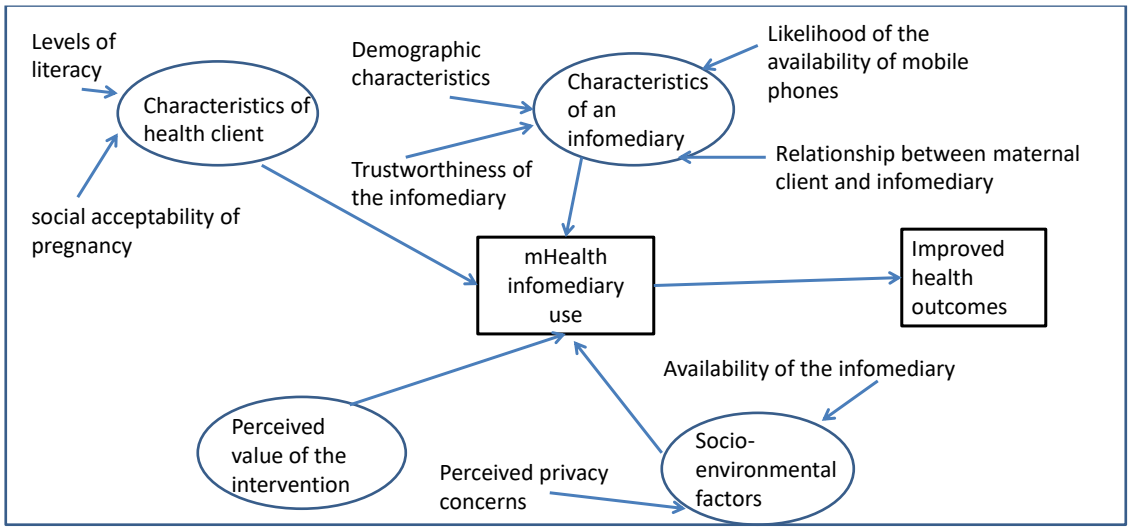
	and why, and the story that each theme tells. Themes and sample codes are presented in Table 4.
Writing up	The findings and discussion section of this study present the results and the interpretation of the analysed data.

Appendix D. Thematic map of mHealth infomediary use



Appendix E. Theme definitions of the main themes and sample codes

MAIN THEMES AND SUB-THEMES	SAMPLE CODES
Perceived value of the intervention	
	"It is a quick hospital service; they help us quickly" [Client 2].
	"CCPF information is very helpful, we were just staying and we were ignorant, we didn't know what to do. Most women were dying because they did not know when to go to the hospital when problems arise, because of lack of proper advice …" [Client 17].
Characteristics of the maternal client	
Literacy	*"The method that was used to access CCPF was difficult at first. It depended on the level of education to use it comfortably. But now it is easy, they have simplified everything ..."* [Community Volunteer 1]
social acceptability of pregnancy	*"I remember starting attending antenatal care when I was six months pregnant and registered for CCPF ... it is shameful to approach people on anything"* [Client 1]
Characteristics of the infomediary	

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Demographic characteristics	*"I was shy and uncomfortable when I found that the community volunteer was a man, I failed to speak about the problems I was facing"* [Client 10]
Trustworthiness	"*Normally I receive maternal related advice from my older aunt or grandmother because they take my pregnancy serious and they cannot disclose my pregnancy to anyone*" [Client 1].
Likelihood of the availability of mobile phones	*"Most of the times the problem is with the volunteers mobile phone… sometimes the phone is not charged… so she tell us to come again …"* [Client 15].
Relationship between maternal client and infomediary	*"Other people sometimes do not allow us to use their mobile phones. Most of the times, we used to use our relative's mobile phones ..."* [Client 17]
Socio-environmental factors	
Perceived privacy concerns	*"I used to get messages on my mother's phone... what was happening is that she could open my message, read it first and then give it to me. Sometimes she could tell me that I received a message from CCPF but someone was playing with my phone and it got deleted"* [Client 8]
Availability of infomediaries	*"You know in a village setup, houses are far apart, so to travel to the mobile phone owner who lives far away and find that the mobile phone owner is not at home is disappointing"* [Client 11].
Improved health outcomes	*"There was a time when my unborn child position was not good, so I called CCPF about it, so they helped me with advice on what I should do so that the child can turn properly... it worked and I had a normal delivery"* [Client 9].

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SWARM CONTROL MECHANISMS FOR MODELLING GENERIC SWARM INTELLIGENCE ONTOLOGIES

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ABSTRACT

Successful coordination of swarms of robotic devices into desired formation is a niche research area in swarm intelligence. Most swarm control mechanisms in the literature are built from mathematical, biological, physicomimetic, or hybrid angles. However, integration of different swarm control views into generic perspectives has been overlooked. The notion of swarm intelligence ontologies (SIOs) is intended to capture the theories, rules, and the policies within different swarm control mechanisms towards the proposition of generic viewpoints. SIOs are envisaged to establish the relationships between different swarm modelling paradigms to bring about generality. A comprehensive survey of inspiring swarm control mechanisms is required before generic SIOs are yield. Two arms of literature are dominant. On one hand, non-interactive swarm control mechanisms are mainly built on physics, mathematics, and other elitist methods. On the other hand, interactive swarm control mechanisms are commonly bio-inspired. This article reviews these two categories of literature with, as proof of concept, the specification of an SIO for path finding robotic devices in mind. We observe that most swarm control mechanisms assume robotic devices that can either recall the paths they previously followed, or those that can perform geometric computation to decide on the paths to follow. Other swarm control mechanisms adopt robotic devices that can use some form of language to communicate directional cues. In some cases, robotic devices can follow chemical tips towards the targets. A small group of robotic devices can use calculus, forces, beacons, or the landmarks in the environment to orientate. The communication strategies taken up by the robotic devices are often explicitly pinpointed (direct message passing, environment mediated, sensor-based, or vision). Also, the type of data shared between robotic devices is often overtly connoted (stacks, vectors, chemicals, forces, landmarks, or beacons). That way, the key activities of robotic devices at individual levels are usually apparent (reading stacks, interpreting language verbs, detecting chemicals, self-localizing, motion planning, or calculating directions). In our view, the knowledge with which to model generic SIOs can be born from these swarm properties and characteristics.

INTRODUCTION

Understanding the different ways in which robotic devices in swarms achieve emergent behaviour is an epic task [1]. In this context, emergent behaviour is the degree to which we see features at swarm level emanating from the individual actions of the members of the swarm [2][3]. It defines the synergy of the robotic devices in a swarm [4][5][6][7]. Grasping the concepts, policies, rules, and processes for coordinating and configuring robotic devices in swarms to cause emergent behaviour in different swarm settings is the main recipe for understanding the component units and building blocks of generic swarm intelligence ontologies (SIOs). This review article seeks to establish the actions of robotic devices in swarms which contribute to emergent behaviour at swarm level with the hope of prescribing the component knowledge domains of generic SIOs. As proof of concept, we assume the specifications of SIOs for path finding robotic devices.

SIOs are envisioned to capture the concepts, policies, rules, and processes of swarms while establishing the relationships between the component knowledge domains thereof through visualized connections.

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Building a generic SIO requires an understanding of the domain in which the SIO serves. A proper SIO can emanate from a comprehensive understanding of the different swarm control mechanisms supported in the connoted domain space. Identification of the basis of emergent behaviour in different swarm contexts and understanding the discrete actions of robotic devices in those swarms, which caused emergent behaviour in different scenarios [8], as well as pinpointing how those actions are interpreted into useful robotic device cues, pose challenges. The goal of this review is to isolate those discrete aspects of robotic devices that use different swarm control mechanisms in different scenarios, in this case path finding robotic devices, and use those aspects as prospective building blocks and basis for prescribing generic SIOs.

Two classes of inspiring swarm control mechanisms are distinguished in this survey. First, non-interactive swarm control mechanisms emphasize mathematics-based, physics-driven, and elitist robotic devices. On the other hand, interactive swarm control mechanisms are commonly built on biological colonies [1]. In swotting each category, we emphasize the control procedures inferred, the theory underpinning the approach, and the communication considerations embraced by the robotic devices of the swarms. Commonalities are pinpointed towards prescribing a general concise methodology for characterizing generic SIOs components.

NON-INTERACTIVE SWARM CONTROL MECHANISMS

This category of swarm control mechanisms is commonly modelled on mathematics, physics laws of motion, or hybrid approaches. The movement trajectories of robotic devices are mostly defined using equations, vectors, or matrices. The robotic devices thereof are characterized by *large storage capacities* [9] in which to keep positions of important objects [10][11][12], vectors [13], or information about the landmarks in the environment [14]. We isolate three sub-groups of non-interactive swarm control mechanisms to contemplate for the modelling of generic SIOs. First, mathematically driven robotic devices are dominant. Then, physics-inspired robotic devices also form a good chunk of swarm control mechanisms in this category. A few models include elitist robotic devices. The next three sub-sections of this section deliberate on the unique *control rules* assumed in each case, the pertinent *communication* policies followed, peculiar robotic device *orientation methods*, and the exclusive *movement cues* thereof.

MATHEMATICALLY DRIVEN ROBOTIC DEVICES

Robotic devices in this sub-category administer rigorous mathematical computations for the swarm to converge on some form of emergent behaviour. Prescribed *mathematical formulae* are used to define robotic device orientation and movement policies [9]. Two branches of mathematics (geometry and calculus) have been used for this purpose.

Geometry-inspired robotic devices neither require direct nor indirect interactions among themselves (hence non-interactive). Rather, each robotic device's positional preferences are based on the *cartesian geometry* of its location in the environment [15]. Robotic devices have abilities to *self-localize* relative to the positions of specific objects in the environment [15]. They perform *independent calculations* out of which they can orientate, measure their distances to targets, or estimate the angles to turn relative to specific objects in the environment [9]. Motion is handled using *velocity profiles* and collision avoidance schemes. Emergent behaviour arises from robotic devices' individual abilities to apply the mathematics laws thereof [9]. However, the requirement for these robotic devices to be computationally savvy, the need for the *ability to generate local coordinate systems* in which to self-localize, and the demand for robotic devices to have *large memory* suggest structurally sophisticated robotic devices. In addition, the need for robotic devices to be able to calculate velocities, distances, orientation angles, and define movement and collision avoidance profiles connote sophisticated robotic devices for the SIOs we anticipate.

Calculus-inspired robotic devices, on the other hand, can *calculate movement trajectories* based on the relative positions of *globally perceived objects* in the environment [16]. The main activity of every robotic device in this group is to *self-localize*. Also, *Jacobian matrices* have been utilized to facilitate robotic device

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self-localization [17]. However, the demand for *extra abilities to solve equations* and calibrate mathematical functions into directional information is heft, inflexible, and lacks the desired robotic device autonomy and simplicity to emulate nature for consideration in the design of the proposed generic SIOs.

PHYSICS-INSPIRED ROBOTIC DEVICES

Physics-inspired robotic devices observe known physics *laws* of motion. For example, a robotic device at rest will remain at rest unless some force acts on it. Also, a robotic device in motion remains in motion at a constant speed unless acted on by an unbalanced force. Additionally, robotic device acceleration or deceleration depends on the amount of force applied at the time. Whenever a robotic device exerts some force to another robotic device, the other robotic device will exert an equal opposite force. Three sub-classes of robotic devices are noticed in this category, namely, forces-based, mechanical, and hybrid robotic devices.

Forces-based robotic devices respond to in-built *virtual forces* for sensing their proximity to other robotic devices [18][19]. These robotic devices can *attract or repel* one another depending on their distances apart [20][21]. Movement speed and orientation are regulated using the *push and pull effects* from the virtual forces exerted between the neighbouring robotic devices [22], thus defining positional and the directional preferences of each robotic device [24][25]. Typical examples of forces-based swarms are connoted in [26][27][28], where it is shown how robotic devices can *self-organize* into mobile hexagonal lattices moving towards some target. The main causes of emergent behaviour, in this case, are the *sensory skills* of the robotic devices. Precisely, the potential field of energy that develops around each robotic devices is the key contributors to subsequent swarm actions – emergent behaviour. However, robotic devices in this class *lack autonomy*. Their behaviour relies on the density of attractive and repulsive counterparts around [29]. Worse still, these robotic devices should have *sensory devices mounted* onto them all the time. These specifications are not attractive for the design of generic SIOs envisioned for coordinating autonomous naïve nanite-like robotic devices.

Mechanically inspired robotic devices, on the other hand, are commonly propelled using *electric motors* physically mounted onto each robotic device. Orientation and subsequent *movement trajectories are predefined* in the motion firmware routines of the robotic devices. These electric motors are often *built with enough energy* to run for the duration of the task [30] given to the swarm. However, swarms in this category prevalently create *pre-programmed outcomes* rather than emergent behaviour. Besides, robotic devices in this class should be deployed in *specific densities*, where each robotic device has a *well-defined schedule of tasks* to accomplish [30][31]. Nevertheless, these robotic device properties are also unrealistic for the context in which we envision the use of the proposed generic SIOs.

Hybrid robotic devices possess a combination of the features of forces-driven and those of mechanical robotic devices. Typical hybrid robotic devices are inferred in [32] where, both virtual forces and geometric rules are put together to trigger swarm navigation. In their case, displacement equations are used when the robotic devices' sensory abilities detect obstacles. However, integration of different robotic device skills does not take away the complexities associated with the use of each model separately. Rather, more *special cases* are added to the design of each robotic devices' motion schemes [32]. Specificities of that nature are unattractive to the design of generic SIOs. Although these physics driven robotic devices are plausible in their own way, we anticipate more nature-inclined component units to the design of generic SIOs because of the robustness, fault tolerance, scalability, and flexibility that emanates from the swarms thereof.

ELITIST ROBOTIC DEVICES

Elitist robotic devices give rise to the third type of non-interactive swarm systems. They are designed with *sufficient memories* to *recall* previous experiences, then use the recalled information to infer appropriate future actions. Two groups of elitist robotic devices are noticed and differentiated by considering the kind of information robotic devices keep and share. One group can *recall the entire path maps* that

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were previously followed [10][33]. The other group *relies on landmarks and beacons* to trigger the actions to take next [14].

Path recalling robotic devices selectively choose the control mechanism to employ at a given time. Sometimes, they may recall the landmarks and beacons around, and use these to steer orientation [11]. In other cases, they may adopt a "memory" of what to do from the behaviour of the neighbouring counterparts [11]. However, when isolated, the same robotic devices may even make use of the direction and angle of the sun to guide their orientation [34]. A similar elitist model has been verified in [35], where robotic devices successfully used the behaviours of the neighbours to navigate with neither internal state access nor sharing of any experiences. A key parameter of emergence in these robotic devices is the mechanism in which path records are kept. Commonly, sequence generation techniques [33], and tabu search strategies [36] are employed.

There are swarm control models in which robotic devices *recall other robotic devices' identities* [37], thereby steering *one-on-one cooperation*. As such, robotic device activities at individual levels, and the degree of success at swarm levels, are dependent on the *quality of the information shared* [38][39]. However, use of *large memory* capacities is not popularly recommended in the design of globally worthwhile SIOs.

Landmarks and beacons-directed robotic devices also require *unlimited memory* [14]. Although the recalled landmarks provide direction *vectors* and orientation information that steer movements towards the desired directions, and though these landmarks are used to *estimate Euclidean distances* between the robotic devices and their targets [13], the *implicit computational demands* are undesirable. Desert ants have been simulated to exhibit such characteristics [40], achieving emergent behaviour without *neither direct nor indirect interactions*. Nonetheless, stigmergic interactions were shown to be completely impossible because the levels of the pheromone used dissipated well before they were useful to other robotic devices due to the harsh conditions in the desert. In other cases, robotic devices possess *selective abilities* to decide how to orientate based on the location of landmarks. Isolated robotic devices may realign by using *sensory hints* [41][42]. Once they are back in formation, they can follow specific vectors triggered by the information held in landmarks or other robotic devices [44]. Thus, the knowledge held by elitist robotic devices is frequently updated until *deterministic emergent behaviour* arises [45]. However, elitism eliminates robotic device autonomy.

INTERACTIVE SWARM CONTROL MECHANISMS

Interactive robotic devices are predominantly *nature* inspired. Most of them are modelled on the behaviours of living organisms such as cells [46], birds [19], DNA [47], bees [19], or ants [48]. Robotic devices in this branch *depend on one another* to complete individual-level tasks. Interactions, whether direct or indirect, are *local*. Two classes of interactive robotic devices are noticed, namely, those in which interactions are one-on-one, and those where interactions are indirectly mediated via the environment.

ROBOTIC DEVICES IN WHICH INTERACTIONS ARE ONE-ON-ONE

This class of robotic devices are commonly modelled with the *ability to exchange information one-on-one*. The information shared is often in the form of *memory blocks* that hold directional data [49], path histories [49], or positions of objects in the environment [12]. In some cases, robotic devices share *explicit calls* made in a specific robotic device *communication language* [50][51][52].

Important considerations in all robotic devices in this class pertain to the requirement to know what information should be transmitted between robotic devices, how the information is transmitted, and when it is appropriate for such information to be transmitted [53][54]. Consequently, three types of robotic devices in this group are distinguished from one another.

The first group explicitly *shares path histories*. In these, message blocks that hold path histories in the form of *stacks* are hopped from one robotic device to another [55]. These stacks usually record the *coordinates* of the paths previously followed [49] or information relating to the *best tours made* thus far

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[56]. Other tuples shared record the entire *environmental maps,* including pointers to promising locations in the environment [12]. Usually, a *learning framework* arises [57] in which robotic devices *learn the experiences of other robotic devices* by explicitly referencing their stacks. Learning robotic devices can create their own roadmaps to pursue based on the experiences of their neighbours [22][23][58].

Although the notion of information sharing is nature-inspired [59], three disadvantages emanate in this category. First, these robotic devices should possess *large memory* capacities to hold the shared message blocks. Also, these robotic devices' memory structures must be compatible with the *message blocks* shared. Thus, all robotic devices should be structurally similar [60]. More so, important information held in the memories of less successful robotic devices may be lost when the path histories of relatively successful robotic devices are preferred. That alone expediates data loss at swarm level.

Robotic devices that can *share geometric vectors* are more promising. These robotic devices do not require relatively excessive memory capacities since they would only keep a record of specific vector components [49]. There are cases where the vectors shared interpreted the levels of *pheromone* on the environment [61]. In other cases, these vectors interpreted the *geometries of specific objects* in the environment [49]. Although the features purported in these swarms may be considered in the design of generic SIOs, the need for substantial memory capacities is perturbing.

Robotic devices in which some form of a *communication language* is used have been reported as well. Most robotic device communication languages are developed with full *syntax*, *vocabulary*, and *semantics* only understood by those robotic devices [50]. Popular in this category are robotic device communication languages based on the *growing point* and *origami shape theories* [51]. In particular, the work of [62] is more inspiring, where a growing point language has been used to implicitly enhance pheromone dissipation in ant-like robotic devices. In other communication languages, high-level descriptions of functions and relationships among robotic devices are required upfront [63]. Such communication languages incorporate processes and properties to coordinate the behaviour of individual robotic devices for the duration of their functionality [64]. In most cases, sets of *pre-programmed coordination laws* and *primitive behaviours* are incorporated in the system upfront [65], together with the vocabulary for robotic devices to use [66]. Other robotic device languages support call protocols explicitly developed into robotic device *verbs* such as move, respond, avoid, recruit, or hello [29][67]. However, these calls are often *broadcast* to the entire swarm, *compromising privacy* and *autonomy* in the robotic devices.

A robotic device communication language based on *geometric primitives* and homeostasis maintenance has also been successfully used as an amorphous medium language [68][69]. In these works, the language was used to describe robotic device behaviour in terms of the spatial regions of the amorphous media [52], where neighbours only communicated utilizing a *shared memory* region [70].

Investigations aimed at identifying the *primitive behaviours* of ant-like robotic devices with abilities to communicate using specific communication languages have also been concluded. However, the proposed language is currently very limited in vocabulary [50]. As such, only a *limited domain of emergent behaviour* can be achieved. Attempts to propose robotic devices that can use *sentence messages* is in progress [71]. However, the results presented so far lack in that the roles of receiver robotic devices are made consequences of the desires of sender robotic devices [72]. In other words, the independence of the receiver robotic devices is grossly compromised. Nonetheless, these debates are bringing us closer to the design of desired generic SIOs.

ROBOTIC DEVICES IN WHICH INTERACTIONS ARE INDIRECTLY MEDIATED

Swarm control mechanisms where robotic device interactions are indirectly mediated are predominantly adopted from *chemistry* or *biological operations*. Virtual chemicals are usually placed on the environment to create a *shared memory* for the robotic devices in the swarm. These virtual chemicals are, often, placed onto the environment in two ways, either by some objects within the environment [73], or by the robotic devices themselves [74][75]. We refer to the robotic devices in the former group as *optimized*, and those in the latter set as *stigmergic*.

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Optimized robotic devices support the use of *chemical markers* that are placed onto the environment by some objects within that environment [73]. For example, chemical plume gradients have been created at specific points in the environment, which guided robotic devices to those plume sources [45][73]. What stands out in optimized robotic devices is the requirement to *self-localize* relative to the chemical sources [51][77]. In other words, *local coordinate systems* arise in which the robotic devices determine the direction to follow relative to the quality and position of particular chemicals around them [78].

In most cases, the chemicals define *unidirectional paths* [44]. As a result, additional *elitist mechanisms* would be required in situations where bi-directional paths are needed [7][34]. A common form of elitism involves robotic devices that can conveniently switch between different interaction strategies when it becomes necessary [12]. At times, robotic devices may use *sensory cues* together with chemical gradients [14]. In other cases, they may use some form of *limited vision* to augment chemical tracing [79]. However, the bulk of optimized robotic devices supplement chemical tracing with *extra memories* to recall previous experiences [80][81]. Further studies towards the identification of the primitive behaviours of optimized robotic devices are outside the scope of this review because elitism is not recommended in the design of generic SIOs [82][106] for the task at hand. Basically, elitism takes away robotic devices' autonomy [18][104][105][106].

Stigmergic robotic devices, on the contrary, can *excrete* specific levels of pheromones themselves [74][75][76]. These robotic devices make use of a *non-symbolic form of communication* mediated via the environment [82][83]. The term stigmergy was first used in 1959 by Grassé [84][85][86]. It is formed from the Greek words *stigma*, which means signs, and *ergon* which means actions. The term, therefore, captures the notion that robotic devices' activities would leave *signs* in the environment, signs which determine robotic devices' subsequent actions [87].

We distinguish between two types of stigmergic robotic devices [88][89]. One group comprises sematectonic stigmergic robotic devices [87] with abilities to *change the physical characteristics of the environment*. Some examples of sematectonic stigmergic robotic devices were depicted in the hole making problem [36], pit construction problem [90], and nest building problem [91][92][93][94][95].

The second group of stigmergic robotic devices are *sign-based*, where pheromone signs are dropped and marked onto the environment. Although these pheromone signs may not have direct relevance to the tasks being undertaken by the robotic devices at the time, they indirectly influence subsequent robotic device actions and behaviours, including those behaviours which may be task related.

In sign-based stigmergic robotic devices, *mobility is probabilistic* [48]. Path selection decisions are based on the levels of pheromones held in the local environment [96]. Sign-based stigmergic robotic devices are further classified into three sub-groups, namely: those that rely on a *single form* of pheromone, those that use *two levels* of pheromones, and robotic devices that can use *multiple levels* of pheromone.

The first group of robotic devices can excrete and perceive one and only one form of pheromone. All robotic devices in this category are sensitive to that single level of pheromone regardless of the task at hand. The source of the single level of pheromone is, often, the robotic devices within the swarm itself [75]. However, there are cases where search targets have been designed with abilities to excrete this single level of pheromone [41]. In such cases, undesired elitism arises [97].

Among the most popular examples of single-pheromone models is the double bridge scenario [74]. In this experiment, ant-like robotic devices excrete one level of pheromone regardless of the direction in which they are traveling across the bridge. The food source and the nest are situated on the different ends of the two-way bridge. The task of each ant-like robotic device was to travel across the bridge in search of food, and upon finding the food source, pick up the resource and return to the nest [33][74][98]. These trips were repeated for the duration of the simulation. Trodden paths emerged along the shorter bridge-way, penalizing longer routes.

In most cases, gradients emerge in which robotic devices move from low to high concentration of pheromone. However, again, elitist strategies are required when bi-directional movements are sought

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[34]. That requirement for elitism deems robotic devices in this group unsuitable for most practical applications envisioned in the design of generic SIOs.

Scenarios where robotic devices rely on two forms of pheromone are understood to minimize the need for elitism. Related robotic devices are prevalently sensitive to two different levels of pheromones that can co-exist in the environment [99]. Commonly, both levels of pheromone are placed in the environment by the robotic devices themselves, where one level of pheromone is excreted when robotic devices are travelling from the nest in search of the food resource, and another level is dropped when robotic devices travel in return trips [48][101]. However, there are cases where one or both levels of pheromones originated from other objects within the environment [100][102]. We envision SIOs that appreciate the later setup towards potential generalizability.

Robotic devices that support multiple levels of pheromone are also available. They are designed to remedy most flaws noted in optimized, single pheromone, and two pheromone driven robotic devices. These robotic devices are usually built on the notion that every extra level of pheromone added would reduce some form of elitism. As a result, the swarm intelligence systems thereof are relatively robust, fault-tolerant, flexible, scalable, and adaptive in supporting robotic device autonomy [41].

Several examples of multiple pheromone robotic devices have been simulated in medical scenarios. The work of [41] is a typical example in which mobile cancer cells were simulated as operating in human blood vessel-like environments. In their model, cancer cell-like robotic devices could excrete the first form of pheromone called cancer pheromone, which was attractive to cancer attacking robotic devices. Cancer-free cells excreted the second level of pheromone called obstacle pheromone, which was repulsive to cancer attacking robotic devices. This mechanism ensured that cancer-attacking robotic devices do not waste time examining cancer-free cells. Upon detecting a cancer cell, a robotic device excreted the third level of pheromone called alarm pheromone, which was attractive to cancer attacking robotic devices still in the seeking mode. As a result, helper robotic devices would be recruited around the cancer cell to destroy the tumour. This model has inspired the development of other nanite-like robotic devices deployed in similar inside-the-body environments [42][43].

Closely related to the cancer treatment model [41], was the wound detection system [97]. In this model, platelet-like robotic devices were simulated as moving inside vessel-like environments. These platelet-like robotic devices had the task to identify wounds inside blood vessels. The wounds excreted a wound pheromone which was attractive to the platelet-like robotic devices. The platelet-like robotic devices would only stick around a location if the concentration of wound pheromone was high enough to connote proximity to a wound. Robotic devices around a wound could excrete the alarm pheromone to attract other platelet-like robotic devices. Clean surfaces were regarded as obstacle-like, excreting some repulsive levels of pheromone to platelet-like robotic devices. This way, platelet-like robotic devices' medical testing time was not wasted on clean surfaces.

A major setback for most multiple pheromone models is that the sources of these levels of pheromones are, often, some objects in the environment, and not the robotic devices themselves, purporting elitism. Robotic devices should thus be able to *selectively perceive* these different levels of pheromone [104], distinguishing between the different meanings thereto [102][103][105].

Some stigmergic robotic devices combined the advantages of two pheromone interaction systems with those of multiple pheromone systems [1]. The study in [1] investigated robotic device activities in scenarios where one level of pheromone was excreted when robotic devices travelled in search of the targets, and another level was excreted when robotic devices foraged back to the nest-like starting point. Related environments supported chemical markers which indicate the positions of the key objects and targets, along with the directional pheromone levels dropped by the robotic devices. The key advantages of robotic devices in this category are *naivety* of the robotic device and *complete freedom* from the need to have large memory capacities. Key information is held in the environment. As a result, errors at individual levels would not affect completion of tasks at swarm levels, connoting robust and fault-tolerant solutions. These are attractive considerations for anticipated generic SIOs.

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DISCUSSIONS AND CONCLUSION

This review mainly distinguished between interactive and non-interactive swarm control mechanisms that may inspire the design of generic SIOs. It emphasized robotic device design strategies, the characteristics of different robotic devices, and the interaction techniques supported (direct or indirect). Different classes of robotic devices were identified (path recalling, geometric, language-based, optimized, stigmergic, calculus-based, forces driven, mechanical, hybrid, or beacon and landmarks based). Commonly inferred communication strategies were also noted (direct message passing, environment mediated, sensor-based, vision, or hybrid mechanisms). More so, the review discussed the different forms of data that is commonly shared where possible (stacks, vectors, chemicals, forces, landmarks, or beacons). Robotic device orientation strategies were summarized (vector-based, language-based, probabilistic, calculated directions, forces based, or cues steered by landmarks). Furthermore, the key robotic device activities at individual levels were also pinpointed (reading stacks, interpreting language verbs, detecting chemicals, self-localizing, motion planning, or calculating directions), together with the key parameters of emergence that characterize each class of robotic devices (robotic device memory, verbs, elitism, robotic device abilities, environment, laws of motion, or communication mechanisms). We make the following four observations that may inspire the creation of generic SIOs:

- Generally, SIOs should emphasize knowledge related to robotic device orientation and movement as the key ingredients for achieving swarm intelligence. Orientation is guided by some form of meta-information such as robotic devices' sensory skills or robotic device memories. On the other hand, movement is commonly based on specific displacement factors such as attraction or repulsion effects. This observation inspires possible computational choices when system developers select the primitive behaviours with which robotic devices can achieve orientation and movements. Robotic device orientation and movement are apparent policies to indispensably consider in the design of generic SIOs.
- Successful robotic device orientation relies on the availability of locally perceived information around the robotic devices (mathematical equations, geometry, forces, sensory factors, chemicals, or other robotic devices). This information is updated regularly to appropriately guide the swarm. The choices system developers may make regarding information update rules such as dropping levels of pheromones, pheromone evaporation or diffusion, vector modulation policies such as message passing, detecting targets, and normalizing vectors, are inspiring observations that may give useful cues to the building blocks for creating generic SIOs.
- Robotic devices require some basic memory in which to store important information. This observation inspires the architectural design of robotic devices and their internal states, which become apparent needs in the design of generic SIOs.
- Although robotic devices remain autonomous and naive, interactive systems often create some learning framework [53] - both at individual and communal levels - in which robotic devices collectively engineer solutions using shared knowledge. Related interactive robotic devices are fascinating, not because they are intelligent as individuals, but because they collectively achieve compelling emergent behaviour. The choice to investigate the actions of robotic devices can be inspired by the cooperative nature and the learning framework thereof. The dominance of interactive systems in achieving stable solutions, as well as the simplicity and naivety of related robotic devices is also compelling. Generic SIOs can learn from these observations.

The value of this review is emphasized by the following two contributions:

- Categorization of robotic devices forms the basis for the design of generic SIO knowledge domains. These generic SIOs will likely capture the different knowledge spaces towards expanding the scope of application of swarm intelligence systems.
- The properties and quantifiers of emergency connoted in each case are also important components of generic SIOs that inspire the choices and features of the SIO parameters.

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A few potential directions of future works emanate from the survey presented in this review. However, three stand out.

- Creation of the much-awaited generic SIO is overdue.
- A survey of approaches for quantifying emergency is also apparent. The pros and cons for using each specific measure of emergence in different situations can be additional meta-data.
- Practical applications in which emergency is evaluated using the envisioned generic SIOs are overdue. In these, specificity of the outcomes may be key.

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OPERATIONALIZING THE FUTURE OF WORK TO MEASURE JOB SUSCEPTIBILITY

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ABSTRACT

Aim/Purpose	This paper focuses on operationalizing the diverse discourses on the Future of Work (FoW) into a research model and instrument to measure the impact on job susceptibility in any given sector.
Background	Over the last few decades, the central focus in the discourse of the FoW has mainly been on how technological advancements have substituted jobs and skilled labor through the simplification of tasks. This has been at the expense of other non-technological factors that influence the FoW. The discourse on the FoW has also been difficult to operationalize with most of it being theoretical and conjectural.
Methodology	The paper adopts an abductive methodology, making use of a critical literature review and Santana and Cobo's (2020) bibliometric review of the FoW.
Contribution	The resultant FoW model and instrument enable the measurement of job susceptibility in any sector and are useful for operationalizing the highly abstract and theoretical concept of the FoW.
Findings	While the primary trigger for the FoW is innovative technological advancement, the discourse has often ignored the equally important and complementary political, social and economic forces that accompany any industrial revolution.
Recommendations for Practitioners	The FoW model and instrument have considerable implications for individuals and organizations as they present a clearer picture of the job risks and opportunities available for skills development. The instrument, subject to empirical validation, holds potential to provide a more holistic projection about the impact of future industrial revolutions as they unfold.
Recommendations for Researchers	The FoW instrument can be used to measure job susceptibility in any sector. The recommendations from each sector can be used to plan and respond to social, political and economic changes affecting work that is affected by technological advancements.
Impact on Society	The instrument enables society to better prepare themselves for careers knowing well the future prospects in the career. It also means that society can better prepare and avoid unnecessary displacement of workers.
Future Research	The paper is exploratory and future work will involve the empirical validation of the research model and instrument.

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Keywords The Future of Work, The Future of Jobs, Job susceptibility, gig work, job precarity, job losses, 4IR, Fourth Industrial revolution, automation, technological unemployment, new forms of work

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INTRODUCTION

Technology has been reorganizing the way people work since the invention of the wheel. The discourse on the role of technology in employment dates back more than 500 years ago when technological innovations notably began to transform production, trade and human livelihoods. In recent decades, the term "Future of Work" (FoW) emerged, describing a topic of interest focused on how shifts in the political, economic, social and technical environments would reshape work, how it would be done, employment opportunities, and threats facing workers.

In particular, the role of digital technologies in shaping the FoW has gained prominence as a field of research driven by the rapid advancements and their disruption of business and society. For example, Travaly & Muvunyi (2020) predict that by 2030, artificial intelligence (AI) will contribute $15.7 trillion to the global GDP. They attribute this growth to increased productivity from consumption effects. They add that augmentation between AI and people will enhance performance and consequently create $2.9 trillion of business value and 6.2 billion hours of worker productivity globally. Empirical data also shows that, globally, organizations are embracing digital technology, ultimately to gain efficiencies, reduce costs, enhance productivity and improve market share and profit margins. The World Economic Forum (2020) notes that companies are increasingly moving to restructure their workforces, transform the composition of their value chains, introduce further automation and expand their workforces to achieve deeper technological integration.

The impact of digital technology on the FoW is inevitable, and the political, economic and social environments must adapt accordingly to ensure that the outlook for the job market is positive. While there is a growing body of literature surrounding the problems and opportunities, there are limited solutions on how to address the identified challenges and prepare the workforce for the changes that are imminent. The implications of being ill prepared are that the social and economic benefits of the technological revolutions will be missed, while workers will face the threat of job losses and displacement. This paper therefore aims to operationalize the extant literature on the FoW and create a model that could help measure job susceptibility as a result of the FoW in any sector. The proposed model should inform or support decisions relating to the pursuit of alternative career paths, skills, education and occupations that will be relevant in the future. This would also enable sectors to better prepare their workforces, or even for individuals to prepare themselves to function in sectors that are changing dynamically. For example, in what some are already labeling the 5IR, such a FoW model would enable a sector to prepare for the changes the advancements will bring.

The rest of the paper is structured as follows; the next section describes the methodology that will be applied. The subsequent section presents the literature on FoW. The results are presented in the discussion and findings section. The conclusions of the study are presented in the final section.

METHODOLOGY

This study makes use of an abductive approach and a critical literature review of key studies to build on Santana and Cobo's bibliometric analysis on discourses of the FoW. Abductive methods embed both inductive (from empirical observations to patterns) and deductive (from patterns to empirical observations) to make sense of phenomenon ((Tolani and Twinomurinzi, 2019).

In this study, Santana and Cobo's (2020) bibliometric analysis on discourses of the FoW provided the base model (deductive) and a critical literature review (inductive) was used to reinforce the model. Table 1 summarizes the results of the abductive process with the identified themes, and the key constructs and their items.

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LITERATURE REVIEW

Gartner defines the FoW as "changes in how work will get done over the next decade, influenced by technological, generational and social shifts". Schwartz, Hatfield, Jones and Anderson (2019) extend this definition by adding the dimensions of 'what work will be done, who will do the work and where the work will be done'. Santana and Cobo (2020) further recognize the FoW as a result of more than just generational and social shifts. They classify the drivers of the FoW into four categories: political, economic, social and technological. Balliester and Elsheikhi (2018) classify the FoW into five dimensions: the future of jobs; job quality; wage and income inequality; social protection systems; and social dialogue and industrial relations. While many authors do not attribute a timeframe under which the future is considered, many studies generally hold a view of a decade ahead. For the purpose of this paper, we define the FoW as the imminent changes driven by shifts in the political, economic, social and technological environment, that will redefine what, how, where, when and by whom work will be done. These changes will affect the jobs available, the quality of jobs, wage and income inequality, social protection systems as well as social dialogues and industrial relations. The FoW is reflected in a new state of the workplace, workforce and jobs. This new state may be better or worse than the preceding state in terms of the social, political, technological or economic conditions.

While the FoW is influenced by forces such as climate change, globalization and demography (Balliester and Elsheikhi (2018), today, the discourse on the FoW is largely propelled by the unprecedented rate at which digital technology is disrupting business and society. In this regard there are two contrasting perspectives on the impact of technology on society, specifically on employment. One perspective emphasizes the threat of job losses, catalyzed by technological innovations such as automation, artificial intelligence, robotics and machine learning. Such innovations replicate human effort in job functions and threaten to displace workers with machines. Zervoudi (2020) reports that 47% of jobs in the United States (US) are at risk of automation, while in Europe, jobs at risk of automation are estimated at between 45% and 60%. The World Economic Forum (2020) argues that while more than 2.6 million jobs were displaced as a result of automation between 2007 and 2018 in the US, there was also a rising demand for skills in non-routine analytical professions.

The alternative perspective relating to the relationship between technology advancements and the FoW argues that technology advances society by improving efficiency, boosting productivity, enhancing the standard of living and improving the quality of life. This view places emphasis on the opportunities associated with technological advancements, rather than the loss of jobs. Economic theorists have researched this phenomenon for years. The work of Romer, which earned him a Nobel prize in 2018, recognizes that economic growth and technological change drive each other Schilirò (2019) .Romer's theories suggests that growth that is driven by technological change requires that there will be reconfiguration for new value to be created, and that the new state will be fundamentally different (Schiliro, 2019). This perspective does not overlook the job losses, but rather suggests that while jobs will be lost, new jobs will be created and there is a general inclination towards better overall economic outcomes. This view aligns with Karl Marx Compensation theory in Piva & Vivarelli (2018), which recognizes that jobs will be lost as a result of innovation but that the market will compensate for these losses. Compensation theory argues on the one hand, that the direct consequence of innovation is the loss of jobs. This occurs because the goal of innovation is to minimize the factors of production (mostly labor) involved in delivering a product or service. Contrarily, it also recognizes that there are economic forces which can compensate for the reduction in employment due to technological progress. Essentially, there are other economic advantages that will be achieved as a result of process improvement. These advantages can be derived in multiple ways, the most relevant to the FoW being as follows:

- Firstly, jobs are created in the areas where the new innovations emerge. Although compensation theory refers to jobs lost because of the introduction of new machines, it can also be relevant to the increase in jobs for information workers; secondly, compensation theory

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recognizes the efficiencies gained from mechanizing or automating processes. These efficiencies, according to Compensation Theory, result in cost reductions, which consequently lead to decreased prices, increased demand for goods and ultimately, increasing production and employment. Firstly, jobs are created in the areas where the new innovations emerge. Although compensation theory refers to jobs lost because of the introduction of new machines, it can also be relevant to the increase in jobs for information workers.

- Secondly, compensation theory recognizes the efficiencies gained from mechanizing or automating processes. These efficiencies, according to Compensation Theory, result in cost reductions, which consequently lead to decreased prices, increased demand for goods and ultimately, increasing production and employment.

Compensation Theory became the foundation of Say's Law in Piva and Vivarelli (2018, p.5) which theorized that "in a competitive world, the supply generates its own demand and technological change fully takes part in this self-adjusting process.". Schiliro, (2019) states that new value is created as a result of the reconfiguration that takes place and adds that the new socio-economic state is fundamentally different. This view is in line with Schumpeter's (1962) theory of creative destruction, which acknowledged the dichotomy between innovation and employment. History has shown that the economies at the forefront of industrialization have flourished, while those that failed to embrace a new paradigm brought about by technological advancements have trailed behind. Therefore, while job losses associated technological advancement are inevitable, the best way to mitigate the negative impact is to predict how best to reconfigure the workplace and workforce to meet the needs of the future state.

To date, literature on the Future of Work has focused on the jobs of the future, the socio-technological changes shaping the FoW as well as the impact of the FoW on the socio-economic conditions of society. Literature in the field is extant and disparate. Mitchell, Shen and Snell (2021) argue that research in the field is broad with few clear linkages or overall direction. Balliester and Esheikhi (2018) agree with this view, arguing that the FoW has many themes with no universal understanding of what it encompasses. Several authors have attempted to deconstruct the subject area by decomposing the concepts and themes. Frey and Osbourne (2017) for example, focused on job polarization issues by attempting to predict the relationships between the nature of work and the threat of job loss due to computerization. Their model predicts that transport, logistics, administrative and service occupations are highly susceptible to computerization and are at risk of job losses, while occupations that require creative and social intelligence are at the lowest risk. Frey and Osbourne's (2016) model is broad and makes assumptions based on the rate of automation of certain job types without considering the non-technology aspects of the FoW. For this paper, we draw on the model developed by Santana and Cobo (2020) which brings together the themes of the FoW over the last six decades and embraces both non-technology and technology aspects.

Santana and Cobo (2020) aimed to "systematize and provide a structure for research into the FoW". They conducted an analysis of key themes across literature over a time span of 60 years and identified key concepts which they classified as political, technological, economic or social. They also used a strategic diagram composed of a classification matrix with axes measuring the density and centrality of literature in each theme to determine its relevance. Themes with a high density of supporting literature and a high centrality (a measure of the level of interaction between a network with other network, that is, a reflection of the importance of the theme) were classified in the first quadrant as motor themes. Motor themes are defined as well developed and important themes. Themes that were characterized as having a low level of centrality, despite having a high density of literature were classified as specialized themes. Transversal themes were characterized as being high in centrality but low in density indicating that the themes are cross cutting multiple areas of interest. The last classification was basic or emerging themes, where both the density and centrality were low, indicating that either the theme is still emerging or it is declining in interest. Their analysis was systematic and rigorous and allowed key themes to be identified and categorized according to their importance. Santana and Cobo's (2020) model provides a foundation to either drill further into specific subtopics or to operationalize the FoW as a whole.

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Singh, Jha, Srivastava and Somarajan (2021) conducted a systematic literature review of the FoW and identified key themes in the research field. They applied the same matrix used by Santana and Cobo (2020) to classify the identified themes in terms of importance (centrality and density). They further expanded on those key themes to draw conclusions and directions for future research. Their study supported the view that while technological changes alter the nature of work, they also raise the standard of living of society by making organizations more productive and efficient. They argue that the HR function is critical in ensuring that the right knowledge and skills are acquired to drive the future work state.

While Singh et al's. (2021) systematic literature review produced more specific recommendations on how to address the challenges associated with the FoW, Santana and Cobo (2020) revealed a very definitive set of themes surrounding the FoW. All the themes identified by Singh et al. (2021) were also present in Santana and Cobo's model. Therefore, this study applies Santana and Cobo's (2020) model to operationalize the FoW by creating a model for measuring their identified themes to better understand their influence on the future of jobs in specific sectors. Table 1 summarizes the key themes identified by Santana and Cobo (2020) and will form the basis of the FoW conceptual model. The model will then be used to develop a research instrument making use of each identified themes as one or more items in the instrument.

DISCUSSION AND FINDINGS

The aim of Santana and Cobo's (2020) classification was to provide a framework to define and understand the FoW, specifically considering the extant literature in the field. This study aimed at operationalizing Santana and Cobo's (2020) bibliometric analysis on the FoW. The aim was to develop a conceptual model of the constructs that determine the FoW in any given occupation or sector, and to identify factors that can influence the outcomes for the future of jobs. A research instrument is developed to test the interrelationships between the identified constructs. Table 1. summarizes the themes and subthemes that were used to construct the conceptual model, based on Santana and Cobo's bibliometric model. Table 1. also lists the questions to be included in the research instrument and relates them to the emergent themes. The consequent conceptual model hypothesizes the relationships between the main constructs. Future research will involve applying the research instrument in an identified sector to validate the conceptual model. The aim of the instrument is to later test the relationships between the constructs for validation and refinement of the conceptual model. Table 1. is followed by a discussion on the key socio-political and socio-economic implications of technology advancements on the FoW. This section is concluded with a presentation of the resultant conceptual model.

Table 1: Summary of key themes and resultant questionnaire items

Classification	**Theme**	**Description**		**Questionnaire items**
				Rate the statements using the Likert scale below about your sector: *Likert scale: 1 – Strongly disagree – 5 Strongly Agree*

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Political factors	Industrial relations	Describes how labor institutions evolve (Santana & Cobo, 2020). Suggests that changes in the nature of work lead to structural and process changes in organizations (Singh et al., 2021). New forms of work are emerging and workers' rights, income are compromised.	P1 P2 P3	• Organizational processes and structures are evolving to suit changes in the workplace. • New forms of work compromise workers' rights. • New forms of work compromise workers income.
	Trade unions	Strong trade unions protect the interests of vulnerable workers and precarious jobs, and avert inequality (Anner & Pons-Vignon, 2019) The influence of trade unions is threatened by changes in the forms of work (Visser, 2019)	P4 P5 P6 P7	• Trade unions protect the interests of vulnerable workers. • Trade unions protect precarious jobs. • Trade unions avert inequality. • Trade unions have a declining influence.
	Educational policy from institutions	Public educational policy should respond to the needs of the workplace. Public education institutions should teach 21st century skills that promote the skills and capabilities to adapt to technological changes. There is a need for supportive programmes to keep vulnerable workers in the labor market (Gruen, 2017)	P8	• Public education is adapting to respond to the changing education and skills demands in this sector.
	Labor market	The balance of power between employers and workers is shifting with new forms of work such as gig work, telework. The job market is more competitive, with workers settling for lower wages with no career progression or basic conditions of employment.	P9 P10 P11 P12	• The job market has become more competitive • Workers have less bargaining power. • Employers have more bargaining power. • There is a gap between the skills required and the available skills.
Economic factors	Wage inequality	The balance of power between employers and workers has changed, causing a higher incidence of wage inequality. This corresponds with the rise of the gig and platform economies and rising unemployment due to technology displacement and job polarization.	E1 E2 E3 E4	• Wages are fair for ordinary workers. • Wages are fair for precarious workers. • Basic conditions of employment are fair for ordinary workers. • Basic conditions of employment are fair for precarious workers.
	Employment	Certain jobs are being made redundant, while the demand for certain workers in certain occupations is increasing and new jobs are emerging.	E5 E6 E7	• There are adequate job opportunities. • Certain occupational types are becoming redundant. • New occupations are emerging.
	Job Polarization	New technologies have reduced the demand for workers performing easily mechanized routine tasks. Low paid jobs are most affected by job losses	E8 E9	• Jobs in the sector can be easily mechanized, automated or computerized. • Jobs in the sector pay medium to high wage.

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		associated with new technologies. There is a higher relative demand for jobs that that require greater creativity or manual or interpersonal skills. Jobs in the upper wage bands (that require creativity and problem solving) and lower wage bands (requiring manual labor) are in increasing demand.	E10 E11 E12 E13 E14	• Jobs in the sector require medium to high skills. • There is a higher demand for jobs requiring creativity skills • There is a higher demand for jobs requiring emotional intelligence skills • There is a higher demand for jobs requiring leadership skills • There is a higher demand for jobs requiring problem solving skills
Job susceptibility	Job susceptibility	Jobs are at risk.	E15	• Jobs are at risk.
Social factors	Job precarity	There is a sense of job and income insecurity.	S1 S2	• Workers feel a sense of job insecurity. • Workers feel a sense of income insecurity (for example earn less in moving from permanent to gig work)
	Satisfaction	Changes in technology have affected the job satisfaction of workers.	S3	• Workers feel dissatisfied with their jobs.
	Burnout	Changes in technology have resulted in burnout of workers as they try to adapt.	S4	• Workers experience burnout in their jobs.
	Work life balance	Changes in technology have resulted in a poor work life balance for workers as they try to adapt.	S5	• Workers experience a compromised work-life balance.
	Vulnerable workers	Certain demographic groups, particularly older workers and less technology savvy workers are at risk of job losses due to the changing demands of their jobs.	S6	• Older or less technology savvy workers feel insecure in their jobs. • Gig workers are treated unfairly
	Talent	There are efforts to attract and retain the right talent to fit the new paradigm of jobs.	S7	• It is difficult to attract the right talent for the available jobs.
	Career	There is a need for constant career development to meet the changing demands on workers.	S8	• There are adequate career development to meet the changing needs of workers.
	Leader's values	Leaders' values should respond to the needs of the organization and workers amidst the changing technological environment.	S9	• Leaders' values respond to the changing needs of the organization.
	Corporate social responsibility	Companies have a responsibility to engage in good governance, fair business practices and investment into developing their workforce and ultimately contributing to the talent pool of the market.	S10 S11 S12	• Organizations in the sector have good governance practice • Organizations in the sector have fair business practices. • Organizations in the sector invest to develop their workforces.
Technological	Gig work	Gig workers fall within the classification of new forms of work, where workers have no long term formal contractual	T1	• Contractors can be appointed to fulfil specific job roles

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		arrangements with an employer and operate as contractors to fulfill very specific roles or tasks.		
	Telework	Refers to the ability to away from a formal, physical workplace. This form of work has become much more widespread since the start of the global Covid 19 pandemic.	T2	• Workers can fulfill their work remotely
	Automation	This phenomenon refers to the ability for jobs or tasks to be completed partially or fully by technology.	T3	• Jobs will be partially or fully replaced by technology
	New forms of work	'New forms of work' is an umbrella term that describes how traditional working arrangements are changing and relates to the place, time and nature of work, as well as the contract between worker and employer.	T4 T5 T6 T7	• The types of contracts between employer and employee are changing. • The place in which work takes place is changing. • Working hours are changing. • The type of work required from workers is changing.
	Crowd work	Individuals outside of the organization can pitch to fulfil projects or roles.	T5	• Individuals outside of the organization can pitch to fulfil projects or roles.
	Innovation	Refers to changes in processes and systems that allow organizations to deliver products and services more efficiently and effectively.	T6 T7 T8 T9	• There are innovations to processes that make work more effective. • There are innovative systems that make work more effective. • There are innovations to processes that make work more efficient. • There are innovative systems that make work more efficient.
	Digital Transformation	Refers to changes in the industry and organizations brought about by new digital technologies.	T10	• Digitization has transformed how work is done.
	E-HRM	Refers to changes in how the HR function is managed through digital technologies.	T11	• The Human resource function is managed primarily through electronic processes
	HR Analytics	Data analytics can be used to monitor worker data and track performance. This is unsettling to workers and may lead to violations of worker privacy.	T12 T13 T14 T15 T16	• Analytics plays an important role in the success of the organization. • Data analytics is used to monitor worker performance • Data analytics is used to track worker data. • Workers feel unsettled by the use of data analytics to monitor their performance. • Workers are unsettled
	Virtual HR	HR functions can be delivered effectively through employee self-service portals and other electronic mechanisms.	T17	• Some HR services are delivered virtually.

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Socio-economic factors

Santana and Cobo (2020) identify three fundamental shifts that have changed the nature of work and have been influenced by advancements in digital technology; these include new forms of work, flexible working arrangements and telework. New forms of work include gig work, platform work, crowd work and on demand work (Cobo & Santana, 2020). Flexible working arrangements and telework refer to how the traditional boundaries of time and place have shifted through the introduction of new digital technologies. Flexibility and telework can also be seen as part of the common theme of 'new forms of work'. While Santana and Cobo (2020) mention that these shifts change the nature of work, they do not mention that the nature of work is also influenced by changes in the actual jobs. Although workers may be able to adapt to changes in the place, time and the contractual arrangements surrounding a job, their ability to adapt to the changes in the actual work that must be done is far more challenging. For example, during the Covid 19 pandemic, workers across the globe were forced to adapt to shifting forms of work. Adapting to changes in the actual work to be done may prove more challenging than adapting to new forms of work. Santana and Cobo (2020) argue that workers may face high levels of stress associated with the need to adapt to new technologies in the workplace and the need to develop new competencies to fulfill changing job functions. Burnout, lack of job satisfaction, poor work-life balance and precarious jobs are cited as consequences of new work forms and changes in occupational types. Cruz-Del Rosario and Rigg (2019) also allude to a shift in the balance of power between workers and employers, where workers operate from "gig to gig, accepting lower wages and volatile contracts with no prospects of financial security, job stability, or career progression". They argue that short term gigs displace permanent positions, resulting in a generation of "net slaves". Cruz Del Rozario and Rigg (2019) add that workers are expected to be on standby to compete in an economic environment that is constantly in flux. These social factors have economic implications. The nature of work affects the challenges and opportunities in the labor market. The changing nature of work results in job polarization (Santana & Cobo, 2020; Campa, 2019), that is, the demand for jobs of a specific nature will decline, while other categories of jobs will become more widely sought after, There is consensus that the demand for jobs that require human intelligence such as creativity, emotional intelligence and higher order thinking will be increasing in the years ahead (Santana & Cobo, 2020; Singh et al., 2020; Balliester & Elsheikhi, 2018; Frey & Osbourne, 2016). Similarly, occupations requiring manual labor have also been predicted to see an increase in demand (Santana & Cobo, 2020, Campa, 2019). Mid skill and mid income jobs have been observed to be most at threat (Campa, 2019). This hollowing out of jobs amongst the middle class is a phenomenon that has been observed in past industrial revolutions (Campa, 2019). However, Frey and Osbourne (2016) predict that the emerging technological paradigm will witness displacement amongst low wage and low skill jobs. Santana and Cobo (2020) identify precarity as an important theme relating to the FoW. Precarity describes conditions of insecurity and uncertainty and often relates to the insecurity of income, jobs and working conditions.

Socio-political factors

There are many technology-induced threats facing workers today. Automation, digitization, autonomous systems and artificial intelligence have rendered many jobs redundant. The platform and gig economies have opened competition amongst workers, offering employers a greater advantage in bargaining wages and working conditions for workers. Advancements in data analytics have improved decision making, efficiency, business intelligence and performance in organizations, but also threaten the privacy and emotional wellbeing of users when used to monitor their data and performance (Silva, 2021). With the emergence of the platform economy, gig work, crowd work and other forms of informal working arrangements, workers face a higher threat of facing unfair labor practices, demanding greater intervention from labor institutions and government. Workers are also facing the threat of displacement by systems that can do their jobs more efficiently and effectively. Researchers agree that there are competencies that must be acquired by workers in order to adapt to the changing nature of work (Balliester & Elsheikhi, 2018; Santana & Cobo, 2020; Singh et al., 2021). Gruen

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(2017) states that educational policies need to be responsive to the dynamic needs of the job market and educational institutions need to focus on 21st century skills that will be relevant in today's job market. This calls for future skills that extend beyond knowledge acquisition, that will ensure that the workforce is adequately skilled for jobs that are changing and jobs that may not even exist yet.

Industrial relations involve the interactions and interrelationships between employees, employers, labor institutions and the state. Trade unions serve to mediate between policy makers, workers and employers to ensure that workers interests are protected. Visser (2019) recognizes the declining influence of trade unions over the recent decades. They observe that in developed countries, the density of union representation has been steadily declining. They also observed that union representation is notably higher in developing countries, and attribute this to the fact that most employees in developing countries do not have formal employee status. In the poorest countries, unions organize about 4 percent of formal workers, in contrast to the 6% in lower-middle-income countries (Visser, 2019). This is supported by Visser's study (2019) which empirically tested the relationship between unionization and labor rights violations and found a significant negative relationship. They also discovered a positive association between union density and economic development. Addison (2020) adds that the diminishing influence of trade unions is a greater concern now because of rising inequality and the loss of the voice of the worker. Unfortunately, Silva (2021) argues that employee relations are an area that have also been disrupted in the new technological paradigm. The rise of platform labor has added complexity to the ability for organized labor institutions to protect workers' interests. Lowe (1998, p.236) describes three philosophical standpoints relating to the FoW, one which champions change, one which hold a pessimistic view of change, and one which "advocates policy responses to shape change in specific directions". While all these positions are valid and are not mutually exclusive, the latter is solution oriented and offers a response to an inescapable situation. As a result, there is a need for critical reflection on the role of public policy and interventions to mitigate the threats to workers' rights in a technologically disrupted workplace. Silva (2019) describes this age as a golden age of creative destruction arguing that there is a need for social and political commitments to redistribute productivity gains to consumers and innovative firms. There is also a need for educational reform to address the knowledge and skills gaps that may preclude the constructive participation of the next generation of workers in a dynamic workforce Gruen (2017). Frey and Osbourne (2019) even recommend tax incentives to encourage mobility of technologically displaced workers.

The imperatives of Future of Work research

The literature review reveals several core interdependent imperatives of FoW research. Firstly, the discourse appears to be concerned with the welfare of workers and their need to be treated and remunerated fairly and to be satisfied within their jobs. Secondly, it emphasizes the impact of changes in the workplace on the socio-economic welfare of citizens as well as the effect on economic growth and development. Thirdly, it seeks to avert the insecurity and uncertainty associated with job precarity and technological displacement. Fourth, it recognizes the role of industrial relations in balancing the opportunities and challenges that may influence employment, affect the wellbeing of workers and support economic imperatives. It is also clear that the FoW is influenced by changes in the social, political and economic environments, while technology appears to be the main catalyst triggering changes in the social, political and economic environments. Finally, FoW research places emphasis on job susceptibility resulting from technology displacement. The FoW should ideally reflect a state in which technology driven changes can best be balanced through the social, economic and political conditions of a sector or country to enhance the wellbeing of workers, to promote equality in economic opportunities and to support socio-economic growth and development. Predicting and responding to the socio-economic and political impact of technology on the future of work may support stakeholders in mitigating the impact on jobs. The goal of FoW research should be to ensure that the right knowledge, skills and policy exist to enable workers to embrace technology to perform

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jobs that are relevant. It implies fully employing technology to make work more efficient, and to optimize the output of workers. The conceptual model is therefore grounded on these principles and is illustrated in Figure 2.

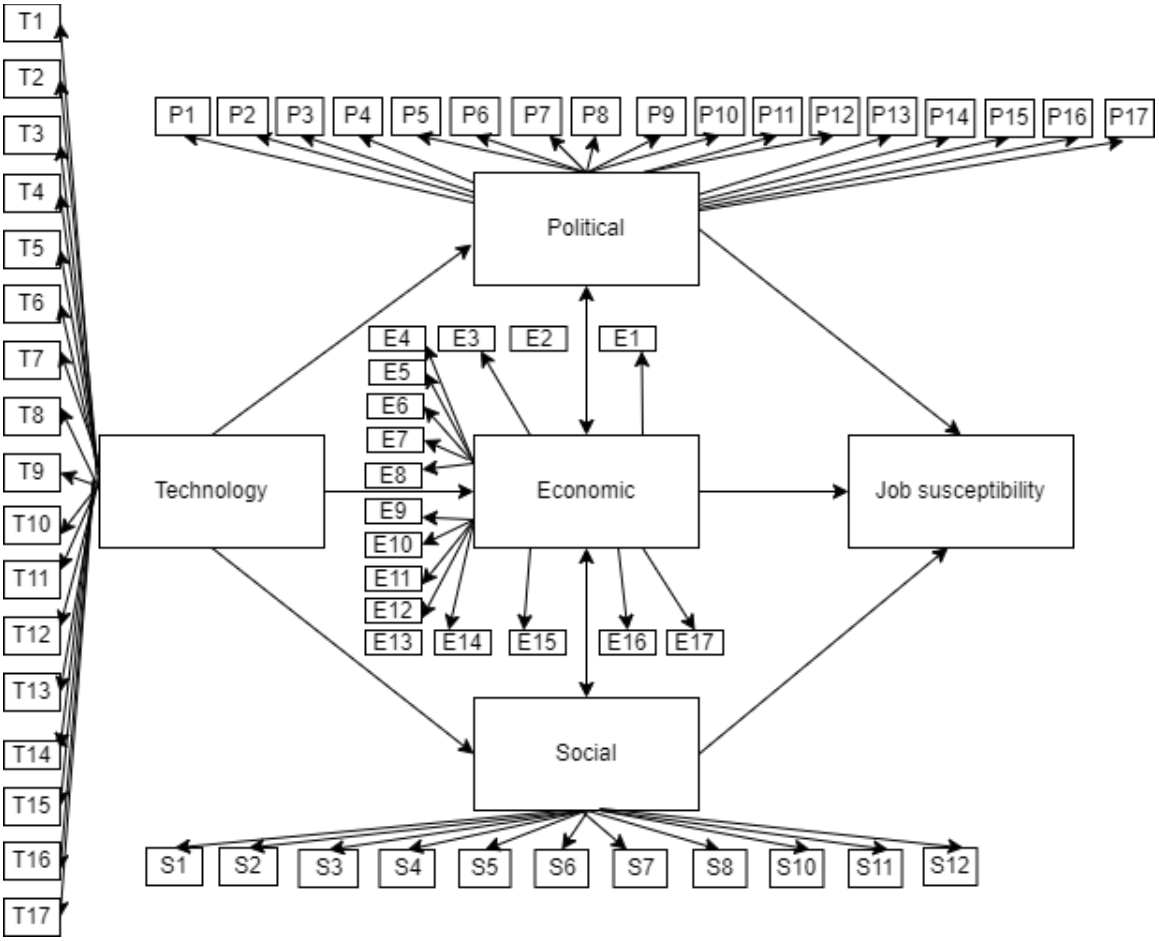

Figure 1: A conceptual model of the Future or Work and job susceptibility

CONCLUSION

This study has defined the FoW, critically discussed the factors that influence the FoW, and identified a measure (job susceptibility) for the impact of FoW research. We have further developed an instrument to empirically assess a sector's susceptibility to job losses and determine ways to prevent or respond to the risk of job losses. Future work will involve conducting a factor analysis to validate and refine the instrument and thereafter, we will apply the instrument to a selection of industries to validate the conceptual model.

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SYSTEMATIC MAPPING OF STUDIES ON THE ADOPTION OF DIGITAL WORK IN DEVELOPING COUNTRIES.

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ABSTRACT

Aim/Purpose	The purpose of this paper was to explore the current challenges and motivations for adopting digital work, the technology acceptance models/ theories used to research digital work and the benefits of adopting digital work identified in primary research articles.
Background	Digital work is one of the Fourth Industrial Revolution (4IR) products and is perceived to be a solution to addressing unemployment. There is a need to find a method to address unemployment in developing countries because of the socio-economic challenges.
Methodology	The methodology of this study is a systematic mapping of papers
Contribution	Identification of gaps in the literature for future research in web-based digital work in developing countries
Findings	Through the mapping of the selected articles, the paper identified the challenges, drivers and benefits of web-based digital work. Moreover, theories applied in the articles were also identified.
Recommendations for Researchers	Research must be conducted to create a framework to adopt web-based digital work. Moreover, research on how small companies in developing countries can benefit from outsourcing digital workers must be conducted.
Impact on Society	The paper contributes towards identifying the gaps in digital work research. These gaps may be used to promote web-based digital work in developing countries to tackle unemployment.
Future Research	Research to create frameworks to promote adoption of digital work in developing countries and the companies within the developing countries
Keywords	Digital work; microwork; freelancing online; crowd work; Digital gig economy, challenges of digital work, benefits of digital work, drivers of digital work; technology acceptance models/ theories

INTRODUCTION AND BACKGROUND

There is evidence of rapid economic and technological growth in Africa (Ponelis & Holmner, 2015). However, such growth has not translated into a considerable reduction of unemployment and poverty alleviation in Africa (Ponelis & Holmner, 2015). On the other hand, developing countries use digital platforms to address economic issues (Maidoki, 2018). In this regard, there are perceptions that digital work could be the solution to economic growth because it avails jobs around the globe (Onkokame, Schoentgen & Gullwald, 2018).

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Digital work is one of the Fourth Industrial Revolution (4IR) products (de Ruyter, Brown & Burgess, 2018). The rise of digital work was due to un/underemployment, companies' need to outsource services to reduce cost and increased connectivity (Galpaya, Perampalam, & Senanayake, 2018). Due to the rising discussions regarding 4IR, there are concerns about specific jobs becoming redundant; however, 4IR also creates new jobs (de Ruyter et al., 2018). Some of the issues associated with developing countries include unemployment, corruption, lack of skills, and infrastructure (Galpaya et al., 2018). In this regard, the increase in unemployment motivates the search for solutions to promote employment.

This paper presents a systematic mapping of studies conducted to explore digital work adoption in developing countries. The paper presents the challenges, benefits, drivers of digital work adoption, and the theoretical frameworks applied in the studies. This paper is structured as follows: the overview section describes terms and concepts related to digital work. The next section discusses the adoption of digital work in developing countries. The methodology and the findings of the mapping are outlined in the section that follows. Lastly, the conclusion and recommendations are presented.

OVERVIEW OF DIGITAL WORK

Digital work encompasses several online activities that range from minute tasks to projects assigned to humans online and are performed either online or at particular locations (Cherry, 2016; Chidoori & Van Belle, 2020; Graham & Anwar, 2018). Sison and Lavilles (2018) refer to digital work as the gig economy or online work. According to de Ruyter et al. (2018), digital work is divided into two main categories, location-based and web-based work, which Chidoori and Van Belle (2018) refer to as the on-demand gig economy and the digital gig economy. Location-based digital work requires the workers to be in a particular location to deliver the service or product (de Ruyter et al., 2018; Johnston, 2020). On the other hand, web-based digital work is when individuals obtain and conduct work online (Johnston, 2020). This paper focuses on reviewing studies conducted on web-based digital work. Web-based digital work is divided into platform creators, freelancers, micro workers, and content creators (de Ruyter et al., 2018).

DIGITAL WORK AND DEVELOPING COUNTRIES

Digital work is perceived to have the potential to contribute to developing countries' economies, which are plagued by numerous developmental issues (Graham, Hjorth & Lehdonvirtan 2017; Rani & Singh, 2019). The problems include extreme employment in the informal sector and unemployment in developing countries (Anwar & Graham, 2020b; Calvão & Thara, 2019). However, there are challenges associated with the adoption of digital work. Moreover, there are complaints regarding the exploitation of digital workers in developing countries compared to their counterparts in developed countries (Heeks, 2017).

Countries like Nigeria, Malaysia, Bangladesh, and Kenya have initiated interventions to encourage digital work (Rani & Furrer, 2019). The interventions include training programs in South Africa, Kenya, Nigeria, the Philippines (Eskelund, Heeks & Nicholson, 2018; Eskelund, Heeks & Nicholson, 2019; Romke & Sayed, 2018). Nevertheless, there is a need for policies, infrastructure, skilling, and internet access affordability to ensure digital work adoption (Rani & Furrer, 2019). Rani and Furrer (2019) further emphasise the need for policies to assess the quality of digital work in terms of working conditions and work content. Moreover, they suggest the need for strategies that delineate how to reap the benefits of online technology rather than blindly embracing it or rejecting it.

The purpose of this paper is to present a systematic mapping of studies that explored the adoption and uptake of digital work in developing countries. This paper will investigate the current challenges, benefits, and drivers of digital work adoption in developing countries. In addition, the paper presents the technology acceptance models used in the selected studies for mapping. The underlying research questions for this paper are defined in Step 1 of the methodology section.

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METHODOLOGY

The methodology for this paper is systematic mapping, also known as scoping studies. According to Petticrew and Roberts (2008), systematic mapping or scoping studies involves searching previous primary studies within a particular field to answer research questions. The search determines the types of studies, geographical location of the study, the outcomes and populations targeted, and the databases used to search for articles. Systematic mapping studies are mainly conducted to provide a structure for a particular research area driven by research questions (Petersen, Vakkalanka, & Kuzniarz, 2015). In addition, a mapping study aims to identify trends and gaps in a specific research area (Kitchenham & Charters, 2007). This paper identifies trends and gaps for future research in digital work adoption through scoping studies that focus on developing countries. The underlying research questions for this paper are used to determine the trends and the gaps.

This paper follows the guidelines and process of mapping studies suggested by Petersen, Feldt, Mujtaba and Mattsson (2008). The steps followed for performing systematic mapping studies are; definition of research questions (Scoping); conducting the search, screening of papers, keywording and abstract; data mapping and extraction

STEP 1: DEFINING RESEARCH QUESTIONS (SCOPING)

This step entails assessing the validity, need and feasibility of mapping studies about a particular topic. The research questions reflect an overview and drive the mapping of the study (Kitchenham & Charters, 2007; Petersen et al., 2008). In this paper, the research questions directed the search for papers in digital work. There is a need to identify gaps in digital work research because of its potential to provide unconventional means of creating employment in developing countries, where unemployment is high (Anwar & Graham, 2020a; Calvão & Thara, 2019; Rani & Singh, 2019). The gaps identified will assist researchers in identifying topics that need to be researched in digital work. Moreover, recommendations of policies may assist in addressing prevalent challenges in digital work. The research questions for this mapping study are as follows:

1. What are the current challenges in adopting digital work in developing countries?
2. What are the current drivers of the adoption of digital work in developing countries?
3. What technology acceptance models/ theories are used in digital work research in developing countries?
4. What are the current benefits of digital work in developing countries?

The search strategies used for this paper was the automated search strategy and the forward snowballing search strategies. The search strategies are defined in steps 2 and 4.

STEP 2: SEARCHING FOR PRIMARY STUDIES.

The automated search, also known as database search, was used for this study (Petersen et al., 2015). The automated search was conducted through searching the key terms' microwork', 'crowd work, 'freelancing online' and 'digital gig economy' and date range 2016 to 2020 in the digital databases and indexing systems. The databases used in this study were Science Direct, IEEE and EBSCOHOST. The indexing system used was Scopus. These databases and indexing system were used to ensure that the selected papers were double peer-reviewed. Clusters of articles to be reviewed and search strategies are also identified at this stage.

The search words used for this study were digital work (which was discarded because the phrase was ambiguous, thus producing some results not related to the targeted papers), microwork, freelancing online, crowd work and digital gig economy. The results were filtered by limiting results to papers published between 2016-2020. The summary of the search results is depicted in Table 1.

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Table 1 Databases, search strings and results

DATABASE	SEARCH WORDS	TOTAL RESULTS	2016-2020 RESULTS
Scopus	Microwork	34	21
	Crowd work	100	76
	Freelancing online	51	40
	Digital gig economy	168	155
Science Direct	Microwork	84	29
	Crowd work	43	37
	Freelancing online	2 427	833
	Digital gig economy	461	233
IEEE	Microwork	9	3
	Crowd work	4	2
	Freelancing online	7	7
	Digital gig economy	6	6
EBSCO	Microwork	195	33
	Crowd work	167	87
	Freelancing online	85	27
	Digital gig economy	97	46
Total			**1633**

The researcher uploaded the results into a folder on RefWorks, and the selection of the studies was conducted. RefWorks is a web-based reference management tool that imports and manages references from various databases (Reichardt, 2010). To add on, RefWorks assisted in the automatic removal of any title duplicates. Moreover, it allowed for manual removal of articles when sorted according to author names. The articles' titles were screened and removed from this database using the exclusion and inclusion criteria stated in step 3.

STEP 3 SCREENING OF PAPERS

In this step, the inclusion and the exclusion criteria are defined. Articles that did not focus on developing countries were excluded. The selection criteria adopted in this study are outlined in Table 2.

Table 2: Exclusion and inclusion criteria

DESCRIPTION	INCLUSION	EXCLUSION
Country of focus	Developing countries as described by the World bank	Developed countries as defined by the World bank
Words in the Abstract, or title or keywords	Implementation, adoption uptake, benefits, challenges, and theoretical frameworks	Any papers without implementation, adoption uptake, benefits, challenges, and theoretical frameworks
Subject	Work obtained and conducted online. Platform work web-based work, the digital gig economy	Location-based work, on-demand economy work
Language	Papers in English	The papers which were written in a different language
Research type	Papers that conducted primary data collection	Literature reviews and systematic reviews

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STEP 4 KEYWORDING OF ABSTRACTS (CLASSIFICATION SCHEME)

Studies were selected based on titles, abstracts, and full-text reading. Forward snowballing was also used to search for more papers on Google scholar. Forward snowballing is identifying new papers that cited a particular article (Wohlin, 2014). The search was conducted by finding studies regarding the adoption of digital work in developing countries using papers identified in the databases mentioned in Table 1.

The selection process and the number of selected papers are shown in Figure 1 and Table 3:

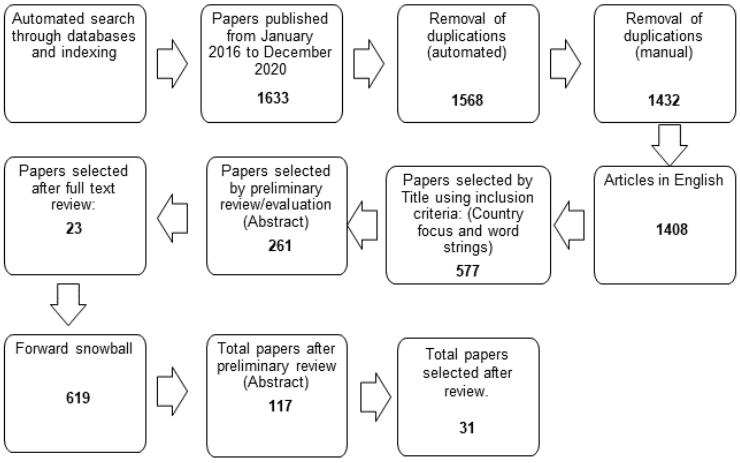

Figure 1: selection process and number of papers in each stage

The selected studies are depicted in Table 3.

Table 3: List of selected papers

NO	AUTHORS	PUBLICATION TYPE	YEAR	ISSUE
1	Agrawal, Lacetera & Lyons	Journal Article	2016	Trade between DC employers and LDC employees online
2	Chidoori & Van Belle	Conference Paper	2020	Attitude and motivations towards digital labour
3	Eskelund et al.	Conference Paper	2018	Impact of freelancing jobs
4	Fardany et al	Conference Paper	2019	Portraying online workers in Indonesia
5	Galpaya et al	Book Chapter	2018	Potential of online freelancing and microwork in Sri Lanka
6	Gandhi et al	Conference Paper	2018	Intention/ motivation to become gig workers
7	Graham et al	Journal Article	2017	Concerns of digital workers
8	Idowu & Elbanna	Conference Paper	2019	Career path for digital workers
9	Idowu & Elbanna	Journal Article	2020	Experience of digital workers
10	Krishnamoorthy et al	Journal Article	2016	Influences of adopting digital work
11	Malik et al	Conference Paper	2017	Motivation and needs of digital workers
12	Mtsweni et al	Conference Paper	2016	Improving task allocation
13	Nawaz et al	Journal Article	2020	Value and stress faced
14	Rani & Furrer	Journal Article	2020	Use of algorithms to assign work
15	Romke & Sayed	Journal Article	2018	The connection between freelancing and unemployment
16	Roomaney et al	Conference Paper	2018	Experiences of mobile digital workers

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NO	AUTHORS	PUBLICATION TYPE	YEAR	ISSUE
17	Sison & Lavilles	Conference Paper	2018	Practices of online software developers
18	Soriano & Cabañes	Journal Article	2020	Finding meaning digital workers
19	Sultana & Im	Journal Article	2019	Self-efficacy and entrepreneurship
20	Wang et al	Journal Article	2020	Experiences of crowdworkers
21	Wood et al	Journal Article	2019a	Job quality of the remote economy.
22	Wood et al	Journal Article	2018	Collective organisation of online workers
23	Wood et al	Journal Article	2019b	Job quality of remote economy
Selected from Forward Snowball				
24	Anwar & Graham	Journal Article	2020a	The role of Africans in Artificial Intelligence (AI)
25	Anwar & Graham	Journal Article	2020b	Role of digital work in African countries
26	Anwar & Graham	Journal Article	2020c	Digital work in African countries
27	Eskelund et al	Conference Paper	2019	Employability of people with disabilities online
28	Graham & Anwar	Journal Article	2019	Presenting global work
29	Malik et al.	Journal Article	2020	Institutional voids in digital work
30	Olsen	Journal Article	2018	Presenting implementation of initiatives to promote digital work
31	Soriano & Cabañes	Book Chapter	2019	Meaning of digital workers

STEP 5. DATA EXTRACTION AND MAPPING STUDIES

The papers were extracted using the template illustrated in Table 4:

Table 4: Data extraction template

ATTRIBUTE	VALUE	RESEARCH QUESTIONS
Article Title	Name of title	
Author name (s)	Set of names of the authors	
Country	The country where the study was conducted	
Research questions	The list of research questions	
Challenges	Challenges identified through the study	RQ 1
Drivers	Drivers identified through the study	RQ 2
Technology Acceptance Model/ Theory	Technology Acceptance Model/ Theory used for the study	RQ 3
Benefits	The benefits identified through the study	RQ 4

The selected papers were used to conduct a forward snowball.

RESULTS AND DISCUSSION

The results and analysis of the data extracted from the selected papers are presented in this section. Firstly, the research methodologies used, year of publication, where the research was based, and the publication types will be presented. Then the papers are mapped to the corresponding research questions.

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RESEARCH METHODS AND DISTRIBUTION PER YEAR

Most of the selected articles were published in 2018. Figure 2 illustrates the number of papers per research method and the years of publication.

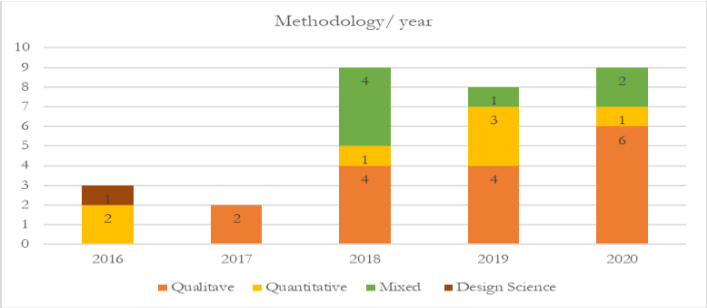

Figure 2: Research methodology per year

DISTRIBUTION OF PAPERS PER COUNTRY AND PUBLICATION TYPE

Most of the selected papers were based on digital work platforms, and only 31 focused on developing countries. The finding is aligned with the observation made by Wood et al. (2018), who stated that studies on digital work tend to focus on platforms rather than particular contexts. The distribution of papers shows that eight studies were conducted in Africa (South Africa 3; Nigeria 2, African countries, 3). Fifteen studies were conducted in Asia (China 1; Philippines 5; Sri Lanka 1; Malaysia 2, Pakistan 3, Bangladesh 2), three both Sub-Saharan Africa (South Africa, Kenya, and Nigeria) and Southeast Asia (Philippines and Vietnam). One paper (Rani & Furrer, 2020) investigated the effect of algorithms to assign work not specific to a particular developing country. Most papers that reported their findings from an African perspective focused on microwork rather than online freelancing. This report concurred with Idowu and Elbanna (2019), who pointed out that most papers in Africa focused on microwork, thus requiring more research on online freelancing. The extent to which freelancing is adopted in African countries is raised. The selected were primary peer-reviewed research. The papers were distributed as follows: Book chapters: 1, Journal Articles: 20 and Conference papers: 10.

CURRENT CHALLENGES OF DIGITAL WORK IN DEVELOPING COUNTRIES (RQ 1)

The challenges faced in adopting digital work as identified in the selected papers are categorised into barriers associated with up-taking digital work, challenges related to being a digital worker, and challenges associated with adopting digital work in the long run. The challenges related to the inability to adopt digital work are lack of internet access due to lack of infrastructure (Eskelund et al. 2018; Galpaya et al., 2018; Malik et al. 2017; Romke & Sayed, 2018) and slow internet bandwidth (Roomaney et al. 2018). Accessing the internet was identified as a barrier because of the high data costs (Eskelund et al., 2018; Roomaney et al., 2018). The studies further pointed out that the limited and lack of electricity was a challenge because it affected meeting deadlines for client service delivery. (Malik et al. 2017; Galpaya et al., 2018).

Lack of resources is another barrier identified in the uptake of digital work (Eskelund et al., 2018; Rani & Furrer; 2020; Wang et al. 2020). The lack of resources (laptops or computers) is linked to a lack of financial resources to obtain these assets. In some countries, although public internet access might be available, there is an issue of curfew in some areas, which could be a problem where a client requires work to be delivered within a specific time frame, thus the need for skills in time management (Eskelund et al. 2018; Nawaz et al., 2020). Lack of technical and interpersonal skills is one of the barriers to adopting digital work in the long run (Agrawal et al., 2016; Malik et al., 2017; Roomaney et al., 2018). Lack of skills can be further propelled by a lack of academic and technical education, as Roomaney et al. (2018) stated.

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Some challenges of digital adoption in developing countries are the negative perceptions associated with digital work compared to the traditional 9-5 office jobs: digital workers are perceived as unprofessional because they do not go to the office (Galpaya et al., 2018). Moreover, there is a stigma against online freelancing in Asian countries (Anwar & Graham 2020b; Galpaya et al.,2018; Romke & Sayed, 2018). These perceptions emanate from the cultural perceptions that when one is at home, they are not working, and thus one must go to an office to work (Galpaya et al., 2018; Romke & Sayhed, 2018). Some negative perceptions are further impelled by the required experience to undertake digital work (Galpaya et al., 2018; Idowu & Elbana, 2019; Romke & Sayhed, 2018). The most common are related to working conditions on digital work platforms. The working conditions identified are depicted in Table 5:

Table 5: Work conditions

WORKING CONDITIONS	EXPLANATION
No perks and benefits	Lack of Health benefits and retirement perks on digital work platforms. (Nawaz et al. 2020)
Disempowerment	Workers cannot negotiate the remuneration. Moreover, there are no contracts which means the 'client' can cancel work. There is also a lack of role clarity where the worker does not know the other processes of the client's business, which could improve the delivery of quality work. (Agrawal et al. 2016; Anwar & Graham 2020a; Graham et al. 2017; Graham & Anwar 2019; Nawaz et al. 2020; Soriano & Cabañes 2020)
Unequal relationship with the 'client'	The micro workers are perceived as independent contractors, but the relationship is like employer and employee. Thus, there is an exploitation of some digital workers (Graham et al. 2017; Malik et al. 2017; Malik et al. 2020; Roomaney et al. 2018)
Non-payment/ low payment	Some workers do not get paid when the 'client' rejects the work. Sometimes there are no explanations for rejecting the work. (Fardany Faisal et al. 2019; Graham et al., 2017; Malik et al. 2020; Rani & Furrer 2020)
Work pressure and physical demands	In some cases, the workers may have pressure from the clients. Anwar and Graham (2020b); Wang et al. (2020)

Furthermore, digital workers do not have consistent income because there is no guarantee that someone will hire them (Anwar & Graham 2020c; Galpaya et al., 2018; Rani & Furrer, 2020). Roomaney et al. (2018) also mentioned that mobile phone digital workers obtain lower pay than traditional jobs in the South African context. The inadequate compensation is because digital workers on the digital work platforms are more than the jobs (Graham et al., 2017; Graham & Anwar, 2019; Olsen, 2020). Galpaya et al. (2018) state that inconsistent income also results in the inability to access financial services such as loans.

Payment methods used by the digital work platforms are usually not aligned with the financial institutions' systems in some developing countries. For example, most digital platforms use PayPal to pay the digital workers; however, no banks in some countries are linked to PayPal (Galpaya et al., 2018; Malik et al., 2017; Nawaz et al. 2020).

Discrimination is evident in some job requirements where certain nationalities and genders are excluded (Graham et al., 2017; Malik et al., 2017). This discrimination could be due to complaints about the quality of work from the online workers in developing countries, which impedes the prospects of hiring online workers from developing countries (Mtsweni et al., 2016; Romke & Sayhed, 2018). Mtsweni et al. (2016) suggest a need for new ways of assessing the digital workers to ensure the alignment of tasks and the profile of the digital workers.

According to Sultana and Im (2019), social media communication with family and acquaintances is perceived to distract from digital work adoption. Social media is usually used to communicate and motivate

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digital work through forums; however, some workers may be distracted when accessing social media due to interaction with friends and acquaintances (Sultana & Im, 2019).

The lack of a defined career path and awareness of digital work may also challenge the adoption of digital work (Galpaya et al., 2018). Some digital workers remain in the same position without training, thus lacking progress in their careers. However, Idowu and Elbana (2018) have an opposite perception, depicted in the benefits of digital work adoption section.

CURRENT DRIVERS OF THE ADOPTION OF DIGITAL WORK IN DEVELOPING COUNTRIES (RQ2)

The drivers of digital work can be categorised into social, infrastructure, intrinsic/ personal drivers, and resources.

Social drivers

One of the identified social drivers is communication with clients and other digital workers (Anwar & Graham 2020b; Chidoori & Van Belle, 2020; Galpaya et al. 2018; Idowu & Elbana, 2020; Wood et al., 2018). According to Galpaya et al. (2018), communications through social media platforms allowed for peer learning and networking, which assisted some digital workers to transition from low-value jobs to high-value jobs (Galpaya et al. 2018; Gandhi et al. 2018; Malik et al. 2017). Sultana and Im (2019) concur with this notion. They state that digital workers receive tips, encouragement, and hacks to build their digital work career as freelancers through social media networking platforms.

Lack of traditional work opportunities, which led to increased unemployment rates, also drives the adoption of digital work (Chidoori & Van Belle, 2020; Idowu & Elbanna, 2020; Malik et al., 2017; Sison & Lavilles, 2018). Awareness about digital work also drives individuals to participate in digital work (Galpaya et al., 2018). The government and other agencies run awareness campaigns and training to promote the adoption of digital work (Eskelund et al., 2018). Flexibility drives caretakers to adopt digital work because they can take care of family members while earning income (Malik et al., 2017; Sison & Lavilles, 2018). Moreover, perceived freedom that comes with the nature of the work motivates individuals to participate in this work (Malik et al., 2017; Sison & Lavilles, 2018).

Resources owned by digital workers.

The resources include financial and material resources (Eskelund et al., 2018). The resources allow digital workers to access job opportunities and perform their assigned work consistently.

Intrinsic/ personal drivers

The skills of the individuals also motivate them to adopt digital workers (Anwar & Graham, 2020b; Chidoori & Van Belle, 2020; Eskelund et al. 2019; Gandhi et al. 2018; Krishnamoorthy et al. 2016; Soriano & Cabañes, 2020). These skills give the digital workers the confidence to conduct the tasks assigned on the digital work platforms (Eskelund et al., 2018). According to Eskelund et al. (2018), training individuals who need employment may promote the uptake and adoption of digital work. The training should also focus on equipping digital workers with psychological resources, which entails consistent reskilling of digital workers (Galpaya et al., 2018). The training motivates potential digital workers to adopt digital work because they become more confident due to the skills they obtained from the training (Galpaya et al., 2018).

Sultana and Im (2019) and Soriano and Cabañes (2020) revealed that entrepreneurial behaviour in unstable environments leads to better performance in digital work, thus leading to sustainable adoption of digital work. Desire to obtain income encourages individuals to uptake digital work (Chidoori & Van Belle, 2020; Eskelund et al., 2018; Gandhi et al. 2018; Malik et al., 2017; Wang et al., 2020), the freedom and ability to work from anywhere (Anwar & Graham 2020b; Eskelund et al. 2019) also motivates the digital workers.

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Infrastructural drivers

According to Krishnamoorthy et al. (2016), a safe and secure system motivates adopting digital work. Infrastructure includes electricity telecommunications infrastructure that promotes bandwidth and internet access because digital work relies on this infrastructure (Malik et al., 2017; Galpaya et al., 2018).

TECHNOLOGY ACCEPTANCE MODELS/ THEORIES (RQ 3)

Table 7 provides the theoretical frameworks used in the studies.

Table 6: Technology Acceptance Models/ Theories

TECHNOLOGY ACCEPTANCE MODEL/THEORY	DESCRIPTION	AUTHORS
Self-Determination Theory (SDT)	The theory proposes that humans are driven to change by three intrinsic and universal psychological needs: Autonomy, competence, and relatedness	Chidoori and Van Belle, 2020 Nawaz et al. 2020
Technology Acceptance Model (TAM)	It was developed by Davis (1989) and asserted that people's behaviour is influenced by attitude. The decisions are essentially influenced by Perceived usefulness and Perceived Ease of use	Chidoori and Van Belle, 2020 Krishnamoorthy et al. 2016
Theory of Reasoned Action (TRA)	The theory was developed by Fishbein and Ajzen (1967). The theory attempts to explain the relationship between behaviour and attitudes. According to this theory, one's behavioural intention is influenced by attitude and subjective norms towards the behaviour.	Chidoori and Van Belle, 2020
Choice Framework	This theory was developed by Klein (2010) to analyse the effects of ICT policies on the targeted beneficiaries and attempt to implement eh capabilities approach (CA).	Eskelund et al. 2018; Eskelund et al 2019
Super's model	It is a career framework that predicts career development stages outlined as Growth, Exploration, Establishment, Maintenance and Decline.	Idowu and Elbanna, 2019
The Job Demands-Control model	The theory was developed by (Karasek & Theorell, 1990) to illustrate how job demands can cause stress for individuals and how they can gain control and autonomy on their work using the stressors	Wang et al. 2020
Sustainable Livelihoods Framework	The Sustainable Rural Livelihoods Advisory Committee developed the framework. The framework depicts the factors that influence people's livelihood and relations between the elements.	Malik et al. 2017
Human capital theory	The Human capital theory attempts to measure the returns/ benefits for investing in education, experience, and skills of individuals	Nawaz et al. 2020
Theory of Planned Behaviour	It started as the Theory of Reasoned Action and attempted to predict human behaviour at a particular time and place. The six con-	Gandhi et al. 2018; Sultana & Im, 2019

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TECHNOLOGY ACCEPTANCE MODEL/THEORY	DESCRIPTION	AUTHORS
	structs of the theory are attitudes, behavioural intention, social norms, perceived power, and perceived behavioural control	
Grounded theory	It is the systematic method of formulating a theory using the findings of the research (Charmaz, 2003)	Sison & Lavilles, 2018
Conceptual Framework	The use of literature and other theories to formulate a framework.	Malik et al. 2020; Romke & Sayed 2018
The following did not mention any theory or model for their research: (Agrawal et al. 2016; Anwar & Graham 2020a, b,c; Fardany Faisal et al. 2019; Galpaya et al. 2018; Graham et al., 2017; Olsen 2018; Rani & Furrer 2020; Rani & Singh 2019; Soriano & Cabañes 2020; Wood et al. 2018)		

CURRENT BENEFITS OF DIGITAL WORK IN DEVELOPING COUNTRIES (RQ4)

One of the identified benefits of adopting digital work is obtaining secondary income for those already employed in the traditional 9-5 jobs (Galpaya et al., 2018; Roomaney, 2018). Graham et al. (2017) and Soriano and Cabañes (2020) state that one of the benefits of digital work in some developing countries is higher income than traditional jobs.

Digital work additionally attracts some individuals to participate because it is flexible; it allows home-based caretakers to obtain income, thus enabling them to have a work-life balance (Graham et al., 2017; Nawaz et al., 2017). The home-based caretakers include those who take care of the disabled, elderly and stay at home mothers (Graham et al., 2017). Moreover, there is less discrimination than traditional employment (Graham et al., 2017). Discrimination is usually experienced by immigrants, the disabled, the less educated, less work experienced, and redundant skills (Galpaya et al., 2018).

People starting their careers can acquire experience and skills by working on digital platforms (Graham et al., 2017). Idowu and Elbanna (2020) concur with this finding as their research also revealed that the skills obtained through digital work are transferable to traditional working environments. Additionally, through skills development, there is potential to build a career path through digital work (Idowu and Elbanna, 2019; Nawaz et al., 2020). This finding contradicts Galpaya et al. (2018), who state that there is no career path in digital work. Digital work allows the unemployed to find social value by building social value for themselves (Nawaz et al., 2020; Romke & Sayed, 2018). Moreover, digital workers can find hedonistic enjoyment by obtaining pleasure through conducting digital work (Nawaz, 2020).

Organisations also benefit from employing digital workers because digital workers improve productivity and costs in some organisations (Rani & Furrer, 2020; Wood et al. 2019a, 2019b). Nations can also obtain benefits by reducing unemployment and avoiding fraud and bribery(Romke & Sayed, 2018; Roomaney et al., 2018). In contrast to traditional work, where bribes and connections offer employment, corruption is evaded because there impartiality on the digital work platforms(Romke & Sayed, 2018). Moreover, there is a notion that digital work can develop and alleviate poverty in developing countries because it opens employment opportunities (Mtsweni et al. 2016; Rani & Singh 2019; Roomaney et al., 2018; Soriano & Cabañes 2020).

CONCLUSION

The purpose of this paper was to explore the current challenges of adopting digital work (RQ 1), drivers/ motivations for adopting digital work (RQ 2), the technology acceptance models/ theories used to research on digital work(RQ 3) and the benefits of adopting digital work. The challenges identified were lack of resources due to high data costs and lack of devices used to conduct digital work. Furthermore, in some developing countries, lack of infrastructure was a challenge, negative perceptions of digital work

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because of lack of long-term contracts, and adverse working conditions. The drivers for adoption were identified as social, infrastructure, intrinsic/ personal motivations. The need for income, social value and entrepreneurial spirit motivates digital workers to continue working even when faced with challenges.

Benefits for individuals included income, the flexibility of freelancing online, employment opportunities and the social value of contributing through digital work. The benefits for companies included reducing costs through outsourcing, and for countries, it is the reduction of unemployment. One of the gaps identified through scoping was the lack of frameworks to adopt digital work to benefit digital workers and the companies within the developing countries. In most studies, the clients or organisations benefiting from digital work are from developed countries. Table 7 provides a summary of the articles that were used to address the research questions:

Table 7: Research questions and authors

RESEARCH QUESTIONS	AUTHORS
RQ 1 – Challenges of adopting digital work	Agrawal et al. (2016); Anwar & Graham (2020a, b); Eskelund et al. (2018); Fardany Faisal et al. (2019); Galpaya et al. (2018); Graham et al. (2017); Graham & Anwar (2019) Idowu & Elbanna 2019); Mtsweni et al., 2016 Malik et al. (2017); Nawaz et al. (2021); Rani & Furrer (2020); Romke, & Sayed (2018); Roomaney et al. 2018 Sultana & Im (2019); Wang et al. (2020)
RQ 2- Drivers for adopting digital work	Chidoori & Van Belle, (2020); Eskelund et al. (2018); Galpaya et al. (2018); Gandhi et al. (2018); Idowu & Elbanna 2019); Krishnamoorthy et al (2016) Malik et al. (2017); Rani & Furrer (2020); Romke, & Sayed (2018); Roomaney et al. 2018; Sison & Lavilles, 2018 Wood et sl. (2018a); Sultana & Im (2019); Wang et al. (2020)
RQ 3- Technology Acceptance Models/ Theories	Chidoori & Van Belle, (2020); Eskelund et al. (2018); Gandhi et al. (2018); Graham and Anwar (2019); Idowu & Elbanna (2019); Idowu & Elbanna (2019) Idowu & Elbanna (2020); Krishnamoorthy et al (2016); Malik et al. (2017); Nawaz et al. (2020); Wang et al. (2020); Sultana & Im (2019)
RQ 4- Benefits of adopting digital work	Galpaya et al. (2018); Graham et al. (2017) Idowu & Elbanna(2019); Idowu & Elbanna (2020); Mtsweni et al., (2016): Malik et al. (2017); Nawaz et al. (2020); Rani & Furrer (2020); Romke, & Sayed (2018); Roomaney et al. 2018; Wood et al. 2018b

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TOWARDS THE CONCEPTUAL DIGITAL SKILLS FRAMEWORK IN SOUTH AFRICAN PUBLIC AND PRIVATE SECTOR

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ABSTRACT

Aim/Purpose	To Proposed conceptual framework for digital skills in south African private and public sector
Background	The Digital skills remains a critical requirement in this era of 4IR, in south Africa the unemployment rate the remain high and the majoring of our youth have university degrees but still lacks the experience and the digital skills which is been sought by their different industries.
Methodology	The methodological approach which has been selected for this study is based on qualitative research methods using grounded theory. Qualitative research is suitable when seeking to understand experiences and understanding their context in words. This study was conducted using primary and secondary data sets. Secondary data sets were sourced from reputable academic sources and recognized international organizations
Contribution	. This research, aims to contribute to the body of knowledge making available literature that can be referenced for implementation initiatives, furthermore the proposed Conceptual Digital skills framework can be adopted by the South African government and private sector to accelerating digital skills development efforts in closing the digital divide and skills shortage in this 4IR era.
Findings	It is evident from the results presented in this study that the conceptualization of digital skills needed for the digital revolution is key to accelerating digital skills development efforts. Indeed, research shows that efforts to successfully deliver these skills should begin at the national level through promoting good practices, developing a National Digital Skills Development Strategy, and building this capacity at school level to equip the young generation with the foundational skills.
Recommendations for Practitioners	That the proposed framework be adopted as work in progress in both public and the private sector and be enhanced where possible
Recommendations for Researchers	That the preliminary finding and the conceptual work be adopted, and further research be conducted to perfect it, so that in the near future it can be proposed to the South African government to adopt it as a full digital skills framework
Impact on Society	The literature also reveals that upskilling of the existing workforce should be a collaborated effort involving a partnership between the private sector, public sector, traditional training institutions, and non-governmental institutions incorporating new emerging learning models
Future Research	The Conceptual framework should be reviewed and be adopted to pave a way for a full Novel Digital skills framework seeking to address high unemployment rate among South African youth
Keywords	Digital skills, Digital readiness, Digital Skills Framework, 4IR

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INTRODUCTION

The digital technology revolution is already transforming and changing working environments and societies. Emerging technologies, which include machine learning, artificial intelligence, and robotics, are advancing at a rapid pace and represent an opportunity to improve operational efficiency and economic growth (Gekara, Snell, Molla, Karanasios and Thomas, 2019). This revolution, however, requires a workforce equipped with appropriate digital skills to thrive (Balacescu, Zaharia and Delia, 2019). South Africa is faced with the mounting task of bridging the digital skills gap prevalent in its economy to compete in the global community and to maximize the many prospects of this digital technology revolution.

Research shows that digital skills are a scarce commodity in the South African workforce (Schofield, 2018). This is more so in the public sector than in the private sector. Consequently, the public sector in South Africa lags in terms of digital transformation whilst the private sector is making progress. The private sector can attract the few skilled workers as it offers flexibility and attractive packages whilst government is often unable to provide such flexibility as it is highly regulated and bureaucratic. Nevertheless, the World Economic Forum (WEF) highlights that the fast pace at which emerging technologies are growing will lead to an increase in the shortage of digital skills in all industries (World Economic Forum, 2019). To overcome this challenge, the WEF recommends a holistic approach to skills development that is targeted at the existing workforce and untapped talent pools (World Economic Forum, 2019).

This study, therefore, proposes a conceptual framework for digital skills in both the public and private sectors in South Africa. It investigates the nature of digital skills requirements for both these sectors and proposes effective and holistic approaches for digital skills development for the country.

LITERATURE REVIEW

Digital skills are considered to be one of the prerequisites for innovation and digital transformations in organizations around the world. The growing use of digital technology in the workplace now demands all workers to have the digital skills that they require to perform their daily tasks (OECD, 2016).

While the concept of digital skills has been around for quite some time, research shows that this concept evolves as technology changes (UNESCO, 2018). Furthermore, the term 'digital skills' is often interchangeably used with terms such as 'digital literacy', or 'digital competence' (International Telecommunication Union, 2018 & Gekara et al., 2017). Consequently, research shows that there is still a lack of global understanding of the definition of these terms (Park, 2019). This Section introduces the accepted definitions and concept of digital skills that are adopted for this study.

DEFINITION OF DIGITAL SKILLS

UNESCO defines digital skills as "a range of abilities to use digital devices, communication applications, and networks to access and manage information" (UNESCO, 2018). This definition encompasses skills that enable individuals to create and share digital content, communicate, collaborate, as well as solve problems in the various spheres of life (UNESCO, 2018). A more comprehensive definition by Gekara et al. (2019) defines digital skills as a combination of digital knowledge, cognitive know-how, practical know-how, and competence that is required for the current and future digital environments (Gekara, Snell, Molla, Karanasios and Thomas, 2019).

This definition recognizes digital skills to be made up of hard technical skills which are needed to operate systems and software; cognitive skills required to process information and data; ethical skills

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for dealing with security concerns; and lastly strategic skills for planning and solving work related problems in the digital era (Gekara, Snell, Molla, Karanasios and Thomas, 2019).

Whilst traditionally the concept of digital skills was more focused on technical skills, or know-how of using software and hardware components, these definitions illustrate that the focus has shifted to incorporating non-technical abilities, such as cognitive, and interpersonal or soft skills (Gekara, Snell, Molla, Karanasios and Thomas, 2019). Subsequently, various literature reveals that digital skills can be categorized or classified into the following categories:

- Basic or generic digital skills
- Intermediate digital skills
- Advanced or specialist digital skills. (OECD, 2016; ITU, 2018; Gekara et al., 2019)

BASIC OR GENERIC DIGITAL SKILLS

Basic level digital skills are recognized as being those skills that enable individuals to perform basic tasks, such as using email, and other productivity tools, such as word processing, files management, searching, and others (OECD, 2016; ITU, 2018; Gekara et al., 2019)

Intermediate digital skills

Intermediate skills are recognized as those skills which enable individuals to create produce, analyses, interpret, visualize data, and create digital marketing or graphic design content (OECD, 2016; ITU, 2018; Gekara et al., 2019).

Advanced or specialist digital skills

Advanced skills refer to specialists skills needed by ICT professionals, such as programming, network specialist, artificial intelligence (AI), big data, cybersecurity, mobile app developers, etc. (International Telecommunication Union, 2018). This category also includes digital entrepreneurship skills required to successfully integrate technology with traditional business processes.

RELATED DIGITAL SKILLS FRAMEWORKS

21st-century digital skills

The concept of 21st century digital skills as defined by van Laar et al. (2017) is an integration of the traditional 21st-century skills, also referred to as 'soft skills' required to function in the knowledge economy, with the digital dimension. According to van Laar et al. (2020), the concept of digital skills no longer just focuses on technical skills but incorporates these soft skills as well. Therefore, the conceptualization of 21st century digital skills aim to meet the demand of the workforce by proposing a set of skills needed by the workforce to participate in the knowledge-based economy while leveraging information and communication technologies (van Laar, van Deursen, van Dijk and de Haan, 2017). The framework proposes the following conceptual skills:

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TECHNICAL SKILLS

These skills refer to the knowledge that workers require for using hardware, software, and digital devices. These skills are dynamic, and they evolve with technology changes (van Laar, van Deursen, van Dijk and Haan, 2020).

COMMUNICATION DIGITAL SKILLS

As a result of the inter-connectivity of the global economy, employees are required to have the skills to communicate using different communication media or platforms (van Laar, van Deursen, van Dijk and de Haan, 2020).

INFORMATION DIGITAL SKILLS

The vast amount of data and information being generated by systems require employees that have the skills for searching analyzing, and evaluating information from multiple sources (van Laar, van Deursen, van Dijk and de Haan, 2020).

COLLABORATION DIGITAL SKILLS

Work in the 21st century is increasingly being performed in groups or teams. This requires employees to be equipped with skills that enable them to work in partnership with each other, understanding their role and the role of those they are working with (van Laar, van Deursen, van Dijk and de Haan, 2020).

CRITICAL THINKING DIGITAL SKILLS

Critical skills are those skills required for solving problems. Critical skills in the age of information and communication technologies entail having the ability to make choices on the type of information or communication that is appropriate for a given context (van Laar, van Deursen, van Dijk and de Haan, 2020). It also entails having the ability to analyses and filter this information. Problem-solving skills involve applying critical thinking skills to find an appropriate solution for a particular problem (van Laar, van Deursen, van Dijk and de Haan, 2020). Creativity skills enable individuals to formulate new solutions to complex problems and to derive new knowledge from information (van Laar, van Deursen, van Dijk and de Haan, 2020).

Digital Intelligence (DQ) Framework

In an attempt to provide a global standard to the concept of digital skills, the DQ Institute in partnership with the OECD, IEEE Standards Association, and the World Economic Forum, has formulated a digital intelligence framework which comprises eight competencies considered to be essential in today's digital environments (Park, 2019).

The framework covers a range of competencies that addresses "technical, cognitive metacognitive, and sociology ,emotional competencies grounded in universal moral values" (Park, 2019).

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Figure 1: DQ framework

The eight competencies of the DQ framework as illustrated in the above diagram, figure 1, are briefly explained in the following list:

Digital Identity refers to the ability to create an online and offline identity (Park, 2019).

Digital Use refers to the skills required to operate and use technology in a healthy and civilized manner, whilst respecting the environment (Park, 2019).

Digital Safety refers to the competencies required to understand and mitigate the security risks associated with the use of technology (Park, 2019).

Digital Security refers to the competencies associated with detecting and avoiding cyber security threats to protect data, networks and digital devices (Park, 2019).

Digital Emotional Intelligence, is the ability to recognize, navigate, and express emotions in one's digital intra and interpersonal interactions (Park, 2019).

Digital Communication is the ability to communicate and collaborate with others using technology (Park, 2019).

Digital Literacy, is the ability to find, read, evaluate, synthesize, create, adapt, and share information, media, and technology (Park, 2019).

Digital Rights is the ability to understand and uphold human rights and legal rights when using technology (Park, 2019).

OECD Public Sector Digital Skills Framework

The technology evolution has transformed the needs and expectations of citizens about how they interact with the public sector and how they access public services (OECD, 2019). In order to drive the digital transformation necessary to meet these expectations, the public sector needs a creative and citizen-centric workforce equipped with the necessary skills to take advantage of the emerging technologies to respond to this need (OECD, 2019). Governments around the world are now, more than ever, increasingly required to increase their effort in digital skills development in order to

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enhance digital transformation (OECD, 2019). The OECD recommends a framework for the types of digital skills required by the public sector for driving digital transformation.

The four areas of this framework are illustrated in figure 2 below (OECD, 2019).

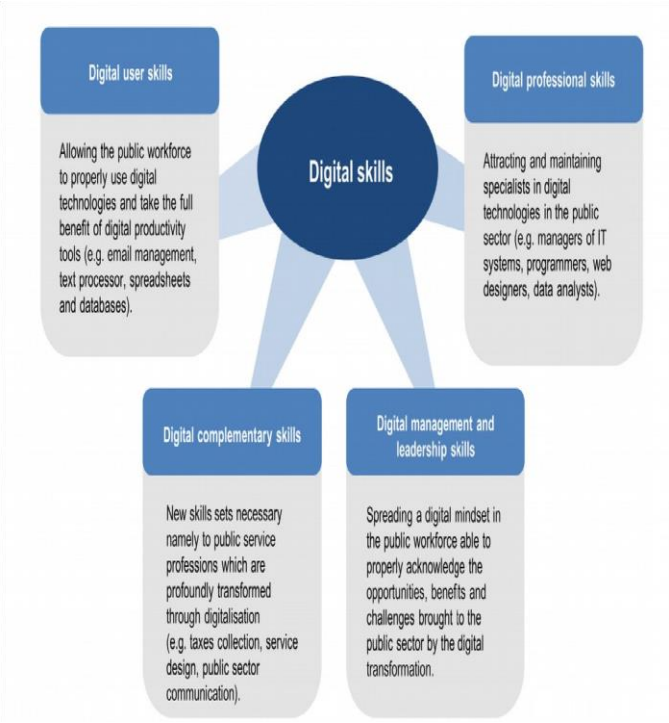

Figure 2: OECD framework

The framework comprises four key skills that the public sector needs to consider for driving digital transformation. They are:

DIGITAL USER SKILLS

These skills include abilities required for operating tools, such as email, word processing, spreadsheets, and presentation tools (OECD, 2019). These skills are already mandatory for most of the public and business sector workforce.

DIGITAL PROFESSIONAL SKILLS

Professional skills include the specialist IT skills required to manage and develop ICT resources (OECD, 2019). These skills include software engineers or developers, network specialists, enterprise architects, data scientist, database administrators, business analysts, product managers, etc. (OECD, 2019).

DIGITAL COMPLEMENTARY SKILLS

These are new skills that are required by the workforce as a result of digital technologies penetration into the different non-ICT-specific business functions or processes (OECD, 2019).

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RESEARCH METHODOLOGY

Research paradigm or orientation to knowledge

The philosophical assumption that underpins this study is based on interpretivism. Interpretivism is based on the assumptions that multiple realities can exist as the world is diverse (Kroeze, 2012). It places emphasis on the meaningful nature of people's participation in the social or cultural context (Mathison, 2005; Saunders, Lewis, and Thornhill, 2016). Furthermore, this philosophical position acknowledges that knowledge is continuously changing and is based on context (Kroeze, 2012). Whilst philosophies, such as positivism, places emphasis on statistical analysis and objective views, interpretivism emphasizes qualitative data and interpreting human experiences and meanings (Kroeze, 2012). Nevertheless, the vast amount of information available in literature on the concept of digital skills and related frameworks is an indication that no single narrative can be ascribed to the study of digital skills. It can, therefore, be assumed that the concept of digital skills is a contextual knowledge that can be studied subjectively. Consequently, as interpretivism assumptions believe that knowledge can only be understood subjectively, this makes it an appropriate view for this study.

Methodological approach/strategy

The methodological approach which has been selected for this study is based on qualitative research methods using grounded theory. Qualitative research is suitable when seeking to understand experiences and understanding their context in words (Given, 2008).

Data collection method

This study was conducted using primary and secondary data sets. Secondary data sets were sourced from reputable academic sources and recognized international organizations. The purpose of the secondary data is to provide the baseline on the concept and common definitions of digital skills found in the literature. One of the objectives of this research was to gain an understanding of the concept of digital skills required in the digital era, therefore, the reviewed secondary data sets will be used to deliver on this objective. Furthermore, the secondary data will be used to identify industry best practice and guidelines in successfully building digital skills capabilities for the workforce.

DEVELOPING A CONCEPTUAL DIGITL SKILLS FRAMEWORK

Proposed conceptual framework for digital skills

The literature reviewed in this study shows that the development of digital skills requires countries to invest in national digital skills frameworks (OECD, 2016); (Bellman and Eggers, 2015); (Gekara, Snell, Molla, Karanasios and Thomas, 2019). Frameworks allow for the capturing and categorizing of the nature of digital skills required by the workforce and citizens to provide a mechanism for countries to monitor and assess digital skills needs.

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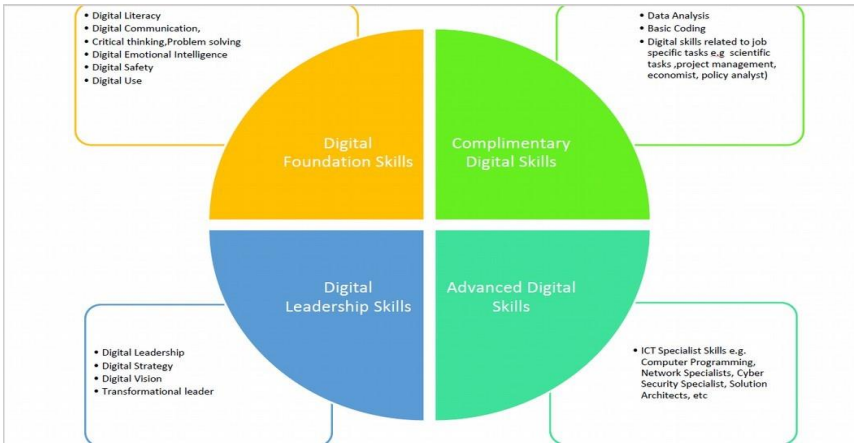
Even though research recognizes more than 60 digital frameworks, not all frameworks are adequate cover the needs of a workforce. Some frameworks, for example, tend to emphasize the basic and soft skills, while others the technical skills. However, this study identified four categories of digital skills required by the public and private sectors in South Africa. As illustrated in figure 3 these skills are:

- Digital foundation skills
- Complimentary digital skills
- Advanced digital skills
- Digital leadership skills.

The skills recommended in this framework were adopted from the two frameworks reviewed in this study which are the Digital Intelligence (DQ) Framework recommended by Park (2019) and the types of skills recommended by the OECD (2019). The skills recommended for this conceptual framework presents a combination of digital skills.

Figure 3: Conceptual digital Skills Framework



Digital foundation skills

Digital foundation skills are the basic skills required by every citizen to function. These skills include the eight competencies of the DQ framework which have been defined in the literature review section. These competencies include the basic skills required for operating hardware or software and the soft skills necessary for collaboration, communication, and relationship management in the digital context.

Digital complementary skills

The digital complementary skills are those skills which are related to job-specific tasks. These skills enable workers to use technology in performing work-related tasks, for example digital marketing, digital graphic design, financial analysis, etc. As technology continues to evolve becoming more integrated into business functions, it is envisioned that this will create new roles.

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Advanced digital skills

Advanced digital skills refer to specialist IT skills required by the IT professionals to implement, maintain, and support IT solutions. These include, among others, skills, such as computer programming, cloud computing, network management, artificial intelligence.

Digital leadership skills

The advent of the digital revolution has also given a rise to the need for leaders who are competent in leading digital transformations to create value for their organizations. The fusion of digital technology in business often creates new business models and introduces new structures that come with complexities and new challenges (Mihardjo and Sasmoko, 2019). Consequently, this change requires a transformational leadership style to optimize technology and create the organisational culture necessary to drive transformation (Mihardjo and Sasmoko, 2019).

CONCLUSIONS AND LIMITATIONS

The main aim of this study was to explore the digital skills required by both the private and public sectors' workforce in South Africa. The study has researched and analyzed existing literature to understand the definitions and concepts of digital skills required by today's workforce furthermore the study proposes the digital Skills conceptual framework that can be adopted by both public and private sector in order to address current skills shortage in south Africa.

How the objectives were met

This study sought to meet the following objectives which were set out in the beginning of the research:

- Gain an understanding of the concept of digital skills in the digital era
- Identifying the type and category of current and future digital skills required by the South African and private workforce to fully harness the opportunities offered by the digital era.
- Gain an understanding of challenges in current digital skills development efforts in the country.
- Identify skills development approaches to address the growing demand for digital skills in South Africa's workforce.

Objective 1: Gain an understanding of the concept of digital skills in the digital era

This objective sought to bring an understanding of the definition and concept of digital skills as it applies to the current digital revolution. Even though the literature reviewed shows that this concept has been in existence for a while, the literature also revealed that this term is often interchangeably used with other terms, such as digital literacy and digital competence. Therefore, the accepted definition which was adopted for this study recognized digital skills to be made up of hard technical skills which are needed to operate systems and software; cognitive skills required to process information and data; ethical skills necessary for dealing with security concerns; and lastly strategic skills required for planning and solving work-related problems in the digital era.

Objective 2: Identifying the type and category of current and future digital skills required

The second objective sought to identify the type and category of skills required by the South African workforce to drive digital transformation and thrive in the digital era. Through the review of global digital frameworks, such as the Digital Intelligence (DQ) framework and OECD framework for public servants, this study proposed the following category of skills required by public and private

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sector workers:
-digital foundation skills
-digital complementary skills
-digital advanced skills
-digital leadership skills.

Objective 3 Gain an understanding of the challenges in current digital skills development efforts in the country

This objective sought to investigate the challenges in digital skills development in both the public and private sectors in South Africa. Through data collected from respondents from the private and public sectors the challenges to digital skills development were identified to be the following:

- Lack of digitally competent leaders
- Lack of overall digital strategy.

Key contributions

This study recognizes the urgency in the South African context to accelerate digital transformation to realize the benefits and opportunities offered by the digital revolution. This research, therefore, aims to contribute to the body of knowledge making available literature that can be referenced for implementation initiatives, furthermore the proposed Conceptual Digital skills framework can be adopted by the South African government and private sector to accelerating digital skills development efforts in closing the digital divide and skills shortage in this 4IR era.

RECOMMENDATIONS AND CONCLUSION

It is evident from the results presented in this study that the conceptualization of digital skills needed for the digital revolution is key to accelerating digital skills development efforts. Indeed, research shows that efforts to successfully deliver these skills should begin at the national level through promoting good practices, developing a National Digital Skills Development Strategy, and building this capacity at school level to equip the young generation with the foundational skills. The literature also reveals that upskilling of the existing workforce should be a collaborated effort involving a partnership between the private sector, public sector, traditional training institutions, and non-governmental institutions incorporating new emerging learning models.

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SKILLING AND RESKILLING STUDENTS FOR RELEVANCE IN A 4IR ECONOMY

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ABSTRACT

Aim/Purpose	This paper examines the current school curriculum, vis-a –vis the literature on what the 4IR economy requires of its workforce. We submit that the current curriculum for Science, Technology, Engineering and Mathematics (STEM) courses at most South African universities do not align with skills requirements for a 4IR economy.
Background	The disruptive nature of technologies such as artificial intelligence, additive manufacturing nanomaterials and robotics has decidedly made the workplace of the future more complex, with traditional skillsets falling short in addressing the demands of the 4IR era. The authors discuss the need for current tertiary students to be skilled for futuristic, technology driven jobs in a 4IR economy.
Methodology	A methodical, structured literature review was conducted for the purpose of this research. The PRISMA framework was employed to select the relevant literature for the study. After screening and elimination of articles, 26 sources remained and were included in the study.
Contribution	The study proposes four critical success factors that government can adopt in order to formulate strategic and sustainable plans to ensure that students are appropriately skilled and positioned to operate in a competitive 4IR economy once they graduate.
Findings	The literature reveals a disjuncture between the current STEM curriculum and the required skillset required in a 4IR economy. The challenge leads to a state of unpreparedness of students in handling the fast approaching revolution in skills demand. The authors also found that soft skills, ideation, creativity and problem solving, which are not taught at school are critical for the workforce of the future.
Recommendations for Practitioners	Probable solution to the skills gap challenges is the implementation of content knowledge, incorporated with experiential techniques. This will lead to the shift from the institutions of higher education to the individuals through investing in skilling and reskilling students in practical ways.
Recommendations for Researchers	Future research should focus on how government, Industry and academia can effectively collaborate in ensuring that students are trained to apply content knowledge in creative ways which can solve many of the continent's problems.
Impact on Society	The findings reveal that government must work closely with academia and industry towards the goal of graduating skilled, employable graduates in the 4IR economy.
Future Research	Future research will investigate the extent to which students are being skilled by faculty to face future challenges.
Keywords	Student Skilling, Reskilling, 4IR, Higher Education, Curricula Design

INTRODUCTION

Historically, Africa is percieved as a laggard with regards to keeping up with technological advances in the world (Adendorff & Putzier, 2018). Countries such as Germany, the Netherlands, Japan and significant

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parts of Europe are now actively living in digitized spaces and taking full advantage of the technology affordances of the era (Shivdasani, 2019). However, the same cannot be said of their African counterparts. The development and influence of the past three industrial revolutions were not highly significant in Africa (Shivdasani, 2019). Many factors have been attributed for this slow pace, among them the dearth of infrastructure, a lack of planning, and a lack of governance (Adendorff & Putzier, 2018).

The Fourth Industrial Revolution (4IR) has been projected as an era with the capacity to deliver accelerated development to Africa (Manda & Dhaou, 2019). Several governments on the continent are scrambling to enact laws, policies and processes which will ensure their relevance, and position the country to take advantage of the opportunities presented by the technologies and capabilities of the 4IR (Kayembe & Nel, 2020). Industrialized nations, commonly referred to as the first world are far ahead of African countries in the adaptation of their economies to the technologies which enable the 4IR (National Planning Commission, 2020). Automation, occasioned by unprecedented technological innovations is the key driver of the 4IR (Baweja, Donovan, Haefele, Siddiqi, & Smiles, 2016). The integration of technologies in diverse digital, physical and biological spaces is a hallmark of the 4IR (Schwab, 2017).

The 4IR has been referenced in diverse terms. Among them are the Information Age, Industrial Internet of Things, the age of robotics, Industry +, the Fourth Economy (Kayembe & Nel, 2020). The era is touted as offering great opportunities as well as considerable threats to African economies (Allen, 2019). Opportunities are available to tap into the global economic value chain, enjoy the economies of scale that are part of a knowledge and data sharing connectedness across similar industries (Yusuf, Walters, & Sailin, 2020). African economies are also able to enjoy access to new technologies that offer affordances for solving peculiar continent problems and exploring new possibilities across the globe (Ayentimi & Burgess, 2019). In spite of the opportunities, research on how the 4IR will increase the inequality gap between Africa and the rest of the developed world abound (Mkansi & Landman, 2021). The disruptive nature of technologies such as artificial intelligence, additive manufacturing nanomaterials, robotics has decidedly made the workplace of the future more complex, with traditional skillsets falling short in addressing the demands of the 4IR era (Butt, Siddiqui, Soomro & Asad, 2020). The reality of this has brought to the fore, conversations about the role of higher education in skilling the future workforce to be relevant in the 4IR economy. In the same space, much has been written about the current university curriculum and its relevance to the skills required in an automated economy as occasioned by the 4IR (Moloi & Mhlanga, 2021). This paper contributes to the literature on the need for a relevant curriculum for universities in the country, and how to skill, and re-skill current students in order to enhance their chances of employability or entrepreneurship after leaving school. The education sector must be positioned to respond to Industry 4.0 skills need by raising technologically savvy graduates who can seamlessly translate their learnt skills and capabilities into the 4IR economic sphere. To achieve this, education as a whole in South Africa, Department of Higher Education and Training (DHET) and University faculties must take a critical look at the current curriculum, and make the necessary changes which would make future graduates employable, and relevant in a technology driven world.

METHODOLOGY

A methodical, structured literature review known as PRISMA was conducted for the purpose of this research. The PRISMA framework is utilised when authors want to contextualize and provide a detailed approach on the selection of the contents that were relevant for a study and how these were employed in order to reach a scientific conclusion. It is vital that there are set processes and procedures that a researcher follows when undergoing a systematic review of literature in a way that can be validated and verified scientifically (Moher, Liberati, Tetzalaff, Altman, & Prisma Group, 2009). The scope and quality of the literature incorporated in a study is as a result of a well-executed systematic review. In this study, the PRISMA framework formed the basis of the recommended steps followed to review literature on key skills required in the 4IR era. This approach was deemed beneficial in order to explicate solid and scientific grounds for the study (Moher et al., 2009).

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An iterative method of identifying critical, relevant, and recent literature on the topic of skilling, upskilling, and right-skilling university students for the 4IR workplace was conducted. The iterative approach is useful when a researcher seeks to understand, in-depth, a certain phenomenon and dig deeper into factors responsible for the phenomenon under investigation.

The iterative approach searches relevant literature which, may assist in the interpretation and appropriation of factors that are important to the successful transition of students from the classroom to the 4IR workplace. The search string with keywords such as upskilling, student re-skilling, 4IR workplace were used to search for relevant literature on the topic. The search parameters were further refined to include 4IR skilling, upskilling and reskilling, university graduates, employability, and 4IR. When the search strategy was defined, strings were used interchangeably to query. The paper's title, abstract and keywords, were searched using various key terms together with Boolean operator "OR", "AND" and wildcard *. "upskilling" AND "student", OR "upskilling AND university student", "Student re-skilling" +*re-skilling* student* AND 4IR, "skills in 4IR". Due to the diversity of search strings, the search result generated numerous inapplicable results. For instance, when sources such as Google Scholar was searched for "upskilling", it included a lot of managerial and workplace related studies without mention of upskilling for a student. Therefore, modifications were done in terms of keywords, "student upskilling" + "fourth industrial revolution". The inclusion of the "student" keyword significantly refined the search results, thus making the exclusion of articles to be more manageable. The selected parameters also contributed to a more refined systematic review.

The search iteration was repeated until the authors reached a saturation point i.e. could not generate new information. Five databases were used to source literature for this study; these include: Emerald, EBSCOhost, Google Scholar, Sage and Science Direct. The databases were selected mainly due to accessibility from the institutional library of subscribed databases; and contains a majority of reputable and high impact factor journals.

The search maintained the same keywords across the various databases initially, however, after seeing the yielded results, adjustments were made on the search strings. Peer reviewed articles from conference proceedings and journals were utilized. Section below details the PRISMA framework process for the study.

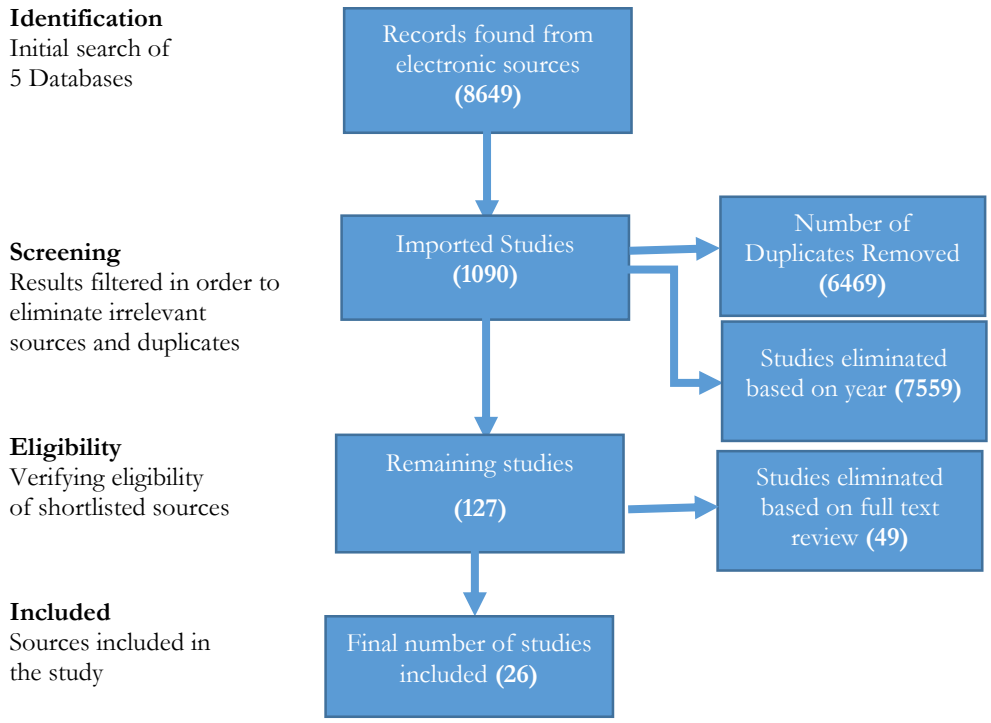

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Figure 1: Adopted PRISMA Model (Olaitan & Mavuso, 2021)

Screening of Articles

A total number of 8649 results were returned from the initial search of the various databases. The yielded results still required screening in order to eliminate irrelevant articles. The first step was to remove all duplicates that existed across and within each of the databases' results. The sorting and elimination of duplicates was done through using search engine filters. For instance, filters such as the period filter which limits the results to studies published between 2011 to 2021. The selected period was to try and get the most recent publications on the selected topic. A regional filter was applied in an attempt to get studies that discuss the fourth industrial revolution in the African context. However, due to the limited studies on 4IR skills in Africa, the filter did not yield much output, hence location was not used as a criterion in elimination of articles. The publications were required to have met the following criteria to be included: peer reviewed conference proceedings, journal articles, technical reports and thesis written in English on the Fourth Industrial Revolution in Higher Education, published between 2011 to 2021. Chain searching was used on these two publication types, hence all other peer reviewed research sources were not included. Articles published prior to 2011 were consulted in relation to any theoretical foundations or related models. Any paper whose full text was not accessible as well as a publication whose focus was not based on the specified search terms was excluded. After the screening process, a total number of 7559 articles were eliminated, resulting in 1090 sources to be put through the eligibility vetting process. Table 1 shows the number of articles per database.

Table 1: Number of articles per database

Database	**Initial search**	**1st order search**	**2nd order search**	**Final articles selected**
Emerald	**994**	94	19	6
EBSCO Host	**1117**	208	24	5
Google Scholar	**3998**	482	41	7
Sage	**1100**	107	22	5
Science Direct	**1440**	199	21	3

Articles included in the study

At the final stage, the remaining 43 articles were acquired in full text version. The steps included acquiring, reading, identifying and vetting of articles. All the articles in this stage were read. Full text reading was done to make sure that all content is in line with the study. The forward and backward method was utilised during the selection phase to further identify the most relevant sources. After reading the full texts, 26 sources were selected. The reduction was caused by the sources not focusing fully on re-skilling students in the Fourth Industrial Revolution. Some articles' full text was not accessible and some were not focusing on student's skilling and reskilling. Table 2 lists a summary of selected key articles deemed to be the most relevant to this study, based on the study's objectives and recommendations given. Key points include: re-skilling of students, 4IR skills shortage and solutions and university students & 4IR.

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Table 2:List of key articles

Author Details	Article's Objectives	Publication Type	Keywords & key search string
Kayembe, C., & Nel, D. (2020). Challenges and Opportunities for Marketing Scholars in Times of the Fourth Industrial Revolution	The article focused on the South African education sector. The findings of the study stated that the education sector in South Africa is facing a number of challenges. The challenges include insufficient funding, infrastructure, and skills to prepare graduates to participate in the 4IR.	African Journal of Public Affairs	Artificial intelligence (AI); Big data; *Fourth Industrial Revolution (4IR);* Internet of Things (IoT); Robotics.
Manda, M. I., & Dhaou, S. Ben. (2019). Responding to the challenges and opportunities in the 4th industrial revolution in developing countries.	The purpose of the study was to understand the challenges faced by developing countries in the adoption of digital transformation agendas in order to influence the social and economic benefits of the digital-driven industrial revolution 4.0.	ACM International Conference Proceeding Series	Socio-technical, *4th industrial revolution*, smart society, digital transformation.
Adendorff, C., & Putzier, M. (2018). A Causal Layered Analysis of South Africa's Readiness for the Fourth Industrial Revolution Towards 2035.	The paper addressed global trends and drivers for change through environmental scanning efforts within the 4IR, and how this directly impacts on the creative economy in general.	IMESA Conference	*Fourth Industrial Revolution* (4IR) Future workforce, digital transformation.
Bennett, D. (2018). Graduate employability and higher education: past, present and future.	The article focused on answering the question: how might higher education students be prepared in order to navigate an increasingly complex world and labour market in which they will need to think for a living? The labour market environment into which graduates transition was closely analysed .	HERDSA Review of Higher Education	Graduate outcomes, graduate attributes, graduate labour market, *university*, graduate work, career development learning, work integrated learning, *higher education* policy.
Mkansi, M., & Landman, N. (2021). The future of work in Africa in the era of 4IR- The South African Perspective.	The paper explored South African universities' 4IR readiness alongside the backdrop of general industry 4IR adoption. Interpretive interviews with three leading 4IR education training and industrial automation company directors were conducted in order to determine the available skills sets and/or labor force readiness.	Africa Journal of Management	*Fourth industrial revolution (4IR,)* automation, labor market, *curriculum redesign.*

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Yusuf, B., Walters, M., & Sailin, S. N. (2020). Restructuring Educational Institutions for growth in the 4th Industrial Revolution(4IR): A Systemic Review.	The study's focus was on how the delivery of education will be undertaken and how educational institutions will be restructured by the 4IR in order to prepare students for challenges in the future.	International Journal of Emerging Technologies in Learning (iJET)	*Fourth Industrial Revolution, Educational Institution*, technology, student and workforce.
Waghid, Y., Waghid, Z., & Waghid, F. (2019). The Fourth Industrial Revolution Reconsidered: On Advancing Cosmopolitan Education.	The article's main objective was on the investigation of the impact of prioritising the cosmopolitan human condition in reference to university teaching and learning, and how the fusion of 4IR fits in.	South African Journal of Higher Education	*Fourth industrial revolution, higher education*, cosmopolitanism.
Sikhakhanea, M., Govender, S., & Maphalalaba, C. (2021). The extent of South Africa's preparedness to counteract 4IR challenges: learners' perspectives.	The aim of the paper was to explore learners' perspectives on how their schools are preparing them to prosper in the Fourth Industrial Revolution (4IR) era which is powered by Artificial Intelligence (AI).	Journal of e-Learning and Knowledge Society	Artificial Intelligence, *Fourth Industrial Revolution,* Level of Preparedness, Technology Acceptance Model.

LITERATURE REVIEW

THE 4IR AND AFRICAN REALITY IN CONTEXT

The 4IR has been described as the era in which technology enables the integration of physical, digital and biological worlds; a blend with the capacity to impact businesses and industry in very profound, disruptive ways (Schwab, 2017). Addendorf et al. (2018) are of the opinion that the 4IR brings critical but necessary disruptions to personal, interpersonal and intrapersonal relationships and affordances in both public and private spaces. The Covid-19 pandemic has evidenced this position as convergence and congruence in the workspace were mostly online for over a year. The nature of jobs, and the required skills to perform them is rapidly changing. It is projected that as many as 40% of current jobs would have become obsolete by 2050, and 65% of youths will have jobs that do not yet exist at this present time (Lewis, 2020).

Additionally, the global youth unemployment rate is three times higher than the adult unemployment rate (Committee for Economic Development of Australia, 2015). Youth unemployment remains high in spite of significant rise in the number of young people who have earned a tertiary degree. The same trend is observable in South Africa, where only a reported 7% of university graduates find it easy to get jobs in the formal economic sector (National Planning Commission, 2020). In this challenging landscape, it is

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conjectured that one of the major reasons for the high level of unemployment is the fact that current curriculum does not align to the requisite skills required by employers (Lewis, 2020). Graduate employability is contingent, not only on the understanding of content knowledge, but proficiency in the use of modern technological artefacts, soft skills and an ability to solve real life problems with creative thinking (Waghid, Waghid, & Waghid, 2019). If the current gap between theory (course content) and practice (skills required in the workplace) is not addressed and closed, graduate unemployment could reach endemic proportions, and this would have significant socio-economic implications for the unemployed youths and society at large (Modiba & Ntshangase, 2021).

McNully (2018) argues that reliance on digital technologies in the workplace will be a major part of futuristic jobs hence current learners must be trained and equipped with the necessary technological skills to fit into these digital roles. Addendorf & Collier (2015) believe that the 4IR will encourage human-machine partnerships and open up new frontiers, thereby stimulating economic growth. The rise and prevalence of these human-machine relationships in the workplace underpins the argument for curriculum change or revamp, especially in universities of technology. Yusuf, Walters, & Sailin, (2020) project that 80% of businesses will establish global networks with linear, streamlined and connected workstations in diverse geographical locations, all under a central leadership or management team. Consequently, the future of work demands new competencies, offering a huge opportunity for students to upskill, re-skill and multi-skill in preparation for the disruption caused as a result of the 4IR (Schwab, 2017). African businesses are far behind in the race for economies to become 4IR compliant in most spheres, hence the continent is at great risk of being left out of the innovative and digital growth on the global stage. This reality also impacts negatively on the ability of African firms to position themselves as global players (Moloi & Mhlanga, 2021).

Poverty and inequality are some of the greatest challenges on the African continent (Olaitan, Issah , & Wayi, 2021). Seery, Okanda, & Lawson (2019) contend that an estimated one percent of Africans owns forty percent of the wealth of the entire continent. Also, three billionaires on the continent have more wealth than the bottom fifty percent of the African population (about 650 million people) (Seery et al, 2019). Many futurists and economists are predicting massive disruptions in many industries because of the evolution of the various technologies, which came with the 4IR. Although the 4IR is not fully operational in the global South, including South Africa, some challenges of disruption do exist. There has been a marked increase in contract work, multiskilling and gig work (working independently on a task-by-task basis for various employers). It is estimated that up to thirty-five percent of jobs could be replaced in South Africa if the 4IR revolution takes off (Adendorff & Collier 2015). It is also projected that more than two billion jobs will disappear by 2030 (Adendorff et al. 2018). These statistics are sobering for a country like South Africa, which already has a staggeringly high rate of youth unemployment and under-employment. To put the argument in context, nearly more than half of the world's population (most of whom are on the African continent,) are yet to experience the third Industrial revolution (Baweja, Donovan, Haefele, Siddiqi, & Smiles, 2016). The delivery of basic services, such a clean water and electricity, are still the source of violent protests in South Africa. The cost of data is also prohibitive and out of reach for the average citizen. In light of all these challenges, it is reasonable to argue that the reference to the 4IR readiness by both industry and government, is at best, an idealistic one whose intention is to sensitize the country about developments around the globe (Olaitan, Issah , & Wayi, 2021). In spite of this, and the reality of low rates of enrolment into the STEM fields at tertiary level in South Africa, it is important for universities, and other higher institutions to prepare the coming generation for careers in the 4IR, and this can only be done if a deliberate and systematic agenda for this purpose is put in place across institutions of higher learning.

Furthermore, some of the technologies touted as part of developments in the 3rd Industrial revolution are yet to be deployed in most parts of Africa (Waghid, Waghid, & Waghid, 2019). The response of Higher Education, in terms of curricula change, to new developments in the world of work is known to be historically slow, when compared to the fast pace at which technologies are evolving. The World Economic Forum suggests that an estimated fifty percent of the curriculum for a technical degree would have become obsolete and irrelevant by the time the student leaves university (WEF, 2020). The challenges of skilling, and reskilling potential graduates in this dispensation is complex, requiring a great deal of co-operation and

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collaboration between industry, universities and DHET (Moloi & Mhlanga, 2021). The next section examines the skill requirements for a technology infused, 4IR compliant economy in the global market place.

SKILLS REQUIREMENT FOR THE 4IR ERA

Twenty-first century skills do not align with the traditional standards of hierarchical workplace structures (Payton, 2017). Work has become more flexible, with knowledge skills at the center of both the experience and remuneration of work (Ayentimi & Burgess, 2019). Today, organizations are shifting and preparing for the future of work. There are now flatter structures, increased collaboration between and within organizations, with many workers choosing to work remotely and telecommuting becoming commonplace (Yusuf, Walters, & Sailin, 2020). To remain competitive in the future, organizations need to prepare for the coming changes. The World Economic Forum (2016) contends that one of the greatest challenges facing human resources practitioners in the new world order is the need to develop a multi-skilled, versatile and nimble workforce. As stated by the International Labour Organization(ILO), "*todays skills will not match the jobs of tomorrow, and newly acquired skills may quickly become obsolete*" (International Labour Organization, 2019). Lifelong learning is considered as an essential ingredient for all member states to overcome the challenges of a rapidly growing, technology infused world. Ernst et al (2019) contend that the skills that are needed by 21st century workers are those that cannot be replaced by robots. These include competencies such as social skills, empathy and interpersonal skills. The World Bank Group (2018) extends this notion further by stating that advanced cognitive skills, socio-behavioural skills and adaptability are critical skills for the worker of the 21st century. Lifelong learning and continuous development are also envisaged to be sought after skills in the new era of the 4IR, as these are skills that may not be programmable for machines (Baweja, Donovan, Haefele, Siddiqi, & Smiles, 2016). The next section examines the significance of the Higher Education sector in positioning current students to become the workforce for a 4IR future.

SKILLING, RESKILLING AND UPSKILLING OF CURRENT STUDENTS

The focus of this paper is on skilling and reskilling students as a way of preparing them for a digital economy, it is therefore important to discuss the meaning of the terms in depth. Reskilling is the ability to learn job specific technical skills but also the acquisition of other fundamental, human competencies such as creativity, communication and collaborative work. Reskilling has been described as learning in service of an outcome, usually involving successful transition into a new job or equipping for the ability to successfully take on new tasks (Quintini, 2011). Reskilling may be achieved through a formalized method whereby the student or employee is taught new, additional skills to prepare them for new challenges or emerging aspects of their career spaces, or informal learning through formative or observational mentoring (Quintini, 2011; Ilori & Ajagunna, 2020).

Although the term reskilling is mostly used to refer to employees, we argue in this paper that students also need reskilling, to update their technical capabilities in response to the latest developments in the 4IR era, in cases where the curriculum has not been upgraded to cover the practical aspects of their chosen careers, such that they can be positioned for employment once they complete their degrees. In reskilling, students are able to expand, improve their current skillset in order to perform their jobs optimally in spite of new developments in the field. Reskilling is a mechanism by which a development plan to ensure that new skillsets are acquired is devised, and personnel are well positioned to get into new roles created by the demands of self, industry and new technologies (Partovi, 2018). Reskilling has become a necessity in view of the challenges of a rapidly evolving workplace (Lewis, 2020). This development makes the prospect of finding gainful and relevant employment difficult for students, if their study years have not responded to the pace of growth happening in the larger society (Wahi, Musa, Mohdali & Hassan, 2019). If reskilling is not considered as a necessary response to major developments in a field of study, students may find that

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they are incompetent to perform the jobs for which they obtained qualifications and are unmarketable for other employment (Gupta, 2019).

CURRENT STATE OF TECHNOLOGY EDUCATION IN SOUTH AFRICA

The South African government has made great effort to position the nation as forward looking, working hard to enact laws and policies for citizens to embrace global developments as outlined in its 2030 National Development Plan (NDP, 2030). According to the NDP, all South Africans must be able to use knowledge effectively, and higher education has a responsibility to ensure that the ICT environment is well structured, and graduates are not disadvantaged by the 'digital divide' (NDP, 2011). To achieve this feat, both teachers and students must be reskilled across a broad spectrum of practical competencies to achieve the kind of revolutionary change required to stay relevant in the era of the 4IR (Waghid, Waghid, & Waghid, 2019).

In spite of the 'good intentions' expressed by government in the NDP, and other position papers, majority of academics in South Africa are not technologically competent, neither are they fully conversant with the technologies of the future, such as AI, Robotics and Machine Learning (Baweja, Donovan, Haefele, Siddiqi, & Smiles, 2016). The Covid-19 pandemic exposed the state of technological advancement, teacher capabilities and available tools at tertiary institutions across the country.

As earlier stated, the skills for the 4IR world requires a practical application of the content to the realities of the era, hence faculty have to be at the forefront of the ability to demonstrate this knowledge in a high value spectrum which machines are not capable of doing. Unfortunately, most previously disadvantaged universities have a workforce which still experience trouble with digitization and technology (Sikhakhanea, Govender, & Maphalalaba, 2021). It can thus be argued that skilling and reskilling of teachers is a precursor to the skilling of students, if Higher Education is to play a meaningful role in the reskilling of students, it stands to reason that government/ university has measures in place to ensure that lecturers themselves are in the loop about current developments and they understand the stakes for this exercise. The skills demand for a 4IR labour market is expected to be filled from colleges, traditional universities and universities of technology. Government, industry and academia must work hand in hand to ensure a symmetrical synergy for the purpose of identifying, addressing and fulfilling the country's labour needs for the 4IR (Ros ario Cabrita, Safari , & Pilar Mu noz Due nas, 2020).

In light of the current curriculum at most institutions of higher learning, it is considered that the skilling and reskilling of both students and faculty is a necessary step towards preparing the economy for a 4IR future. The education sector has to be at the forefront of preparing students for this complex landscape as education plays a major role in the transformation of society (Scepanovic, 2019). Currently, there is tension between academia and industry on the former's role in ensuring that graduates have the requisite skills to prepare students for the 4IR.

South Africa needs to have an urgent, and creative plan towards ensuring that a fundamental shift occurs in education, ensuring that students are skilled for the innovations of the future. Skills development will be fundamental to the country's ability to benefit from the gains of the 4IR. Moloi & Mhlanga (2021) argue that the Department of Basic Education(DBE) is not equipped to position both educators and pupils to prepare for the 4IR era. Research has consistently documented a mismatch between the skills of unemployed youths and the skillsets required by employers (Jackson, 2016). The convergence and intrusion of pervasive technologies such as mobile phones, automation and the inroads made into robotics will contribute to youth unemployment unless they are skilled to take advantage of the technologies which empower and power a 4IR economy. The main characteristics that employers are looking for in this industrial age include problem solving, team work and critical thinking. The concept of lifelong learning and knowledge co-construction are also considered as vital skills in the new world (Committee for Economic Development of Australia, 2015). Government, on its part, is grappling with many socio-cultural and unprecedented challenges, hence preparing for a revolution that is still to come seemed unrealistic (Allen, 2019). In view of all these, and the pace at which developments are rapidly evolving, we propose four critical success factors(CSFs) to consider in the process of skilling and reskilling current students to

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fit into the 4IR workplace. These CSFs are based on the literature reviewed and practical steps taken by some developing countries to right-skill their youths for relevance in a 4IR economy. Although South Africa is still behind in running a fully-fledged 4IR economy, we believe the time to position for the eventuality is now.

CRITICAL SUCCESS FACTORS TO PREPARE CURRENT STUDENTS FOR A 4IR ECONOMY

Pournasir (2013) describes critical success factors(CSFs) as necessary for a particular objective to be achieved. Critical Success actors are the steps that an organisation has to take, if it were to accomplish a stated goal. We are of the opinion that government, and Higher Education, in collaboration with industry, must address the following issues if it would prepare current students to partake of the opportunities presented by the ongoing wave of the 4IR.

CSF 1: An urgent curriculum revisit- In spite of the many challenges faced by the government and education sector in the current dispensation, there is no option but to skill and reskill students who are in the system to face a technology world. Current curriculum must be futuristic and reflective of what future workforce must be equipped to do (Partovi, 2018). We propose an urgent revisit of the education curriculum initiated by DHET, in collaboration with industry and academia. This will ensure that DHET's curriculum is responding to Industry needs and the academic community ensures that this is translated into the skilling, and reskilling of students for the future of work (Mkansi & Landman, 2021; Ros ario Cabrita, Safari , & Pilar Mu noz Due nas, 2020).

CSF 2: Funding, equipment and support of vocational education and training(VET)- Most technikons have been converted to universities, and enrolment in the few ones remaining are not very optimal as university education is perceived as superior. The level of vocational education and training(VET) worldwide has been described as low by several researchers (Jackson, 2016). An additional challenge is the lack of resources, making it difficult for students in STEM fields to access on-the-job training as part of their skilling. In view of the emphasis on training in practical skills in the 4IR economy, we propose a revisit of the VET kind of training for students, especially those in STEM careers. According to Payton (2017), the wide gap between the actual skills profile of recent graduates and their stated qualification is a cause for concern. We believe VETs can close this gap and provide the much needed practical and vocational training required for these sets of graduates to be work-ready in a 4IR era. Evidence from Australia, a fairly developed economy, and India, a developing economy both point to the fact that vocational training empowers students not only to envision what would be required of them in the workplace, but to have a firsthand experience and make the necessary adjustments before they leave the schooling system (Gupta, 2019; Payton, 2017). Vocational training and education must be re-imagined around the skills of the 4IR, hence students need to be trained to multi-skill, develop soft skills in highly technical environments and focus on problem solving skills.

CSF 3- Strong, global collaborations are essential to student skilling and reskilling- Technology has, and continues to play a great role in enabling collaborations between countries, institutions across several areas of human endearvours. The unprecedented rate of breakthroughs in the control and management of the Covid-19 pandemic provides great evidence of this fact. We believe that one of the critical factors to empower students by skilling, and reskilling them to fit into the workplace of the future is to create collaborative spaces between South African students and students in similar careers in countries where the 4IR has already taken root (Yusuf, Walters, & Sailin, 2020; Ayentimi & Burgess, 2019).

CSF 4- Educational safe spaces for the development of soft skills- researchers agree on the fact that soft skills such as communication, people management, critical thinking and the ability to multi task are critical for success in the 4IR (Payton, 2017). We submit that government, through the Department of Higher Education should ensure that such skills are learnt at school by graduates before they get into the

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workplace. These can be done through collaboration with the personnel divisions of relevant industries, or facilitating peer-to- peer, or teacher to student learning as part of the broader process of getting the students ready for the 4IR workplace. The path to prosperity in the 4IR era will be through innovation, ideation, creativity and nimble problem solving skills (Ayentimi & Burgess, 2019). Workers who are skilled in these areas will be hugely rewarded in the era (Karr, Loh, & San Andres, 2020).

Conclusion

The paper examined the relevance of the curriculum being taught to current students at the institutions of Higher learning in South Africa to the skills demands and requirements in a 4IR economy. Evidence from the literature revealed that South Africa is still behind in crafting a curriculum that will keep current students relevant, employable and productive in a 4IR economy. We discuss various challenges, which may hinder these students from being able to access opportunities presented by the 4IR. We therefore propose four critical success factors that the government should address, in the quest to equip students with the right skills, and position them to take advantage of the many opportunities presented by a digitalized economy. These critical success factors are; (a). An urgent curriculum revisit, (b). Funding, equipment and support of vocational education and training(VET), (c). Strong, global collaborations are essential to student skilling and reskilling, (d). Educational safe spaces for the development of soft skills.

The paper makes a theoretical contribution to the literature on curriculum challenges within the STEM field in South Africa and how the challenges could be overcome. We noted the time lag in implementing the review of curriculum, and the fast pace of development in the workplace as a result of technological advances. The paper makes a practical contribution to the topic by proposing four critical success factors that could be addressed in order for students to be right skilled and positioned to take full advantage of the opportunities presented by a digitized economy as exemplified by the 4IR era.

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CREATIVITY IN THE 4IR CURRICULA WITH ARTIFICIALLY INTELLIGENT TECHNOLOGIES

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ABSTRACT

Aim/Purpose	[Artificial intelligence has become pervasive in the Fourth Industrial Revolution and is challenging traditional notions of what it means to be creative in skills development. This paper suggests newer and nuanced ways of conceiving creativity in the 4IR era dominated by artificially intelligent systems that are capable of creative outputs.]
Background	[The notion of creativity is reviewed. A framework for reconceptualising creativity in the 4IR skills development era dominated by artificially intelligent devices is then proposed.]
Methodology	[An integrative literature review of the notion of creativity is done to ascertain what it entails to be creative in the 4IR learning contexts and the Actor-Network Theory is used to sustain a proposed framework for understanding creativity in the 4IR skills development context.]
Contribution	[A framework for reconceptualising the notion of creativity in the 4IR skills development contexts is proposed?]
Findings	[Skills development in the 4IR is happening in an era where humanity is deeply entangled with artificial intelligence. Creativity in learning contexts should go beyond the confines of the mind contrary to traditional pedagogical thinking. Creative learning in the 4IR should be driven by thought processes, human beings' inherent crafting capabilities and the computing power of artificial intelligence.]
Recommendations for Practitioners	[Skills development and consequently learning programme design in the 4IR should occur in a framework that appreciates the fact that creative abilities have moved past capabilities confined to mental acts but should include both human beings' manipulative abilities as well as the computing power of artificially intelligent systems]
Recommendations for Researchers	[4IR researchers are encouraged to develop newer lenses and paradigms of understanding and defining creativity in the 4IR skills development context taking into consideration the pervasiveness and creative capabilities of artificially intelligent technologies.]
Impact on Society	[The age of the machines has arrived, much of what is taught, learnt and the creative approaches used to arrive at solutions is changing together with what it means to be creative]
Future Research	[Effort should be directed towards developing educational methodologies that shift skills development systems, so stuck in traditional pedagogies that prime the human mind as the custodian of creativity, to philosophies and theories that are compatible with the 4IR such as post-humanism and connectivism]

Keywords 4IR, Creativity, Pedagogy, Skills Development

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INTRODUCTION

The Fourth Industrial Revolution (4IR) curriculum is being conceived and implemented in a period of major disruptions to societal traditions and educational practices because of technology. What is learned, how it is learned, and how it is assessed is consequently changing. A scoping review of critical skills and competencies of the 4IR by Chaka (2020) primes generic soft skills namely communication, creativity, and problem-solving together with hard skills such as computer programming. The 4IR curriculum is becoming personalized and unstructured emphasizing, amongst other skills, creativity complex problem solving, flexibility, and innovation (Tsekeris, 2019). It is therefore important that certain skills, especially that of creativity should become central in the 4IR curricula design, learning, and assessment. The notion of creativity is, however, diverse and inexact to the extent that Høffding (2011) acknowledges that it is difficult to define without being repetitive. Others like Fischer et al (2005) and Barrett (2006) give the subject a rather weird stereotype of a lone thinker.

The subject of creativity is well debated and its association with thinking or mental visualization is apparent in most philosophical writings on the subject. Høffding (2011:54), consequently, writes that "to be creative, is to see possibility, to see something that is not yet there, to see that things could be different or that empirical reality is not absolute". Philosophers such as Kant centre creativity on the power of imagination (Gaut & Livingston, 2003). Descartes (1998) proposes that doubt and the active negation of pre-held beliefs are the hallmarks of creativity. It is seen as emerging from the 'de-absolutization' of beliefs. Others, like Edward de Bono, have tried to systemize the process by emphasizing lateral thinking and proposing different 'thinking hats' for different situations (de Bono, 2019). Their idea of creativity involves "generating new ideas, alternatives, possibilities, and new concepts". Boden (2004) stresses that creative artefacts and ideas must be new, surprising and valuable.

Malafouris (2014) observes a handicap in research on creativity resulting from an obsession with the mental processes of the human mind. They advance that human beings are born creators of physical objects through the inherent ability to be manipulative, crafty and giving form to matter thereby producing tangible artefacts. They call this creativ*e thinging* – the "capacity for inventiveness that is inseparable from the capacity to affect and be affected through movement and sensation from the phenomenal qualities of the materials that surround us" (pp: 144). They argue that creative *thinging* [crafting] does not take the form of some special representation in a human mind but "emerge as part of a dynamical process of enactive discovery and material engagement that criss-crosses the boundaries of skin and skull" (pp.147). This form of creativity emphasizes making something.

Gaut and Livingston (2003) identify the duality of *originality* and *value* as the widely regarded standard of creativity. It goes without much debate that useful or 'creative-worthy' acts in the 4IR skills development should emphasize both thinking (mental acts) and *thinging* (creation of valuable objects). It is however worthwhile to note that computer systems are now capable of producing creative outputs that are close to human actions in artworks such as music (Sturm et al. 2019). These creative abilities of machines can be attributed to the field of artificial intelligence. Taking some of the creative and perceptual of human acts such as creative arts, as examples, it is becoming clear that artificially intelligent systems are edging closer to reaching human-like creativity levels. Perceptive and creative arts were viewed by Coulson-Thomas's (2017) as somewhat resistant to machine take over but this is changing. Artificially intelligent systems are composing music, for example, the album *'I AM'* was composed by an artificially intelligent system (Sturm et al., 2019). Systems that can recognize the emotional status of human beings are emerging (Dormehl, 2017) as well as pet bots that are, chatty, therapeutic, cuddly and can even make eye contact (Fulmer, 2018). Similar developments are also happening in other fields such as sciences, medicine, arts or commerce. Creative outputs, in the sense of both thinking and *thinging* can no longer be confined to human mental and actions. Granted, artificial intelligence is a creation of the human mind but its application and use create a social agency of its own that is independent of the being. There is a reason for intrigue when the machines can now, as Fulmer (2018) puts it, independently invent, discover and revolutionise existence.

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The dramatic increases in the capabilities of artificially intelligent applications in creative work create a need for a close assessment of the notion of creativity in the 4IR skills development. It is worthwhile to assess the pedagogical implication of having artificially intelligent systems that are capable of creative works or exhibiting what Ertel et al. (2017) describe as person-like behaviours in terms of intelligence. The question to consider is *how to conceive creativity in a skills development context in the 4IR era of artificially intelligent systems capable of creative outputs.* Hamilton-El Aquil's (2021) even ponders whether creativity is intrinsically human.

The integrative literature review approach is used, in this paper, to explore the notion of creativity in an educational context by examining how it is positioned in different pedagogical theories. The review is qualitative, non-systematic (Snyder, 2019) and focuses on the literature around the notion of creativity in the context of 4IR pedagogy. The concept of creativity is then reconsidered factoring in the abilities and capabilities embedded in artificially intelligent machines. A framework for conceptualizing *creativity* in the 4IR skill development context is proposed together with possible application contexts. The framework persuades that skills development in the 4IR is happening in a post-humanistic entanglement of humans and machines. Artificially intelligent technology is viewed as playing both assistive and co-creative roles with humankind in the 4IR.

This paper differs from mainstream research on creativity in skills development in that it does not attempt to propose another prescriptive tool on how to be creative like what others like de Bono (2019) did with the thinking hats. It does not join the philosophical debate on whether creativity is related to imagination, whether the process is rational nor whether it is a virtue as what (Gaut, 2010) did. It analyses the notion of creativity metaphysically by exploring and proposing new and nuanced ways of conceiving it when teaching in an era dominated by 'more capable machines' whose roles have become central and gone beyond being mere assistive gadgets.

CREATIVITY AND PEDAGOGY

A viable starting point to understanding the notion of creativity in a skills development context is to examine how it is construed in the different theories of education - the mechanisms by which academic knowledge-creation is systemized and implemented. As indicated by Edwards-Schachter et al. (2015), the understanding of creativity and innovation varies depending on the underpinning philosophies driving a particular curriculum system.

Behaviourism, an early educational philosophy of education, emphasizes the creation of observable changes in learners' behavioural actions in response to environmental stimuli as the cornerstone of teaching and learning processes (Kay & Kibble, 2016). Behaviourist learning is criticized for not promoting creativity as it bases learning actions on repeating and reinforcing established patterns as well the selection of correct responses from a predefined set of facts (Rawat, Qazi, Hamid, 2012). Consequently, as confirmed by Ertmer and Newby (2013), behaviourism, does not promote the acquisition of higher-level thinking skills needed for deep synthesis. Another early theory of learning, cognitivism premises learning on mental processes. It emphasizes "cognitive processes such as thinking, problem-solving, language, concept formation and information processing" (Ertmer & Newby, 2013:50). Creativity in the cognitivist learning paradigm is seen as a mental act thereby emphasizing actions such as building and reorganizing mental models as well as how these are imposed on problem-solving processes (Mayer, 1989). Even the social constructivist paradigm, which is seen as an improved successor to early educational theories, advances that knowledge is created through human activities as meaning is a social construct emerging from interactions with other beings (Fosnot, 2013). Constructivist pedagogy persuades that creativity emerges from complex social and cultural teachings. Chandler and Teckchandani (2015) indicate that to be creative, in the constructivist sense, is to be an independent thinker, a critic, and a problems solver.

Pragmatic educationist, John Dewey, however, rejected that learning could be a 'mind-only' thing as it may be perceived (Miettinen, 2000). The formation of proper judgments (critical reflection) is

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important in Dewey's approach to creative thinking (Rawat, Qazi, Hamid, 2012). Dewey in Miettinen (2000), in addition, emphasizes that education and learning are not passive but involves using hands, feet and tools. Even Lave and Wenger (1991:52), when commenting on the notion of understanding, a presumably mind thing, elaborate that it involves doing (*read thinging*) because active participation "dissolves dichotomies between cerebral and embodied activity, between contemplation and involvement, between abstraction and experience: persons, actions and the world are implicated in all thought, speech, knowing and learning". If learning could not be a 'mind only' thing in Dewey's thinking then creativity can as well be seen as an active process. Efforts to wean knowledge-creation from the 'mind centric' approaches continue in later pedagogical thinking such as in the work of Siemens (2004). Their connectivist learning proposition, designed in the technological era (read 4IR), doubts that *all* learning occurs solely 'inside' a person. According to Siemens (2004), knowledge resides in both beings and networked artefacts including appliances and machines. Knowledge creation, understanding or even creativity may as well be construed as the ability to create, use or manage the interconnected labyrinth of beings, artefacts, and machines in the connectivist learning approach.

Dewey's inclusion of body parts such as hands, and feet, as well as apparatus and appliances (devices) in knowledge creation as well as the emergence of philosophical thinking that removes the being from the centre of the social, create a wider perspective for contemplating the notion of creativity in the 4IR skills development context. There is a basis for tackling Hamilton-El Aquil's (2021) question on whether creativity is intrinsically human. The next section proposes a new approach to thinking about the notion of creativity when developing skills in the 4IR of machines and artificial intelligence

THE 4IR SKILLS DEVELOPMENT CREATIVITY WHEEL

Artificially intelligent systems are ubiquitous in many facets of life in the 4IR and education is not an exception. Systems capable of creating artworks, music or sophisticated architectural designs will soon rather than later invade the learning space. These systems are unlike most learning technologies such as the mathematical calculator, Learning Management Systems or the internet whose role is mostly assistive. Artificially intelligent systems exhibit creative abilities and can produce outputs that are close to human creativity. As an example, how would the assessor treat an artwork from a student where artificially intelligent technology has been used in producing the artwork? Would this be the case of a cheat or a creative techno-genius? The easier option would be to resist the use of these creative technologies in pedagogy for as long as is possible. The sustainable option would be to embrace artificial intelligence systems in pedagogy and to seek accommodative frameworks for understanding creativity in the 4IR era dominated by creative machines as proposed in the next paragraphs.

A critical analysis of the works of philosophers Kant, Descartes, and traditional pedagogy (behaviourism, cognitivism, and constructivism) primes the mind as the initiator of all that is creative, original, and valuable. Dewey's pragmatism, Malafouris' (2014) creative thinging (making), and connectivist positions on pedagogy suggest an entanglement of the human creative mind, bodily parts, and artefacts (artificially intelligent systems) into an inseparable web of existence. Unpacking this entanglement could be what lies at the core of understanding what is needed to be creative in the 4IR skills development. Early scholar and pragmatist Dewey bound the mind, the body and devices (apparatus and artefacts) in the problem-solving process. Artificially intelligent systems are now not only ubiquitous but have self-agency which is the capability of conducting their own intelligent and creative work. Artificial intelligence can as well be considered as an additional *thought agent* available to humanity in creative processes. Creativity in the 4IR skills development context should, thus, involve the use of the mind (thinking), creating (*thinging*), and artificially intelligent technologies. It is, therefore, proposed that 4IR skills development should be pivoted (fulcrum denoting centrality) on creative problem-solving that is supported (enabled) by (but not limited to) *thinking, thinging and artificial intelligence*. The visual metaphor of a wheel (ancient machine) is used to crudely represent this conceptualization of creativity in the 4IR skills development as illustrated in Figure 1.

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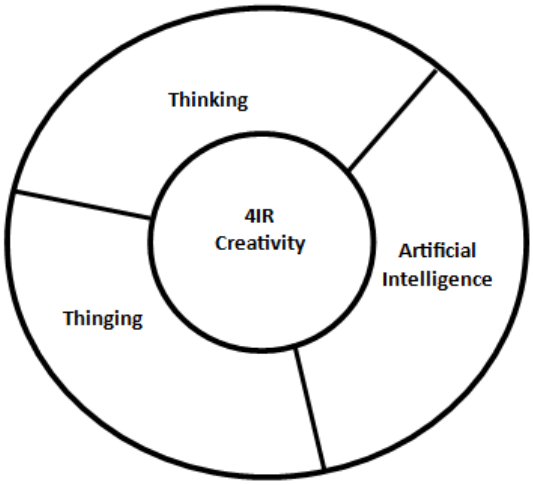

Figure 1. The 4IR Skills Development Creativity Wheel

How do the three aspects hold it together to inform creative actions in the 4IR skills development? The wheel is a metaphoric and a symbolic denotation of the 4IR societal progress resulting from the creativity that is driven by thinking, '*thinging'* and artificial intelligence. While it is easy to tie thinking and *thinging* together because of their conceptual association with human actions, putting artificial intelligence at the same level is, understandably, problematic. First, thinking and *thinging* are both human processes while artificial intelligence is an artefact. Second, artificial intelligence is a product of human thinking and *thinging* thus reinforcing the widely accepted superordinate-subordinate relationship between human capabilities and artificial intelligence. The Actor-Network Theory, conceived in the materialistic philosophy, helps explain the somewhat difficult characterization of the 4IR skills development depicted in Figure1. Using the Actor-Network Theory, as a referential theory, the proposed 4IR skills development creativity wheel must be conceived as an assemblage of constituent elements as opposed to a connection of related parts. A helpful explanation of this assemblage is Kamp's (2019) explanation of the social in an Actor-Network. They argue that the social should be seen as an assorted and constructed collection of humans and non-humans that does not privilege humans above other actants. Latour (1996:370) indicate that what binds such networks is not "concentration, purity and unity", but "dissemination, heterogeneity and the careful plaiting of weak ties". Consequently, the emphasis of what is proposed in Figure 1 is not on labouring the relationship between thinking, *thinging* and artificial intelligence but a realisation that their presence creates a new social dynamic that is altering the face of how to be creative in the 4IR era. Post-humanistic theories also confirm this decentering of the human from the 'social' by suggesting that existence is now distributed in both social and material networks (Frauenberger, 2020). Putting human actions such as thinking and thinging at par with artefacts such as artificial intelligence as done in this instance (Figure 1) is thus theoretically sustainable. Examples of how the 4IR skills development creativity wheel can be put into practice are presented in the next section.

THE 4IR CREATIVITY WHEEL IN ACTION

Viewing creativity as a process driven by thinking, *thinging* and artificial intelligence provides a basic framework on which 4IR skills development can be hinged. Two classical examples are suggested.

Skills development programmes could be conceptualised in which curriculum designers configure learning and assessment outcomes based on the constituent components of the proposed 4IR creativity wheel. They will categorize, for example, which parts of the creative learning outcomes should emphasize thought (as in thinking), *thinging* (*read creating, making, building*) or the use of co-creative technologies such as artificial intelligence systems. The same logic can be easily cascaded to

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assessment tasks. This opens the door for the adoption of artificially intelligent systems in creative learning activities together with a framework guiding their role in the creative mix.

The framework also lays a foundation to help the debate around rewarding and recognizing the creative outputs of work that involve the use of assistive and creative technologies such as artificial intelligence. An analysis of such creative works based on what can be attributed to thinking, *thinging* and the work of artificially intelligent technologies lays a defensible basis for apportioning credit when considering aspects such as rewards, recognition and copyrights.

There are two probable misconceptions on the framework that should be addressed. Firstly, the three constituent parts of the 4IR creativity wheel that are advanced should not be seen as exhaustive. These are the barest minimum that have been unearthed at this juncture to sustain a persuasion for a move away from traditional and stereotypical thinking about creativity. Secondly, there is also no 'proportionality' implied in the size of each segment attributed to thinking, *thinging,* and artificial intelligence in the creativity wheel in Figure 1. It is, also, pertinent to observe that the proposed framework is very crude in its current state. It only persuades a rethinking of the basis on which creativity is viewed in literature by drawing attention to creative abilities embedded in artificially intelligent devices.

CONCLUSION AND FURTHER OPPORTUNITIES

The Actor-Network Theory was used to design a framework on which creativity in the 4IR skills development could be hinged. The 4IR creativity wheel considers that 4IR skills development is happening in times dominated by technologies that have gone beyond being merely assistive but possessing some creative abilities. A reconfiguration of what it means to be creative becomes necessary to include creative technologies. The aspects that should drive creativity in the 4IR are the human thought-capacity, their manipulative and crafting ability (*thinging*) as well as capabilities inherent in artificially intelligent technologies.

There are implications of the proposed framework for skills development in the 4IR era. Firstly, the ubiquity of independently capable and creative technologies should be a cause for consideration to educators when designing both learning outcomes and most importantly assessments. Unlike the calculator or the word processor and the computer whose assistive role in pedagogy can be ascertained, artificially intelligent systems exhibit a self-agency that need careful consideration when teaching and assessing.

Follow up research is recommended to flesh up the ideas advanced in the 4IR creativity framework. A good starting point would be to design curricular and learning tasks in a specified skills development programme based on the creativity wheel where its applicability and usefulness could be evaluated. The long-term research trajectory should be to move 4IR skills development programmes to philosophies that are more amenable to what Frauenberger (2020) considered the decentred social. Post-humanistic schools of thought that advance that the human is *part of* and not *the centre of* the universe can provide guidelines. One such attempt is Siemens' (2005) connectivism proposition on learning which realizes that knowledge exists nodes within and out of human brains to include cyber repositories and connections such as the internet.

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EXTENDED ABSTRACTS AND SHORT PAPERS

DATA ANALYTICS FOR SOUTH AFRICA'S SEXUAL CRIME LANDSCAPE

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ABSTRACT

Aim/Purpose

The aim of this paper is to motivate the need to address sexual crimes through predicting sexual crimes trends using data analytics algorithms that may help the police and law enforcement agencies prevent or reduce violence against women and children, specifically sexual crimes, in South Africa.

Background

A key public health issue around the world is sexual crime, which violates human rights. The findings of Öberg et al. (2020) show that various forms of violence are widespread among girls and women in childhood, adolescence, and adulthood. Sexual crime is the use of force or manipulation to make someone engage in unwanted sexual acts without their consent, as described by the National Sexual Violence Resource Center (2010). The World Health Organisation (WHO) defines sexual crimes as, "any sexual act, attempt to obtain a sexual act, unwanted sexual comments, or advances, or acts to traffic or otherwise directed against a person's sexuality using coercion, by any person regardless of their relationship to the victim, in any setting, including but not limited to the home and workplace" (World Health Organisation, 2012).

Sexual crimes have a long psychologically damaging effect on sexual assault victims, who suffer both immediate and lasting psychological and physical pain, and the survivor may be left with horrific physical injuries that threaten and violate the internal perception of what it means to be a woman (Clark, 2014; Landström et al., 2016). The harmful effects of sexual crimes not only cause serious damage to physical health, but also may lead to loss of life, risky miscarriages, extreme feelings of shame, and sexually transmitted infections (including the Human Immunodeficiency Virus) (Altinyelken & Le Mat, 2018).

Sexual crimes range from verbal harassment to forced penetration as well as other forms of coercion ranging from social pressure and intimidation to physical violence (World Health Organisation, 2012). According to the Minister of Police, Bheki Cele, "sexual crimes involving GBV-related incidents increased by 5% in the fourth quarter of 2020. According to the statistics, 12,218 rape cases were reported between October and December 2020, representing a 1.5 percent increase from July to September of the same year. Most cases were reported in Inanda and Umlazi in KwaZulu-Natal and Lusikisiki in the Eastern Cape. The location where the rapes took place shows that over 4,900 happened in the victim's or rapist's home, 570 were related to domestic violence and 547 of the rape cases in this category involved female victims and 23 male victims, the minister said at a media briefing" (Health-e News, 2021; Nganga, 2021).

The rate of sexual crimes in South Africa is among the highest in the world

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(Deane, 2018; Interpol, 2021; Ajayi et al., 2021). Unfortunately, women are the main targets of sexual crimes in South Africa (Deane, 2018) and there is almost never an alternative to negotiate safe sex (Wojcicki, 2002). In addition, men hold the power and women are largely marginalized by the existing patriarchal society (Pitcher & Bowley, 2002). These deep-rooted patterns of sexual crime have not disappeared with the transition to democracy as they are rooted in the oppressive patriarchy of colonialism, apartheid, and the Cold War (Britton, 2006).

Since sexual crimes have become an important problem that needs to be resolved before it becomes too impossible to deal with in society, it is important to seriously address this problem of sexual crimes and predict trends in sexual crimes using data analytics algorithms that may help the police and law enforcement agencies prevent or reduce sexual crimes in South Africa. Sukhija et al. (2020) conducted a linear regression study to assess the correlation of characteristics associated with rape crimes in Haryana to discover relevant variables that can help police officers prevent crimes more effectively. This can be replicated in the context of South Africa.

Methodology

This paper provides a comprehensive review of the existing literature on sexual crimes, their causes, research developments, and challenges related to sexual crimes against children and women. Through various reports and literature reviews, this paper analyses the causes of and responses to sexual crimes in the broader South African context.

Contribution

Motivation and proposal for law enforcement, police, and the government of South Africa to use a data analytics tool capable of predicting sexual crimes in South Africa to prevent or reduce violence against women and children in the Country.

Findings

The following key findings were derived from the data analysis:

- Sexual crimes are a violation of human rights and a significant public health problem around the world.
- Sexual crimes have a long psychologically damaging effect on sexual assault victims, who suffer both immediate and lasting psychological and physical pain, and the survivor may be left with horrific physical injuries that threaten and violate the internal perception of what it means to be a woman.
- The rate of sexual crimes in South Africa is among the highest in the world; these deep-rooted patterns of sexual crime have not disappeared with South Africa's transition to democracy as they are rooted in the oppressive patriarchy of colonialism, apartheid, and the Cold War.

Recommendations for Practitioners

Practitioners such as data scientists, developers, etc. can embrace this strategy by working with the government, law enforcement and researchers to design an application that can help curb sexual crimes in the country.

Recommendations for Researchers

Further research can be conducted to test the accuracy of the proposed data analytics tool for the South African sexual crime landscape.

Impact on Society

Data analytics tools that can predict the occurrence of sexual crimes will help the South African government, law enforcement agencies and society, especially women and girls, to be aware of the occurrence of sexual crimes and report to the police or law enforcement agencies when such a crime is happening around

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them or to them; this way, sexual crimes will be curbed progressively.

Socially, this could mean that schools become part of the solution for young victims (Deane, 2018). Curricula that promote positive societal attitudes, educate people about dating violence, and encourage behaviours aimed at combating sex criminals should be included in these classes and strategies. Beliefs and supportive behaviours related to sexual crimes must be reflected in the curricula (Deane, 2018).

Future Research

Further research can be conducted by extracting existing sexual data from the South African crime statistics dataset and building a predictive model capable of predicting sexual crime occurrences in South Africa's nine provinces.

Research can also be done on how to reduce other types of violent crime and how to implement curricula that promote positive social attitudes and educate pupils about dating violence in schools.

Keywords

Sexual crimes, South African landscape, data analytics, algorithms, prediction.

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Olayemi S. Falope is pursuing her Masters in Information and Communication Technology at the Durban University of Technology, Durban, South Africa. She has been working in the field of Data Science for about 2 years now. Her interests include Data analytics, Data Mining, Machine Learning, Cyber-security, and Artificial Intelligence.

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Digital skills development for digitally maturing South African Higher Education Institutions

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ABSTRACT

Aim/Purpose

Research institutions face and experience and array of challenges as they transition from a traditional Higher Education (HE) campus to a smart HE community. These challenges can in part be solved by addressing the underlying digital skills shortcomings in HE communities. Universities across South Africa are yet to design and implement a framework describing the lack of basic and advanced digital skills in their communities as they move towards becoming smart communities. There exists an observed lack of digital and technical comprehension within community member groups when designing systems that are intended to address the identified challenges within their smart communities. Thus, the researchers theorised that the creation of a digital skills development framework can be beneficial to university management and user-groups to address the lack of basic digital skills by delineating the digital skills shortages and by identifying key stakeholders in the community in order to solve campus related challenges effectively.

Background

The researchers investigated the journey of South African HE campuses as they move from functioning as traditional campuses towards becoming digitally innovative campuses using 4IR or "smart", technologies optimally to enhance HE. Campuses can be seen as micro-cities that lend themselves well to the study of the transition from the traditional to the new, and the author viewed that researching this transition journey of a South African campus – the challenges incurred, basic digital skills requirements, and the roles and responsibilities of the stakeholders involved - may provide insights into similar transition journeys of other HE communities. The objectives of the study were to determine the challenges faced by Higher Education campuses in South Africa as they transition from traditional campuses to digital campuses using "smart technologies", the digital skills required on this journey, and to identify the different stakeholder groups/individuals who will be able to solve these smart campus related challenges. The digital skills required to participate optimally in the functioning of a "smart" campus, overcoming the mentioned challenges, served as a starting point for the investigation.

Methodology

The philosophical discourse of the study was interpretivism. The researcher aimed to interpret and analyse the perceptions of the participants in order to ammend the proposed framework as per the feedback from the participants. To answer the primary research question, the study adopted a Living Lab (LL) methodology. The flexible and iterative nature of the LL methodology allowed the researchers to make ongoing adjustments to the digital skills framework. The adjustments to the framework were based on the end-user feedback. An online survey was distributed to 15 participants. The survey included questions

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	of both a qualitative and quantitative nature. Thereby, improving the validity of the research conducted. Participants were purposively selected. The participants included first year, second year, third year, final year, honours and master's students studying at the University of the Western Cape.
Contribution	The researchers contributed to the current body of knowledge regarding research within the field of smart campus development in South Africa. Thus, study is expected to clarify the surrounding smart campus community concepts, the need for digital skills, and digital inclusion in a South African HE context.
Findings	Finding 1: Lack of basic digital skills. Students transitioning from a traditional HE campus towards a smart campus community need the necessary basic digital skills to function optimally and productively in an innovative environment. The respondents identified the following basic digital skills as being adequately skilled at, *problem solving, handling information, transacting* and *personal life skills*. The basic digital skills the respondents were least equipped with included *communication* and *content creation skills*. Subsequently, by proposing 13 challenges to respondents, a variety of new digital skills (not found in Digital Skills Framework One) was presented by the participants to solve HE campus related challenges. The researchers added additional digital skills to the proposed framework. Finding 2: Identifying ecosystem stakeholders. The respondents identified their lecturers as being key stakeholders within the ecosystem to supply digital skills to students. Therefore, it is imperative for lecturers to be fully digitally equipped in order to transfer the digital skills to their students. Hence, the findings indicate that an HEI can only transition to a smart campus community as fast and effectively as students and lecturers are digitally equipped to manage and operate the technological advancements in the smart campus environment.
Recommendations for Researchers	The question surrounding the supply of digital skills to a HE community is a vague area that has not been fully addressed in IS research. The researcher motivates that in order to clarify this area of uncertainty, an array of stakeholders from a range of different sectors should form part of the sample of the study. The addition of multiple stakeholders in the data collection process could determine the key responsibilities stakeholders share to supply digital skills to digitally transitioning HE communities. A focus group session can prove valuable to gain insight into the digital skills required by community members in a smart campus community and to delineate the responsibilities of those required to supply those digital skills.
Impact on Society	The lack of digital skills in HE institutions is an under-researched area. Addressing the need for basic and advanced digital skills in HE communities can greatly benefit students working towards entering the job market. Additionally, campus management and relevant stakeholders can ensure that all students have equal opportunities access to digital skills training and services on campus.
Future Research	In the near future it would be advantageous for research institutions to develop a framework to establish and affirm the responsibilities of those involved in supplying digital skills to higher education community members. Finally, the research was exclusively conducted at the case study intuition. An opportunity exists for the study to be replicated at other South Africa HE communities.

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Keywords Higher Education, Smart Communities, Smart Campus, Living Labs, Digital Skills Development, Digital Skills, Quadruple Helix

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POSTGRADUATE POSTERS

SOCIAL EXCLUSION IN AI-INFUSED GAMIFICATION

Emil van der Poll: PhD Candidate in Information Systems at the University of South Africa

Introduction

Gamification is the use of game-related features in environments not related to entertainment; e.g. education (Deterding, 2015) – see Figure #1. The Pew Research Center (PRC) (2012, para.11) write that "by 2020, gamification … will not be implemented in most everyday digital activities … gamification … will not advanced much beyond being an interesting development." In terms of Artificial Intelligence (AI), the PRC (2018) acknowledges its proliferation in everyday activities; however, by 2030 AI will raise questions about its detrimental impact on human capability, such as speech.

Gamification and AI has been used in a cooperative manner to augment one another; e.g., AI can increase the difficulty level of a gamified learning task if it detects the player is bored (Barata et al., 2015). Research question: *What are the potential drawbacks of AI-Infused gamification in education?* Research purpose: Deploy action research to identify and draw attention to the potential drawbacks of AI-infused gamification in education.

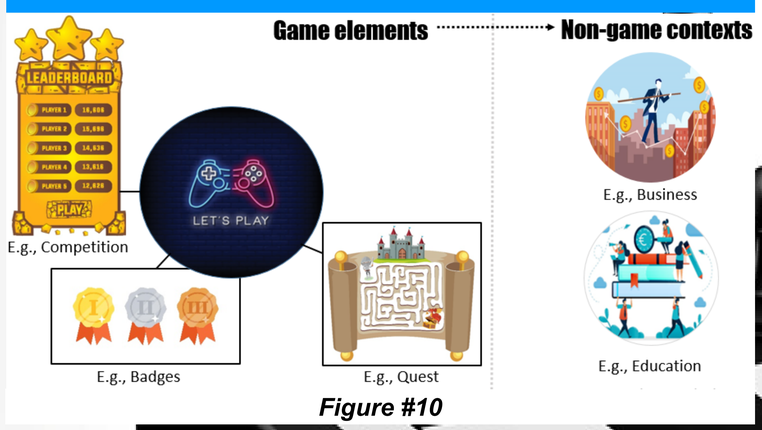

Figure #10

Research Problem

Although AI made significant strides in predicting human needs, AI cannot account for all human needs. Indeed, AI might inadvertently become a learning barrier in learning.

Methodology

Action research guided data collection. Action researchers (1) diagnose a problem, (2) plan actions, (3) implement planned actions, (4) evaluate actions to determine if problem has been solved, and (5) reflect on process (Oates, 2006) (see Figure #2) . Table #1 illustrates these phases in the context of this present study.

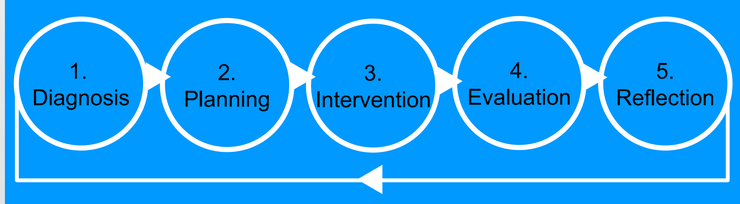

Figure #2

Diagnosis	Explain the purpose of Gamification
Planning	Choose a gamification strategy
Intervention	Engage gamification
Evaluation	Assess whether the game resulted in a more engage and motivating learning experience by conducting interviews and focus groups
Reflection	Reflect on outcomes

Table #1

Gamification strategy

The study sample was a group of Information Systems (IS) students at a University of Technology.

Student participants chose Quizlet Live (QL) (2018) as a gamification strategy.

In QL, students – divided into teams – take a quiz (based on learning content) on digital devices.

Each team member plays on their own device. While all devices receive the same question, only one device has the correct answer. Team members must collaborate to determine which device holds the correct answer (see Figure #3).

During gameplay, the instructor displays their progress against other teams as a race via an interactive leaderboard.

If a team answers a question incorrectly, QL resets the team's progress to zero on the interactive leaderboard; they must start again.

- I regard 'progress-reset' as AI.
- Rapid automation of a time consuming task.
- Human instructor not able to execute progress-reset as quickly and effectively as the technical system.

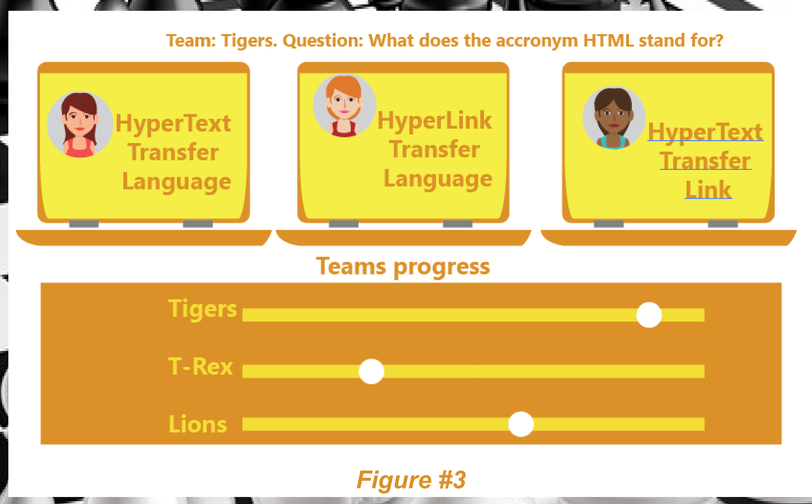

Figure #3

Findings

(i) AI cannot account for poor group communication and (ii) AI cannot account for poor English speaking skills.

(i) AI cannot account for poor group communication skills

At the time data for this study were collected, QL placed a strong focus on group play. The strong focus on group play is consistent with a strong emphasis on teamwork in IS education and industry. Considering that only group play (and not single play) in QL at the time this study was conducted, teamwork as a predominant approach is seemingly a consistent trend that appears to permeate Artificial Intelligence, too. An implication is that many students struggle to *communicate* in a group, which led to many progress-reset. Therefore, following each progress reset, Artificial Intelligence indirectly reinforces the notion that severe penalisation is the result of poor communication skills. This demotivates students. Below follow student opinion about progress-reset:

> It is a bit harsh ... what they could do, they could keep like okay you got the wrong answer – minus a point. Or, the more you get wrong, the more points get minus, like that: first term, one point; second term, double (Student 5).
>
> It is a bit frustrating to be honest because you could be on question 29 out of 30 and get the last one wrong and you get reset back to zero. So I think maybe the system could change a bit if you get a question wrong, it just minus a mark or two and go back to a previous question that changed instead of resetting all the way back to zero (Student 14).

(ii) AI cannot account for poor English speaking skills

This finding stems from the field notes (specifically participant observation) data collection method. I observed Student 11 looked unnerved and little collaboration occurs between him and his teammates. This issue became more problematic in instances where the team realized that Student 11's device might have the correct answer to a question. The result was a breakdown in group communication. The lecturer explained that Student 11 struggles to communicate in English; French is his first language. Student 11 do not only struggle to communicate in English, but also to understand the meaning of context of IS terminology; As Student 6 opines:

> But isn't it like Java or something where it's…if you are in a medical area, you say medical words and another person won't understand…it is something like that where you…where it's certain concepts, and if you translate it, it doesn't make sense (Student 6).

Discussion

Proposition 1

Students who find it difficult to communicate in a group indicate that they might perform better in individual play, away from the distractions of group communication. Future research is planned to compare individual play and group amid AI components.

Proposition 2

Although students criticizes progress reset, they do not reject it in its entirety. Students acknowledge that progress-reset adds an interesting dimension to the QL's competition element. Nevertheless, students suggestion to improve progress-reset should not be ignored. Broadly speaking, future research should investigate design science models where students have access to a game's source code and change features to meet their needs. For example, apply changes progress-reset such as move progress one level down in response to an incorrect answer.

Proposition 3

Progress-reset (digital technology in general) has an effect whereby students are inspired to learn or improve their English skills. The idea is two-fold: (i) to compete, with an improved grasp on English, against progress-reset and deal with the challenges in an English mediated technological world; and (ii) to communicate better with teammates in group play or teamwork environments. Future research is planned to examine these theories.

Conclusion

AI is narrow, cannot account for all social factors. Democratize gamified information systems. Develop IS content in other languages, despite Beliefs of English as the de facto language. Include students in the design of gamification technology so that they can communicate their needs. Use gamification technology that have both single and multiplayer mode.

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EFFECTIVE UTILISATION OF HUMAN RESOURCE INFORMATION SYSTEMS IN THE SOUTH AFRICAN HEALTH SECTOR

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ABSTRACT

The argument that continues to gain momentum is that Human Resource Information Systems (HRIS) are change enablers that assist organisations to achieve a competitive advantage, especially within the healthcare environment. The need for functional HR performance in the healthcare environment is high often leading to several research endeavours. Additionally, the benefit of using an HRIS in healthcare is always in the limelight in the research space. Interestingly, researchers are yet to prove how HRIS can be effectively utilised for skilled workforce sustainability in the South African healthcare environment. The research questions are: What are the reasons for the lack of effective HRIS in the health sector? What impact does HRIS usage have on the performance and sustainability of skilled workers in the health sector? and How can HRIS usage assist the health sector to improve its service delivery to the public?. Using the mixed method, data were purposively collected from four hospitals, with forty-one interviews and forty-six questionnaires. Atlas-ti and SPSS were used for data analysis. The study found that the lack of HRIS stems from reasons such as lack of awareness and education of HRIS. Notably, the continued preference for manual HR processes, dilapidated infrastructures, outdated information systems, leads to a severe lack of access and non-documentation of necessary data/information of staff. Thus, effective use of an improved HRIS is needed to assist in the management of skilled healthcare workers. Additional recommendations include guidelines for effective HRIS and future research directions in this study.

INTRODUCTION

- In achieving a strategic objective, organisations rely on an effective Human Resource Department (HRD). Information Systems (IS) are prevalent in all professional fields, including the field of Human Resource Management (HRM). These IS's, despite their various identities, have been the subject of numerous studies in the fields of information technology, psychology and social sciences (Barik, 2015; Al-Dmour, Obeidat, Masa'deh & Almajali, 2015; Ruël & Bondarouk, 2018). Interestingly, IS are the driving force of an efficacious organisation, the one that characterises a proficient HRD would be based on the effective utilisation of Human Resource Information System (HRIS). An effective HRIS would be expected to authorise a non-manual and paperless functionality of the HRD (Barišić, Poór & Bach, 2019; Valcik, Sabharwal & Benavides, 2021). Within the healthcare sector, the HRM processes data such as workforce information management, payroll, and other HR-related information, which can be supported using effective HRIS to achieve sustainable healthcare delivery services. Nevertheless, the role of effective HRIS as enablers of effective healthcare services, the effectiveness of HRIS has been disregarded as a subject of research in the healthcare sector of South Africa (Udekwe, Iwu, de la Harpe & Daramola, 2021). Numerous HRIS software package available in the market (Tariq, Sang & Gulzar, 2016). However, the HRIS adopted by the South African public health sector is known as the PERSAL system, which is used to manage their HRM system (Mathews, 2017).

- The public health sector is regarded as one of the most essential sectors for economic growth and also the sustenance of human lives (Iwu, 2013; Muthoka, 2016). The healthcare sector is further recognised as one of the most treasured, fast-growing and substantial sectors for growth and development in a country. Moreover, countries that do not consider human lives as important in their growth strategy might find it difficult in achieving their goals (Rispel et al., 2019). Perhaps, the governments can make use of HRIS for strategic decisions about their skilled health workforce in the country. This signifies that HRIS is critical in the health sector of a growing economy (Maruru, 2014; Kuyo, Muiruri & Njuguna, 2018). Furthermore, the health sector is regarded as the amalgamation of all sectors, institutions and resources that are interrelated and managed for improving healthcare services in a country. Therefore, HRIS should be regarded as an important system that could assist to monitor the efficiency of skilled healthcare workers in general (Mahlulo, 2020). The skilled healthcare workers in this study refer to people that specialised in clinical and medical functions in the sector such as nurses, doctors, pharmacists to name a few.

- Considering the importance of healthcare in an economy, there is a need to research to identify the reasons for the lack of effective HRIS in the health sector, to determine its impact on skilled healthcare workforce management and the sector in general (Tursunbayeva, Pagliari, Bunduchi & Franco, 2015). In doing this, the reasons for the lack of effective HRIS to support HR functions within healthcare can be revealed (Alam et al., 2016). This according to Tjoflåt et al. (2018) may assist in determining the potential of HRIS towards contributing to healthcare effectiveness.

- The study, therefore, explores the effective utilisation of HRIS in the South African public health sector. There are three steps that define the logic of the study: First, the need to determine the reasons for the lack of effective HRIS, secondly, the effect of HRIS usage on the performance of skilled health workers and sustainability in the health sector, then thirdly, the effectiveness of HRIS for service delivery in the health sector. The study seeks to attend to these three issues through an abductive methodological approach.

RESEARCH METHOD

- A mixed-model research method was initiated with the combination of qualitative and quantitative methods. Four (4) hospitals in the Western Cape Provincial Health Department of South Africa, with forty-one (41) interviews and forty-six (46) questionnaires collected. Atlas-ti and SPSS were used for data analysis.

- This study is subjective as it refers to the effectiveness of HRIS therefore, the ontological philosophy is subjectivism and the epistemological philosophy is interpretivism.

- An abductive research approach was followed (Bhattacherjee, 2012). Multiple case study research strategy was used in the study. The non-probability sampling method of data collection was used to purposively select the participants from the four hospitals.

- This was a descriptive and exploratory study, aimed at gaining an in-depth knowledge of the barriers to the effective use of HRIS in the health sector (Saunders, Lewis & Thornhill, 2019).

- A guideline will be proposed in the main research paper for the effective utilization of HRIS in the South African health sector.

RESULT

Figure 1: Summary of reasons for lack of effective HRIS in the health sector

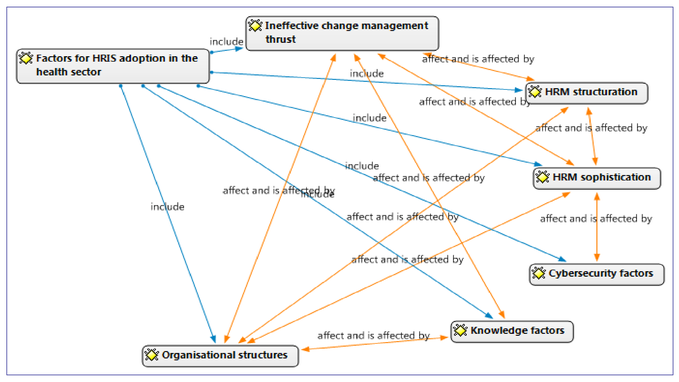
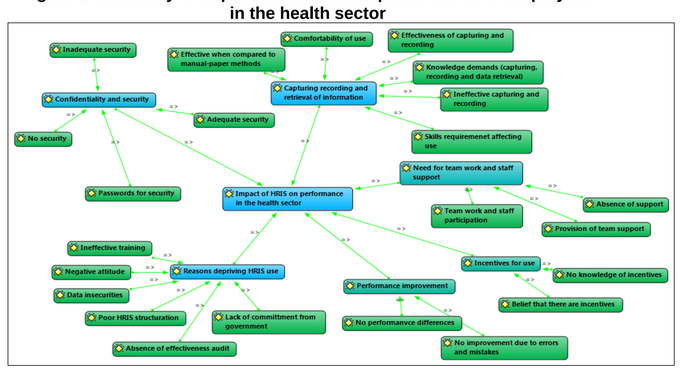


Figure 2: Summary of impact of HRIS to the performance of employees in the health sector



DISCUSSION

- There is a lack of awareness and education of HRIS by the majority of the respondents. What appears to be the reason is that HRIS is an outdated PERSAL which most skilled workers are not aware of how it works.

- Most of the respondents indicated that they do not have an HRD. Could this be the reason for frequent errors – poor data management including payroll management which warrants frequent visits to the regional office by workers to resolve HR related problems.

- Security of workers information is also an issue of which the respondents indicated that the lack of HRD and also lack of access to HRIS in most of the healthcare facilities compromises HR information. Although, it is understood that there is a reasonable form of security of information on PERSAL, but not very effective due to the manual nature of most HR functions in most of the healthcare facilities.

- The high level of disagreement among the respondents on HR functionality enhancement was blamed upon the dependence of manual processes of HR functions. Also, the lack of upgraded HRIS in healthcare does not allow skilled workers to access the system, which does have a negative effect on their performance and sustainability in the health sector.

- The size of the healthcare facilities was also pointed out by most of the respondents as a reason for not having an effective HRIS in the sector. Most facilities had to work through the regional offices HRD to get their information on HRIS (PERSAL) captured.

DISCUSSION

- Having few HR personnel to work on HRIS (PERSAL) is a challenge that could attract errors, omissions or misplacements in the capture and retrieval of HR information. This is also attributed to documents being lost in transit to the regional office HRD.

CONCLUSION

- Perhaps, HRIS can alter the healthcare needs to be brought to the awareness of the skilled healthcare workers. Also, the need for education and training to advance the knowledge and awareness of HRIS and how it can assist skilled healthcare workers in the performance of their duties is relevant.

- An HRD with people with the right skills and expertise, and also an improved HRIS, may be enlightening to action the above thoughts.

- The need to have an HRIS that allows skilled health workers access through an automated system, to minimise/eliminate manual HR processes.

- An HRIS to conduct HR functions, to eliminate manual processes and frequent payroll errors, omissions and documents lost in transit to the regional office HRD.

- The need for adequate incentives and motivation that will be used to carry the entire skilled health workers along in their contribution towards an effective HRIS in the healthcare sector.

- Also, the need for a change management process to assist the government in making decisions that will improve the current HRIS used in the public healthcare sector.

- The use of HRIS for both administrative and strategic decisions to save time and resources in the management of skilled health workers. It will also assist in the monitoring and management of skilled health workers and also sustainability in the healthcare of South Africa.

THEORETICAL CONTRIBUTION

- A core theoretical contribution of the study is that it will add to the discussions on how the South African public health sector is able to efficiently manage its skilled workforce

PRACTICAL CONTRIBUTION

- Its contribution will be linked to possible policy framing for better service delivery in the South African healthcare sector

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NEMISA SUMMIT: 15-17 February 2022

SMME Readiness Framework for Smart Manufacturing Adoption in South Africa

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Introduction

Background of Study

Smart Manufacturing (SM) is a Fourth Industrial Revolution (4IR) paradigm for transitioning manufacturing firms from traditional legacy manufacturing to Digital manufacturing (Gumbi and Twinomurinzi, 2020).

SM is conceptualized as a fully integrated, collaborative and automated manufacturing system enabled by the convergence and integration of advanced DT (Cloud Computing, Cyber-Physical Systems, Big Data, Internet of Things, Smart Sensor and AI 2.0).

Figure 1: Smart Manufacturing Concept

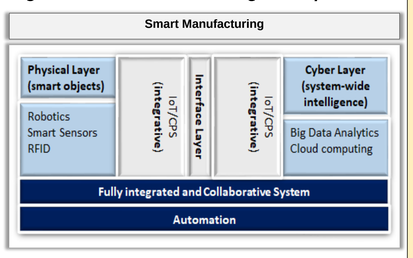


Figure 2: Smart Manufacturing Concept

SM is a key enabler for optimizations of manufacturing supply and value chains, business model innovations such as servitization, mass customization, customer participation, and flexibility in the manufacturing processes (Davis et al., 2012; Thoben, Wiesner and Wuest, 2017a; Yin, Stecke and Li, 2017).

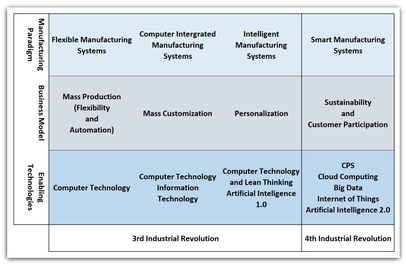
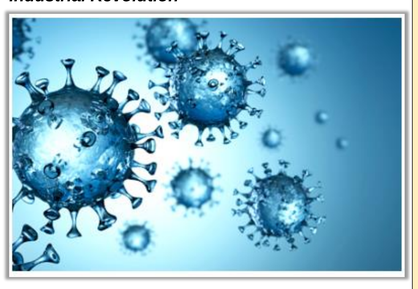


Figure 3: Smart Manufacturing in the Fourth Industrial Revolution

COVID-19 is disrupting various firm activities, is threatening to obliterate manufacturing firms in particular Small, Medium and Micro Enterprises (SMMEs) globally (Tairas, 2020) and is severely limiting traditional manufacturing businesses (Bragazzi, 2020; Priyono, Moin and Putri, 2020; Tairas, 2020).



The advent of **COVID-19** and the dawn of **4IR (SM)** are now a very compelling motivation for manufacturing firms to digitally transform to remain sustainable and viable in the current business environment (Priyono, Moin and Putri, 2020). However, only a small group of high tech large multinational corporations are adopting SM (Mittal, Khan, Romero, et al., 2019).

SMMEs are struggling and lagging behind in readiness for SM adoption (Jun et al., 2017; Mittal et al., 2017; Ramakrishna, Chen Khong and Leong, 2017; Mittal, Romero and Wuest, 2018).

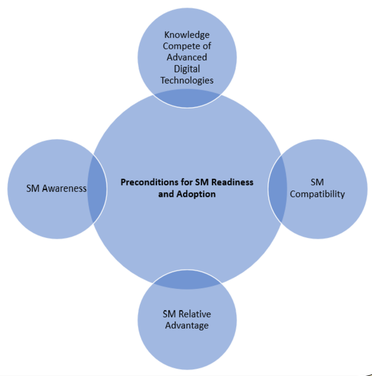
Problem Statement

The performance of the manufacturing sector in the past 2-3 decades has been poor and rapidly declining (Madonsela, Mbecke and Mbohwa, 2013; Black, Craig and Dunne, 2017; Kuhn, 2017) as a result of increasing *operational costs* and *declining productivity*.

SM is a solution to address the problem of increasing operational costs and declining productivity. However, SA Manufacturing SMMEs are not ready for SM due to context specific preconditions (Seseni and Mbohwa, 2018; Mbuyane, 2020)

- Lack of knowledge competence of advanced Digital Technologies (DT)
- Lack of awareness of SM
- SMME incompatibility to SM
- SMME lack of know-how in perceiving the relative advantage of SM for SMME specific context

Figure 4: SMME Smart Manufacturing Preconditions



Existing Frameworks are not suitable for SMME Readiness for SM adoption

- They do not address the aforementioned systemic SMME context specific preconditions (Mittal et al., 2018; Gumbi and Twinomurinzi, 2020)
- They assume SMMEs are at the same starting point as the large high tech firms

Research Objectives

Table 1: Research Questions and Objectives

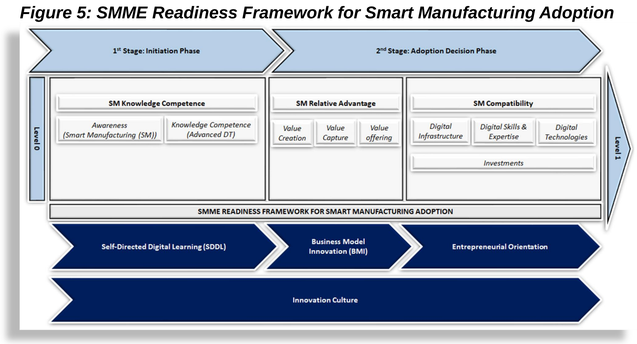
PRIMARY RQ: *HOW CAN SOUTH AFRICAN MANUFACTURING SMMES ADOPT SMART MANUFACTURING?*	PRIMARY RO: *DEVELOP AND EMPIRICALLY TEST AN SMME READINESS FRAMEWORK FOR SMART MANUFACTURING ADOPTION*
Secondary RQs	Secondary ROs
1. What is the level of manufacturing SMMEs Smart Manufacturing (SM) knowledge competence (SM awareness and knowledge competence of advanced DT), and how can this knowledge competence be developed?	1. Determine the level of manufacturing SMMEs Smart Manufacturing (SM) knowledge competence (SM awareness and knowledge competence of advanced DT), and what influences the development of smart manufacturing knowledge competence (awareness and advance DT) for manufacturing SMMEs
2. What are the benefits (relative advantage) of Smart Manufacturing for manufacturing SMMEs, and how can these benefits be perceived by manufacturing SMMEs?	2. Identify the benefits (relative advantage) of smart manufacturing for manufacturing SMMEs, and what influences the perception of manufacturing SMMEs in the identification of smart manufacturing benefits (relative advantage)
3. Which technologies are seen as key to the concept of smart manufacturing in relation to SMMEs?	3. Determine key core technologies for smart manufacturing in relation to SMMEs?
4. What is the level of Smart Manufacturing incompatibility to manufacturing SMMEs, and how can manufacturing SMMEs be compatible with Smart Manufacturing?	4. Determine the level of smart manufacturing incompatibility with manufacturing SMMEs, and key factors influencing manufacturing SMMEs compatibility with smart manufacturing
5. What is the level of smart manufacturing readiness for adoption by SMMEs in the manufacturing sector?	5. Determine the level of smart manufacturing readiness for adoption by SMMEs in the manufacturing sector

Methods

Innovation Adoption Theory

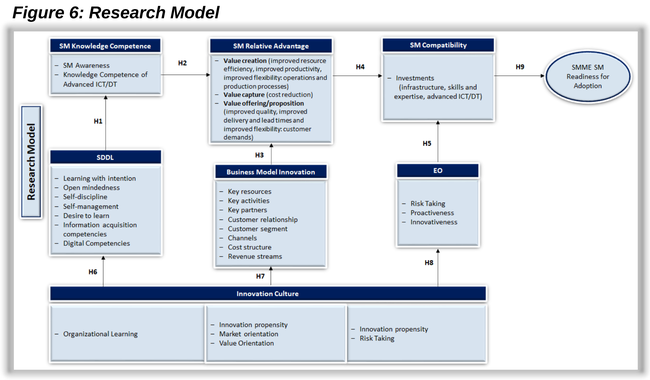
In this study, the Innovation Adoption Process Theory was used to develop the SMME Readiness Framework for SM Adoption (Nooteboom, 1994; Pichlak, 2015).

Figure 5: SMME Readiness Framework for Smart Manufacturing Adoption



A research model comprising of 7 constructs and 9 hypotheses has been developed to empirically test the framework.

Figure 6: Research Model



Research Design

- ❑ **Research Philosophy: Critical Realism**
  - Accepts the use of a scientific method (SMME Readiness Framework) approach to theory development based on some degree of objective reality;
  - While also allowing for context specific social structures and constructions (SMME Preconditions and Context) to emerge (Mcevoy and Richards, 2008; Modell, 2009; Saunders, Lewis and Thornhill, 2009; Maxwell and Mittapalli, 2010; Halcomb and Hickman, 2015)
- ❑ **Research Method: Mixed Method Research Design**
  - Two Phase Exploratory Research Design
- ❑ **Techniques and Procedures**
  - Interviews (semi-structured questionnaire) and an online survey (structured questionnaire) are used for this study
  - Structural Equation Modeling statistical technique is utilized for quantitative data analysis
  - Content analysis is utilized for qualitative data analysis

Figure 7: Research Methodology

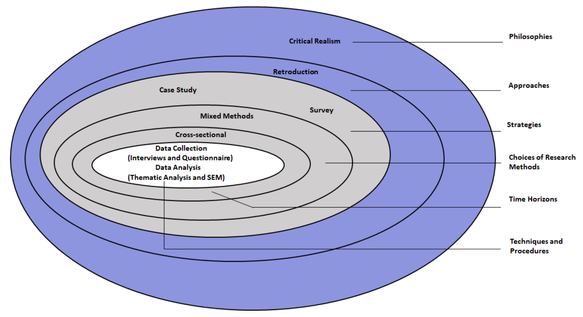
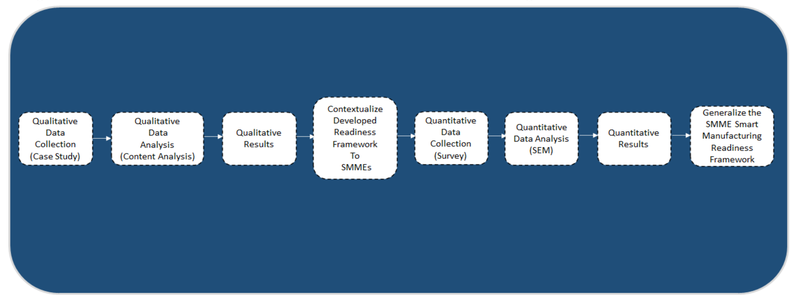


Figure 8: Two Phase Exploratory Mixed Method Research Design



Results

The author is currently collecting data through interviews to explore the research model's constructs and hypothesized relationships. The interviews are also assisting the authors in having a deeper understanding of the contextual factors and further unearthing new additional SMME context specific preconditions. Initial results support H1, H2, H3, H4, H6 and H7, however, the author is still in the initial stages of the data analysis process. The findings of the interviews will be used in phase 2 to refine the research model which will then be empirically tested using a quantitative survey.

Conclusions

SM has been identified as a 4IR viable solution to address the problem of manufacturing SMMEs increasing operational costs, declining productivity and unexpected pandemics such as COVID-19. However, SA Manufacturing SMMEs are not ready for SM due to context specific preconditions. Currently, there are no existing frameworks that are suitable for SA manufacturing SMME Readiness for SM adoption. As a result, an SMME readiness framework for manufacturing SMME SM adoption contextualized to the manufacturing sector preconditions in South Africa has been developed and proposed in this study. The objective of the framework is to support the digital transformation of the South African manufacturing sector, the national effort in the re-industrialization of the manufacturing sector and the development of South Africa specific SMME smart manufacturing national policies and strategies.

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Towards AI algorithmic fairness

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Introduction

Despite Artificial Intelligence (AI) being one of the fastest-growing fields due to its ability to enhance competitive advantage in organisations, there are growing concerns around its inherent bias.

AI allows systems to perform tasks that would normally be performed by humans. Data is collected and processed to provide results that mimic human intelligence over rules learnt over time. There are three categories of AI, namely, Narrow AI, General AI and Super AI, and some of the popular AI's are natural language processing, computer vision, and artificial neural networks. Apple's Siri, Google Maps, Google predictions and Smart replies by GMAIL are some of the well-known AI solutions.

Fairness means impartiality in decision-making, making decisions without any self-interest in the outcome. AI is prone to AI algorithmic bias, which could result in operational and reputational damage. AI has the potential to be unfair to certain groups of people like race and gender. AI systems need to be fair and respect human rights, democracy, values, and principles.

AI development is always focused on the results and not the input and bias in the data or process of developing the AI. This has resulted in biased AI being implemented, and such issues only picked up by the public. A framework that supports the emphasis on shifting the focus from AI standards to **fair processes** that are adaptable to AI's continuous innovation has been developed.

The Jurgen Habermasian critical theory of communicative action, the lifeworld and meaning was used to develop a process framework on AI algorithmic fairness.

- ❑ The framework engages logical-semantic, procedural and performative rules that can be applied to the development process of AI to avoid any domination before, during and after the AI development process.

The purpose of this research is to collect data and demonstrate the Habermasian approach to AI Fairness processes framework.

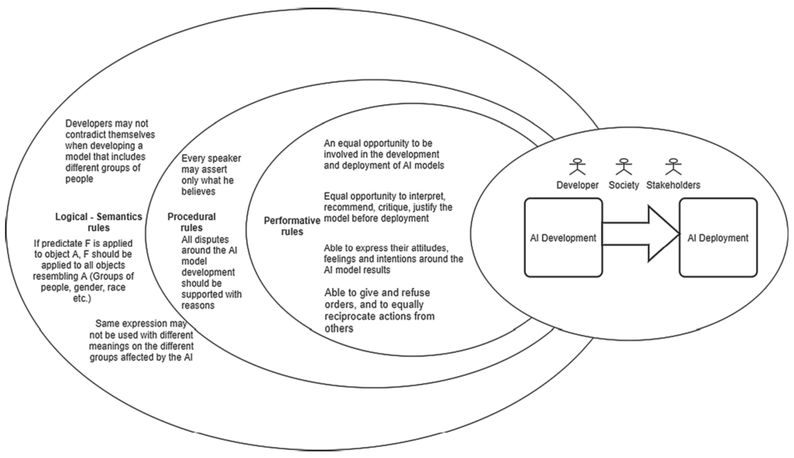

Figure 1 - Process Framework for AI algorithmic fairness – A Habermasian Approach

Objectives

The main question that will be discussed in this research is as follows:
How can the Habermasian approach to AI algorithmic fairness process framework help reduce bias in AI algorithms?
The following questions will also be investigated in support of the main question:

- ❑ How does the involvement of society affected by AI, developers and management during all the development phases of AI help reduce bias in AI algorithms?
- ❑ How does following the Habermasian discursive requirements through the development stages of AI help reduce bias in AI algorithms?

Methods

Design science research will be used to develop a solution that will use the developed framework to reduce bias in AI algorithms. The solution will allow for the different parties to be involved in the whole process of AI development. Professionals in the AI development field can use the solution to reduce bias in AI algorithms. The solution developed will be used by developers, the society that will be affected by the AI and management sponsoring the development of the AI.

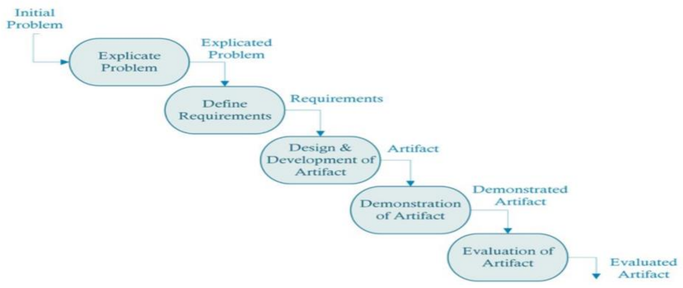

Figure 2 - Design Science Research Method Framework

Population and Sample

The Habermasian approach to fair processes in AI will be presented to AI professionals for their feedback. AI professionals will see the value in using such a framework when developing AI.

A solution for reducing AI bias in algorithms will be built based on the framework. The solution will be used by developers, society and management, demonstrating the framework during an AI development project. The built solution will be used to capture all inputs from the different parties.

- ❑ **Management** will use the solution to capture their requirements and expectations of the AI.
- ❑ **Developers** will use the app to capture the details of the development approach, input data and rules that will be used in the development.
- ❑ **Society** will use the app to question any areas of concern and express their feelings.

All parties involved will use the solution for any disputes and reasons for their disputes.

Any bias will be picked up during the development stages and resolved before the AI solution is implemented in the live environment.

Expected Contributions

Involving affected parties, stakeholders and developers in the development and implementation stages of AI, and incorporating the logical-semantic, procedural, and performative rules during these stages is an essential step in :

- ❑ Ensuring that all parties are involved throughout the different stages of AI implementation;
- ❑ Picking up bias before the AI is implemented onto the live environment;
- ❑ Resolving bias before implementation;
- ❑ Avoiding any backlash from society; and
- ❑ Avoiding any reputational damage or financial loss to the organisation.

Publications

- ❑ A Systematic review of AI algorithmic Fairness - Xivuri, K. and Twinomurinzi, H. (2021) *A Systematic Review of Fairness in Artificial Intelligence Algorithms, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. Springer International Publishing. doi: 10.1007/978-3-030-85447-8_24.

- ❑ Xivuri, K. and Twinomurinzi, H. (2022) *A Habermasian Approach to Fair Processes in AI Algorithms, Jembere E., Gerber A.J., Viriri S., Pillay A. (eds) Artificial Intelligence Research. SACAIR 2021.* doi: https://doi.org/10.1007/978-3-030-95070-5_22.

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A blockchain solution to drugs counterfeiting in the South Africa pharmaceutical supply chain

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UNIVERSITY OF JOHANNESBURG

Introduction

Pharmaceutical supply chain processes are complex and involve multiple stakeholders. Counterfeit drugs are one of the major global challenges in the pharmaceutical supply chain and healthcare sector that put patient lives at a high risk. The danger of counterfeit drugs is that once the drugs are tempered, they become prone to inflicting unknown side effects to the patients. In the pharmaceutical supply chain, blockchain can reduce instances of counterfeit drugs by tracking and tracing drugs effectively from the manufacturer to the patient.

Objectives

This study aims to develop a blockchain solution to address drugs counterfeiting within the South African pharmaceutical supply chain, therefore it aims;

1) To investigate the contributing factors to drugs counterfeiting in the South African pharmaceutical supply chain.
2) To develop a blockchain artifact as a solution for drugs counterfeiting in the South African pharmaceutical supply chain.
3) To theorize the adoption of the blockchain artifact in the South African pharmaceutical supply chain.

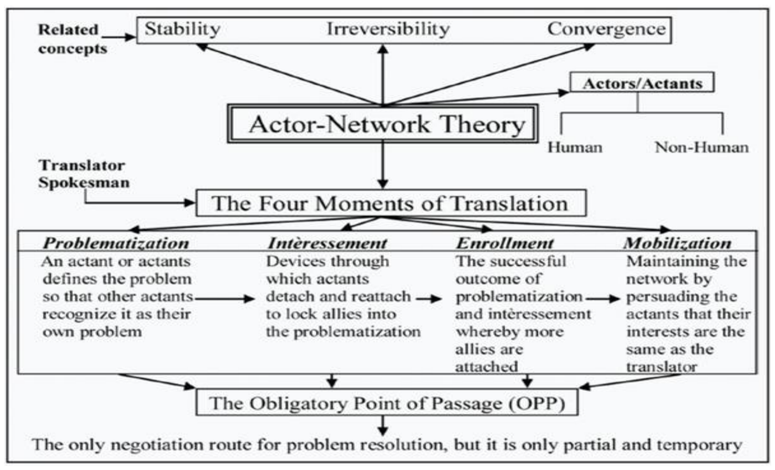
Theoretical Framework

Actor network theory (ANT) is a sociotechnical theory that depicts how power shifts in a network of human and non-human actors as well as their interactions within heterogeneous networks (Callon, 1986).

ANT is in line with blockchain technology and supply chains. Blockchains are interconnected networks of decentralized nodes.

Supply chains are networks of organisations, people, activities, data, and resources invested in delivering a product or service to a customer.

Figure 1: Moments of translation (Adopted from Iyamu & Sekgweleo, 2013)



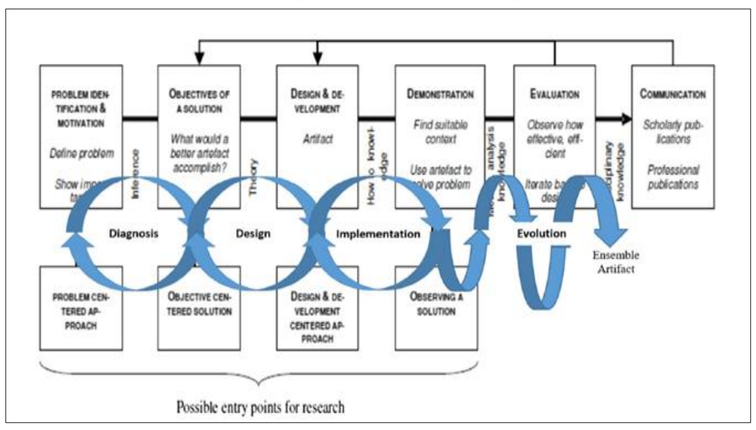
Methods

This study will adopt Design Science Research (DSR) methodology. DSR is defined as a research paradigm whereby a researcher answers questions relevant to human challenges (Iivari & Venable, 2009). The questions can be answered by creating innovative artifacts and contributing new knowledge to the body of scientific evidence. In particular the study use Action Design Research (ADR) which is the branch of DSR.

ADR utilises the following iterative processes:

1) Diagnosis
2) Design
3) Implementation
4) Evolution

Figure 2: Action Design Research (ADR) (Adopted from: Mullarkey and Hevner, 2018)



Data Collection

This research study will collect data in two phases.

1) In phase one, qualitative data will be collected through interviewing PSC stakeholders about counterfeit drugs challenges.
2) Phase two involves data collection through the artifact evaluation.

Study Contribution

Contribution to this study is three-fold:

1) Academic contribution:
2) Artifact:
3) Framework:

Current Publication

Buthelezi, B. E., Ndayizigamiye, P., Twinomurinzi, H. & Dube, S.(2022). A Systematic Review of the Adoption of Blockchain for Supply Chain Processes. *Journal of Global Information Management (JGIM). (Accepted for publication)*

Conclusions

This proposal presented the underlying challenge of counterfeit drugs in the pharmaceutical supply chain followed by the objectives. It also presented the literature on the pharmaceutical supply chain, the blockchain technology, the counterfeiting of drugs, the theoretical framework to be used, and the adopted methodology which is design science methodology. It also highlighted on how data is going to be collected and gave the overview of the study contributions.

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DEMOCRATIZING DATA SCIENCE EDUCATION FOR THE NON-SCIENCES

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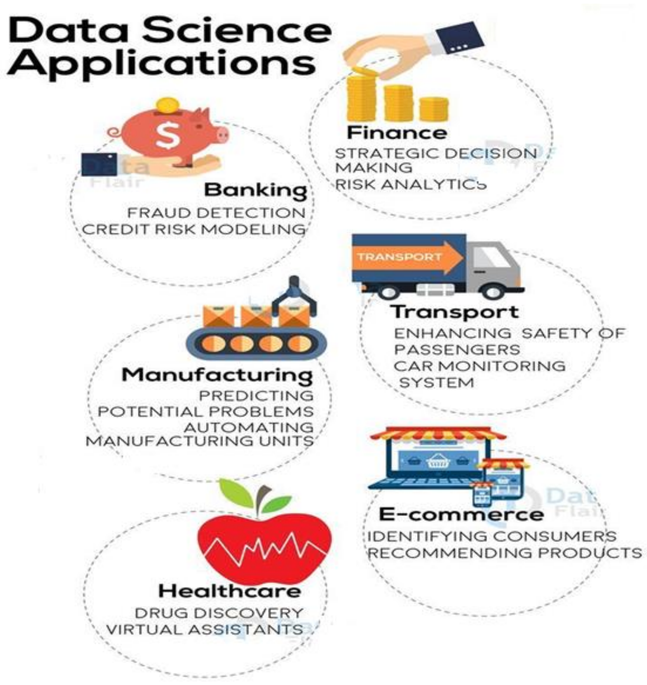
Introduction

Data is today described as a new and desirable and organisations increasingly require data science skills to harness this commodity. The proliferation of data and the affordance of modern technologies has triggered many organizations to contemplate data science. However, data science skills are scarce, and even more challenging is that data science education and training programs are inconsistent and adequate.

Data science or the "science of data" is one of the emerging ICT specialist disciplines that have attracted many scholars in information systems (IS). Data science tasks range from the technical understanding of business problems to coming up with algorithms to generate knowledge (Wang et al., 2021). Below are some examples of how data science is applied in different industries.



Problem Statement

The interdisciplinary nature of data science raises concerns about competencies/skills, resources, and commitment within the education and training space. The main challenge is that there are not enough data science skills available, especially in non-sciences. This is due to lack of programs focusing on data science education for non-sciences. As it stands, the gap between organisational demand and supply of data science cannot be filled immediately. Data science is fast-paced, and the existing pedagogies cannot adapt quickly to fill the gap. This study plans to investigate how micro-credentials may support data science education for non-sciences to close the skills gap.

Research Question

How can data science education be democratized for the non-sciences using micro-credentials?

Purpose of the Study

The study intends to investigate how to democratize data science education for the non-sciences, with micro-credentials as the ideal mechanism.

Methods

Design Science Research (DSR)
To solve field problems by designing artefacts that practitioners can apply rather than filling the knowledge gap

Process Model: Elaborated action design research (e-ADR)

The e-ADR (Mullarkey and Hevner, 2019) serves as an extension and alteration for the original ADR (Sein et al., 2011). This theory is beneficial by providing a well-structured process model that is inclusive of action research and design science research (Sein et al., 2011). The study will follow the four (4) phases as

1. Diagnosis
2. Design
3. Implementation
4. Evolution

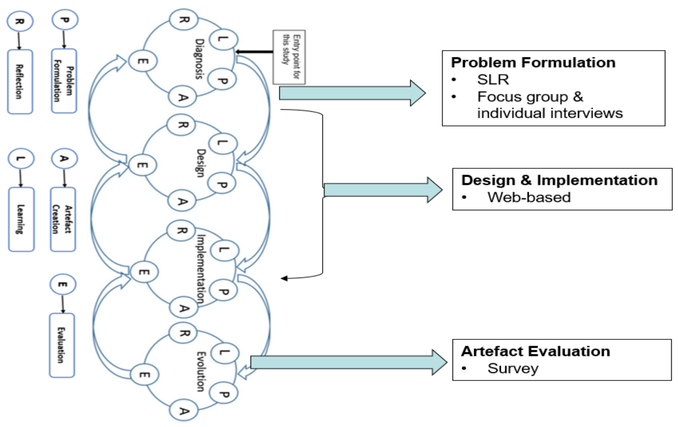
Critical Realism

The study argues for critical realist informed sociotechnical network perspective, that it offers an opportunity to conceptualize a framework that considers socio-technical issues, humans, organisations, and technology (material) dimensions and can provide the basis of a more practical approach to researching and building data science education artefact.

Data Collection

Two-phased data collection

- Phase 1 - Focus Group (Problem Formulation)
- Phase 2 – Artefact Evaluation



Population Sample

- **IS/IT and data science lecturers (public educational institutions)** - course structures and development, how to embed technology, and teaching pedagogies.
- **The university executive management** - perspective on policy such as recruitment of students and resource allocation.
- **Employers (ICT sector)** - how data science roles are filled within their organisations, the role they can play in data science education?

Data Scientists - Insights on qualifications required , challenges they face in the field

Expected contribution

Theoretical Contribution

- The study will offer guiding principles towards implementing data science education micro-credentials for non-sciences

Methodological Contribution

- Lessons from applying the recent e-ADR process model by Mullarkey and Hevner (2019)

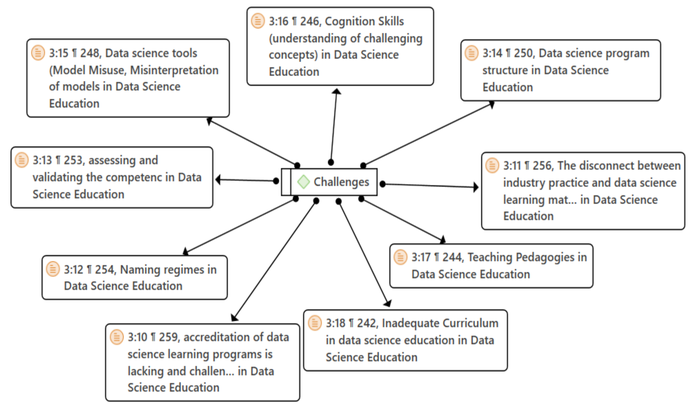
Practical Contribution

- This study proposes a framework towards democratizing data science education for non-sciences
- Case study on non-science domain micro-credential
- The study will further propose a digital prototype for hosting data science education micro-credentials

Work in Progress

Data Science Education - A Systematic Literature Review

The study presents a review on data science education research. The main aim is to identify the opportunities for and challenges in data science education



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BEYOND TOUCH: AN EDUCATIONAL DESIGN INTERVENTION TO INVESTIGATE THE AFFORDANCES OF EMBEDDED TACTILE AND SENSORY TECHNOLOGY

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Introduction

The pandemic brought many changes to educational innovation due to the immediate shift to online learning not always supported by appropriate learning design processes. This resulted in questioning how useful the existing tools and methods are for online pedagogies (1). Limited blended learning experiences were observed with little concern for engagement, participation and deeper learning. A formalised approach to learning design is therefore needed to adjust to blended teaching and learning practices.

Embedded Tactile and Sensory Technology (ETaST) pedagogies are showing potential to support blended learning through socially constructed forms of learning (2). However, these have so far only been used in limited settings for traditional STEM-based education (3). So far, it has not been integrated across disciplines in Higher Education (HE) and there is little research done due to a lack of pedagogical knowledge, limited access to such technologies and outdated curricular practices, inter alia (3;4).

ETaSTs like 3-Dimensional Printing (3DP) have shown potential to improve learning outcomes in HE through multi-sensory experiences (5;6). However, in South African HE, the implementation has been problematic and remain underexplored (3). This is due to resource and institutional constraints, but also entrenched pedagogical practices that inhibit innovation (7). This presents a twofold problem: universities cannot afford certain aspects of these technologies such as upskilling with appropriate technology literacy and simultaneously HE are not offered suitable opportunities to engage with these technologies (3).

This study explores the fundamental hindrances and opportunities of integrating ETaSTs such as 3DP in blended educational practices. A 3DP programme at an undergraduate level will be designed and implemented at a University of Technology (UoT) across a variety of disciplines. This programme will be designed to stimulate co-creative engagement and learning through the lens of experiential learning theory. The research will reflect critically on the outcomes of this programme at both micro (classroom) and meso (institutional) levels. Simultaneously, the study unpacks the affordances of 3DP as an ETaST for a contemporary educational landscape in South Africa. In doing so, it grounds this research in the national (macro) discourse of 4IR, which foregrounds the transformative potential of emerging technologies (4;7).

Problem Statement

Educators need to develop a meaningful understanding of the potential and/ or limitations (affordances) of emerging technologies, to identify pedagogical opportunities. If no understanding of the technology's affordances can be generated, its effectiveness for teaching and learning will be compromised (8).

Aims and research question

This study aims to co-design an intervention for Embedded Tactile Sensory Technology (ETaST) from within an UoT, across different disciplines to better prepare learners for 4IR. A secondary aim of the study is to investigate to what extent or how HEI curricula and pedagogical practices respond to the implementation of ETaSTs.

What are the educational affordances and hindrances of embedded tactile and sensory technology for embodied learning within a UoT context?

Theoretical frame

This study is grounded in Kolb's Experiential Learning Theory (ELT), which is structured on four modes of practice (Figure 1) that involve Concrete Experience, Reflective Observation, Abstract Conceptualisation and Active Experimentation (9;10;11).

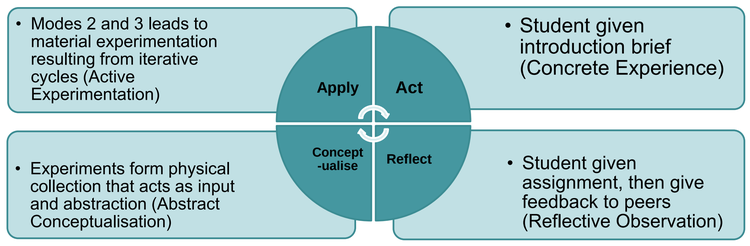

Figure #1 Experiential learning

Methods

The methods that will be employed in this study will be qualitative and follow a DBR approach due to focusing on a practical rather than a theoretical problem. Interventions are developed within specific limitations and implemented to investigate how well they function in specific contexts. A cyclical process is followed to establish the functionality and to modify these interventions. This systematic DBR process applies specific steps to create, test, investigate and refine interventions. An adjusted version of the 4-phase Reeves model will be adopted for this study (12).

In **Phase 1** analysis of the problem takes place through collaboration and literature review. In **Phase 2** development of solutions are created through combining design principles with emerging technology and further literature reviews. **Phase 3** tests and refines the design principles through case studies, interviews, data analysis, identifying improvements and a 2nd iteration. **Phase 4** reflects on the design principles tested in phase 3 to implement enhanced solutions that will contribute to theory and practice (Figure 2).

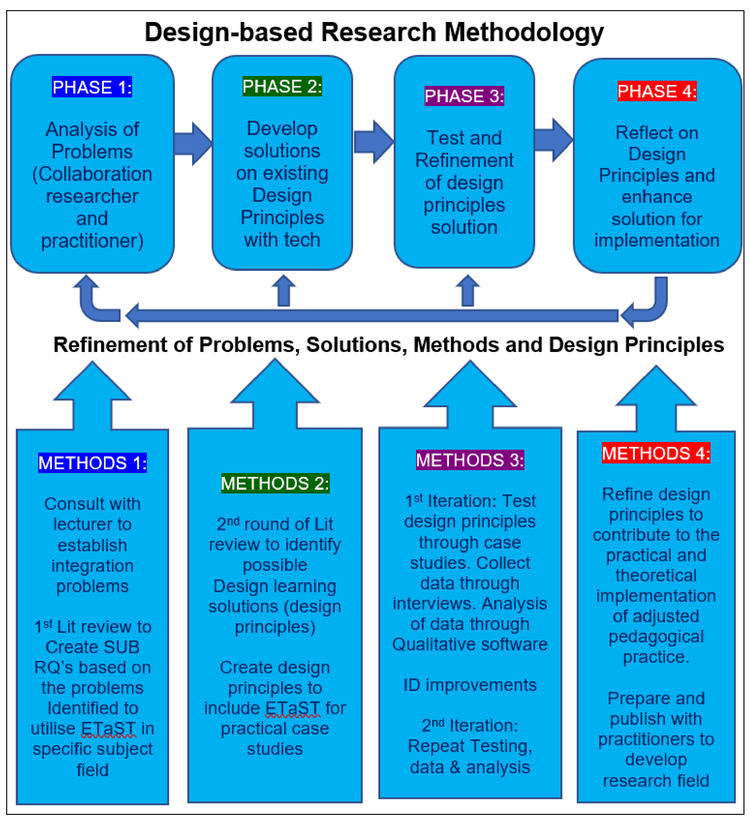

Figure #2 new DBR 4-phase Reeves model

Expected contribution

This study will explore new methods of educational practices to identify opportunities and hindrances in the use of emerging technologies such as ETaSTs 3DP across various disciplines. From a theoretical perspective, it will add to the body of knowledge of tactile and sensory pedagogical practices and how they can be used in new ways across various disciplines. It will lead to better understanding of how the affordances of ETaSTs could ready the UoT landscape to adapt to the challenges and opportunities brought by new innovative teaching and learning practices. From a methodological perspective, it will adopt various conceptual frameworks that integrate emerging methods such as CDIO, DBR, TPACK and Connectivism. From a practical perspective, it will contribute to the development of pedagogical practices to produce a newly informed understanding of the use of ETaSTs, across disciplines, to produce better-equipped graduates at a UoT-level.

Conclusions

ETaSTs like 3DP evidently improves learning outcomes in HE. However, in SA HE, implementation of such technology seems problematic and underexplored, due to resource and institutional constraints. The preliminary literature review shows that universities cannot afford these technologies and lecturers and students are not allowed to engage with these technologies. This study explores the fundamental hindrances and opportunities of integrating 3DP in educational practice. A 3DP programme is designed to stimulate engagement and learning. The study will reflect critically on the outcomes of this programme at both micro ("classroom") and meso (institutional) levels. It will also unpack the affordances of ETaST 3DP for the 'modern' educational landscape in South Africa. In doing so, the study grounds this research in the national (macro) discourse of 4IR, which speaks to the transformative potential of emerging technologies (4).

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