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Toward a Dynamic Capabilities Framework for Engendering 4IR-Enabled Circular Economy in a University of Technology

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Universities are placed in a disadvantaged position as it pertains to the holistic adoption of 4th Industrial Revolution (4IR) technologies and their subsequent deployment toward improving circular economy (CE) performance. Accordingly, literature relating to the contribution of 4IR technologies in driving effective CE implementation in higher education institution (HEI) contexts remain limited. In this study, the need for a dynamic capabilities' framework for managing the deployment of 4IR technologies toward enabling CE implementation within the context of a South African University of Technology (SAUoT), is articulated. A single case study research design was adopted for the study with SAUoT serving as the case. Qualitative data was elicited through a brainstorming session with 18 discussants from SAUoT. Thematic analysis was utilized in analyzing the data. Findings highlight the opportunities and challenges associated with the deployment of 4IR technologies in driving CE implementation within SAUoT. Also, it provided the reasons behind the inability of extant management frameworks to facilitate successful deployment of 4IR technologies for improved CE implementation in HEIs. These findings culminated in the proposal for the adoption of a dynamic capabilities-driven framework for improved strategic management in such contexts. The proposed framework presents a platform for facilitating the effective adoption and implementation of 4IR technologies for improving CE implementation performance. This study holds salient implications for the policy makers, academic leaders, and innovation managers in university ecosystems in developing country contexts.

Keywords: circular economy, dynamic capabilities, universities, 4th industrial revolution, developing countries

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INTRODUCTION

The quest to embed sustainability and sustainable development ethos into society's fabric continues to gain momentum (Ayre and Callway, 2013; Barbier and Burgess, 2017; Olawumi and Chan, 2018). As purveyors of knowledge in society, universities have, quite understandably come under pressure to assume leading roles in the transition toward sustainable futures (Cortese, 2003; Leal Filho, 2011; Awuzie and Emuze, 2017; Ramakrishna et al., 2020). Accordingly, universities are expected to cater toward deepening sustainability-oriented education, innovations, and sustainable regional development (Peer and Stoeglehner, 2013; Soares et al., 2020; Thomas and Pugh, 2020; Garcia-Alvarez-Coque et al., 2021; Radinger-Peer et al., 2021).

Globally, an increasing number of universities have committed to operationalizing sustainability transformations across all facets of their core activities namely: teaching and learning, research, and operations (Lozano et al., 2013, 2015; Nejati and Nejati, 2013; Amaral et al., 2015; Findler et al., 2019). This commitment has given impetus to the description of universities which are able to achieve substantial integration of sustainability tenets into these facets as sustainable universities (SU) (Disterheft et al., 2015). In furtherance to this, Van Weenen (2000) recommended a sustainable university classification model to allow for a delineation of universities according to the level of incorporation of sustainability tenets into various activities, and strategically across the engagement and organizational axes. See **Figure 1**.

The Fourth Industrial Revolution (4IR) is characterized by the "fusion of technologies that is blurring the lines between the physical, digital, and biological spheres" (Schwab, 2016). Schwab (2016) admits that the possibilities associated with the 4IR are strengthened by the emergent technological advancements in aspects like artificial intelligence, robotics, etc., which are evolving at an exponential rate. The utility of these technologies in driving sustainable development at universities has been reported (Du Preez and Sinha, 2020; Hoosain et al., 2020; Nkosi et al., 2020). However, literature focusing on the use of these disruptive technologies in enhancing circular economy (CE) implementation performance in universities remain scant (Ramakrishna et al., 2020), a contrast with what obtains in other organizations (Liu et al., 2021).

The CE has been described as a restorative industrial system which facilitates optimal materials, energy, labor, and information flows hence supporting the rebuilding of natural and social capital in the most efficient manner with minimal waste (Ellen MacArthur Foundation, 2013). Other scholars describe CE as a sub-discipline of sustainability which is premised on the principles of reduce, reuse, remanufacture, recycle, and recovery of materials hence resulting in effective resource usage (Geissdoerfer et al., 2017; Urbinati et al., 2017; Schroeder et al., 2018). It attempts to minimize value destruction whilst maximizing value creation in each link in the production system (van den Beukel, 2017).

Ramakrishna et al. (2020) allude to CE's potential to radically improve resource productivity, whilst driving innovation, job creation and new value chain development. Continuing, they posit that the concept can confer competitive advantages to early off-takers. Although this is mostly the case for technology innovation entities and other for-profit organizations, Teece (2018a) admits to the similarities which exist between universities and conventional organizations with regards to the "innovation for competitive advantage" trajectory. In acknowledging this, Masten (2006) admits to the increasing competition among universities and colleges in both "input and output" markets for patronage just like conventional organizations. This has resulted in the transformation of universities from being traditional platforms for knowledge creation (research) and dissemination (teaching and learning) into entrepreneurial entities (Jongbloed, 2015) just like organizations seeking to actualize financial sustainability. The case for CE has become more compelling in the present age given the world's pull on the limited resources because of production growth and "throwaway culture" shaped by the linear

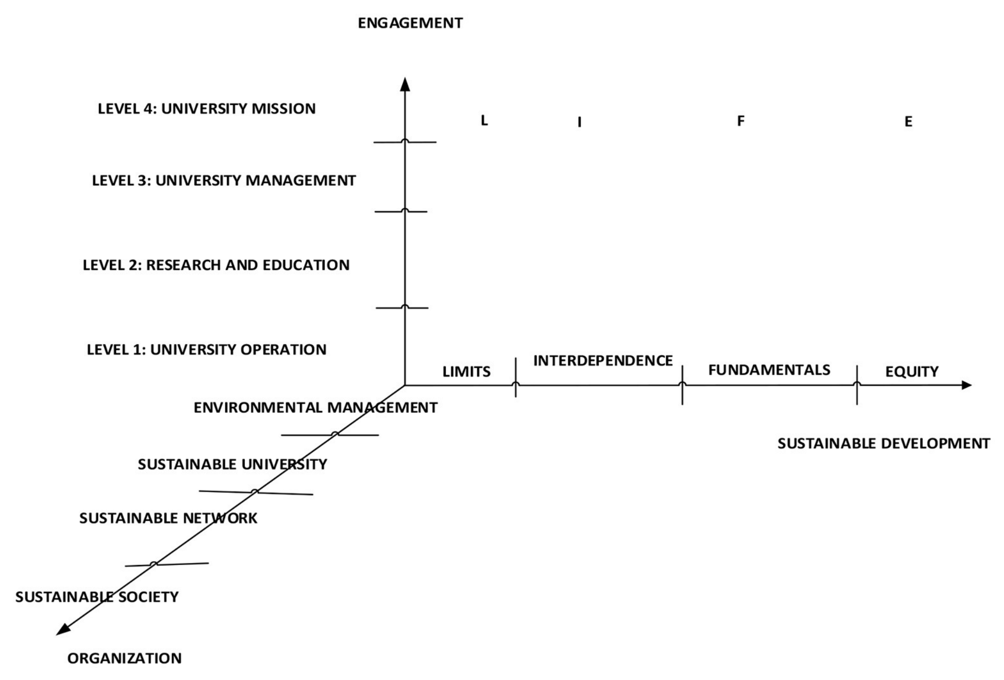

FIGURE 1 | A sustainable university classification model (Van Weenen, 2000).

economy model perpetuated by earlier industrialization eras (Rokicki et al., 2020).

The significant contributions made by CE toward the attainment of the sustainable university aspiration has been highlighted (Maruyama et al., 2019; Ramakrishna et al., 2020; Stephan et al., 2020). The emergence of 4IR technologies have been described as having the potential to drive optimal CE implementation within universities and their environs (Ramakrishna et al., 2020). Therefore, universities are making strides toward optimal engagement with 4IR technologies in operationalizing CE (Penprase, 2018; Liu et al., 2021).

SAUoT is a University of Technology situated in South Africa's central region. The institution is positioning itself to make significant impact in the socio-economic as well as ecological landscape of the country through the development of both social and technologically innovative solutions for sustainable development, with increasing focus on improved circular economy implementation performance within the institution and its host city. Recent technological advancements have led to the need for SAUoT to harness its capabilities to enable it to explore and exploit the trends associated with 4IR in achieving its sustainable university aspirations. No doubt, this will add verve to its sustainability aspirations whilst conferring it with competitive advantage among peer institutions. Yet, achieving this requires effective strategic management. However, strategic management frameworks for facilitating the implementation of CE for various purposes in the Higher Education Institution (HEI) contexts remain limited (Mendoza et al., 2019a,b). Similarly, there is a paucity of reportage on procedures for deploying 4IR technologies toward enhancing CE implementation performance in HEIs and their environs (Ramakrishna et al., 2020). This study contributes toward bridging this gap by exploring the utility of a dynamic capabilities' theoretical framework in guiding the management of ordinary and microfoundation competencies in a manner that fosters flexibility and adept responsiveness to changes in the institutional environment and beyond based on contextual peculiarities elicited through a brainstorming session comprising of major stakeholders.

The rest of the paper is structured as follows: section CE and 4IR Technologies Examples in Universities provides a review of relevant literature concerning the deployment of 4IR technologies and CE implementation in HEI contexts. Section The SAUoT CE Landscape provides a brief synopsis of SAUoT's stride for improved CE performance through a reliance on 4IR technologies. The research methodology used is presented in section Research Method whilst the presentation and discussion of the findings is articulated in section Presentation and Discussion of Findings. In section Preparing Universities for 4IR + CE Futures: A Case for a Dynamic Capabilities Framework, a case is made for the adoption of a dynamic capabilities framework for managing the use of 4IR technologies in facilitating improved CE performance in universities. Section Conclusion consists of the conclusion.

CE AND 4IR TECHNOLOGIES EXAMPLES IN UNIVERSITIES

Few studies have sought to explore the nexus between 4IR technologies and CE implementation and how such incorporation can be effectively managed. The potential of such technologies to facilitate CE is highlighted in **Table 1**.

In furtherance to these, van den Beukel (2017) identifies 4IR technologies like the Internet of Things (IoT), Robotics and Additive Manufacturing as critical drivers of the CE agenda as these technologies enable prevention of waste of value, recovery of value from waste as well extended product lifecycle. Although the use of 4IR technologies in enabling CE implementation appears to be recent given the currency of associated literature (Despeisse et al., 2017; Knudsen and Kaivo-Oja, 2018; Tseng et al., 2018), in the distant past, universities had commenced a shift toward the adoption of these technologies albeit for different purposes (Penprase, 2018). This has mainly been the case in developed countries. In such climes, these technologies have been used in facilitating the development of smart campuses (Omotayo et al., 2021) and engendering remote and asynchronous learning (Oke and Fernandes, 2020).

The time-honored reputation of universities as platforms for the creation, and dissemination of knowledge to society (Awuzie and Emuze, 2017), and as testbeds for shaping future technological advancements (Ramakrishna et al., 2020) has been heralded. This accords them the role of training future generations and providing a well-resourced workforce for contemporary society and the future workplace. Therefore, the advent of 4IR places more responsibility on these institutions to ensure that the future graduate is equipped with requisite knowledge and competence to compete favorably in Society 5.0 and beyond. Society 5.0 is centered on the concept of a society that is driven by a juxtaposition of the following constructs: human-centredness, cyber-physical systems, knowledge-intensity, and overt reliance on data (Deguchi et al., 2020). Continuing, the authors posit the need for these constructs to "balance economic advancement with the resolution of social problems through the provision of goods and services that address latent (societal) needs)" (Deguchi et al., 2020: 1). Institutions that can achieve this feat will obviously gain competitive advantage above their peers as such features are increasingly influencing future matriculants' choice of universities (Calitz et al., 2020). Also, with ever-dwindling university budgets, there is need for universities to engage more robustly with industry and society in the co-creation and/or co-production of new relevant knowledge. This will serve as an impetus for securing third stream income. Yet, this will not be possible if universities do not take leadership in 4IR and CE (4IR + CE) facets, as these are becoming topical and central to industry and societal development and sustenance.

Penprase (2018) highlights the need for universities to respond to the 4IR citing the power of such technologies to either boost societal development or to destroy same if not properly managed. Continuing, the author bemoans the irreversible loss of control over networks of artificial intelligence (AI) agents

TABLE 1 | Intelligent asset value drivers for CE.

	Intelligent asset value drivers		
Circular economy value drivers	Knowledge of the location of the asset	Knowledge of the conditions of the asset	Knowledge of the availability of the asset
Extending the use cycle of an asset	Guided replacement service of broken component to extend asset use cycle	Predictive maintenance and replacement of failing components prior to asset failure	Improved product design from granular usage of information
	Optimized route planning to avoid vehicle wear	Changed use patterns to minimize wear	Optimized sizing, supply, and maintenance in energy systems from detailed use patterns
Increasing utilization of an asset or resource	Route planning to reduce driving time and improve utilization rate	Minimized downtime through to predictive maintenance	Automated connection of available, shared asset with next user
	Swift localization of shared assets	Precise use of input factors (e.g., fertilizer and pesticide) in agriculture.	Transparency of available space e.g., parking to reduce waste (e.g., congestion)
Looping/cascading an asset through additional use cycles	Enhanced reverse logistics planning	Predictive and effective remanufacturing	Improved recovery and reuse/repurposing of assets that are no longer in use
	Automated localization of durable goods and materials on secondary markets	Accurate asset valuation by comparison with other assets	
		Accurate decision-making for future loops (e.g., remanufacturing vs. recycling).	Digital marketplace for locally supplied secondary materials
Regeneration of natural capital	Automated distribution system of biological nutrients	Immediate identification of signs of land degradation	
	Automated location tracking of natural capital, such as fish stocks or endangered animals.	Automated condition assessment, such as fish shoal size, forest productivity or coral reef health	

Source: Ellen MacArthur Foundation (2016).

with increasing autonomy over important aspects of human existence. This implies that with the shift toward a machine-enabled future, there is a greater need for universities to develop and propose competencies which will enable human control over these machine-oriented solutions. Also, Nunes et al. (2018) elucidates the salient contributions which universities can make to the sustenance of CE through engagement with students and society.

Ramakrishna et al. (2020) highlight the prevalent trends depicting the adoption of 4IR + CE concepts in universities for the purposes of creating new knowledge, driving efficiencies, and increasing competitiveness. The hybridization of the traditional education delivery system and the Massive-Open-Online-Course (MOOCs) in many universities remains a significant accomplishment (Du Preez and Sinha, 2020). This disruptive technology has nearly obliterated the place-based notion of learning delivery whilst allowing for exponential growth in the number of students with access to education (Du Preez and Sinha, 2020). Data mining is another vista created by the adoption of 4IR technologies in universities. Presently, the availability of big data and protocols for big data analytics has led to a preponderance of ground-breaking research (Diño and Ong, 2019). The role of data analytics and digital technologies in enabling the development of sustainability competences among learners as well as fostering teaching and learning in universities has been observed (Popenici and Kerr, 2017; Keller et al., 2019; Membrillo-Hernández et al., 2020). Also, data analytics and artificial intelligence (AI) have been used in ensuring quality assurance in HEIs (Mishra, 2019) and improving inclusive and remote learning and tutoring through improved access in the face of poor infrastructure (Du Preez and Sinha, 2020; Nkosi et al., 2020). They have also been applied in the development of smart campus operations in a manner that facilitates resource efficiency on these campuses. In another study, Omotayo et al. (2021) articulated the use of these technologies within the university setting for achieving the smart campus network grids, smart buildings, effective learner management systems, campus equipment management services, energy management systems, performance measurement, management and forecasting among others.

In recognition of the pivotal role of universities in driving the CE concept, the Ellen MacArthur Foundation created a platform for inter-institutional engagement for CE. This platform serves as a global network for universities that seek to explore, develop, and critique key ideas and priorities associated with the transition toward CE.

These universities have been making profound contributions to the CE discourse. According to the Ellen MacArthur Foundation website (Ellen MacArthur Foundation, 2017), UCL has accorded prominence to CE in teaching and learning through: the establishment of a continuing development programme in Life Cycle Assessment and the CE; development of an MSc module on Industrial Symbiosis with CE application sessions; development of an MSc module on Waste Management and Resource Efficiency, and an MSc Sustainable Resources programme. On the research front, UCL has set up CircEL: an inter-disciplinary CEL Lab, which utilizes internal capabilities to explore and resolve challenges associated with product and buildings design through the CE theoretical lens. Another example provided is the Rochester Institute of Technology (RIT) through its Golisano Institute of Sustainability (GIS). GIS has developed postgraduate qualifications- PhD programme in sustainability (sustainable production) and an MS with three tracks (sustainable manufacturing, sustainable energy systems, and sustainable mobility) as well as a Master of Architecture programme with a focus on the incorporation sustainability in built environment architectural design. On the research front, GIS has been involved in the $140 million REMADE project initiated by the US Department of Energy and other stakeholders for the development of less expensive ways of reusing, recycling, and remanufacturing of metals, fibers, polymers, and electronics (Ellen MacArthur Foundation, 2017). The areas of expertise for the GIS are listed as comprising of Design for Remanufacturing, Remanufacturing Process Technology, Remanufacturing Policy, and Applied Research in Sustainable Manufacturing (Ellen MacArthur Foundation, 2017).

At the University of São Paulo in Brazil, the partnership with the Ellen MacArthur Foundation has resulted in the development of a community of practice for research and knowledge development for a multidisciplinary CE; the integration of CE content into graduate and undergraduate courses within the institution; the development of CE education programmes for the society, and, provision of technical and scientific support on research, innovation and knowledge transfer to the society (Ellen MacArthur Foundation, 2017). Whereas, these instances have focused on CE, the utility of 4IR technologies in achieving CE remains underexplored (Ramakrishna et al., 2020).

None of the universities mentioned in these categories is situated in Africa. By implication, the African continent may not be able to play salient roles in the emerging 4IR scenario if the universities in the continent do not commence moves to operationalize these tenets within their institutions and, in collaboration with universities outside their immediate domains (Ramakrishna et al., 2020). Neither will they be able to utilize 4IR technologies in driving CE within their geographical domains.

Within the South African HEI landscape, Xing et al. (2018) reiterate the need for training and employment systems to be retooled to cater for the anticipated changes in the workplace, buttressing the need for universities in the country to play a critical role in enabling this. They identify the adoption of new technological developments as an important vista for doing this as it will contribute to producing graduates who fare differently from those of the previous years in skills and competence. According to Xing et al. (2018) new training programmes in the universities should maintain a balance between the time to adoption (technology-related elements) and time to adoption (human-related elements). In their analysis of the South African 4IR landscape, these authors opined that the South African higher education sector should position itself to not only benefit from the emergence of 4IR through the deployment of 4IR technologies in resolving the challenges facing them, but also to drive the wholesome adoption of these technologies in society.

SAUoT's aspiration to play a leading role in the emerging 4IR and CE contexts is premised on such observations as put forward by Xing et al. (2018). Yet, the lack of a definite framework to be adopted in enabling this reality within universities like SAUoT poses a challenge.

THE SAUoT CE LANDSCAPE

SAUoT has over the past decade, expressed a vision to transform into a sustainable university, providing itself as a platform for the development of a knowledge-based economy in the central region of South Africa and beyond. To this end, SAUoT has evolved a comprehensive sustainable development policy as well as an implementation framework. Also, various initiatives have been introduced to engender the attainment of this aspiration. These initiatives include *inter alia* the incorporation of sustainable development ethos into extant curricula, the alignment of the pedagogical approaches with sustainable development competencies, the smart campus and smart farm initiatives, etc.

In realization of the nexus between its sustainable university aspirations, CE and 4IR technologies, SAUoT has decided to leverage on this relationship to drive its aspirations. To this end, a taskforce was inaugurated to prioritize the deployment of the 4IR technologies in enabling CE and associated knowledge in the institution whilst engaging in knowledge transfer to the wider context for regional and national developmental purposes. **Table 2** illustrates research, innovation and teaching and learning efforts of SAUoT regarding 4IR + CE.

As such, SAUoT seeks to capitalize on the presence of these ordinary capabilities to contribute to the emerging 4IR + CE implementation ecosystem. The question remains: how can these capabilities be managed or aligned strategically to enhance the institution's ability to sense, seize and transform based on the opportunities available in the emerging 4IR + CE era? This is what this study contributes toward answering.

RESEARCH METHOD

A case study research design was adopted for the study. The case study research approach is noted for its utility in studying phenomenon within organizations (Buchanan, 2012). SAUoT served as the case in this instance. The usefulness of brainstorming sessions for enabling collaborative ideas generation and fostering group creativity within organizational settings has been highlighted in relevant literature (Litchfield, 2008; Seeber et al., 2017; Gilmartin et al., 2019; Obi et al., 2021). Concurring, Sutton and Hargadon (1996) admit to the use brainstorming sessions for the product design by firms. Gilmartin et al. (2019) describes brainstorming sessions as meetings lasting about 2 h where a group consisting of 6–12 persons share opinions and ideas. Continuing, they posit that these sessions allow for complex high-quality information

TABLE 2 | CE/4IR Capabilities and on-going activities at SAUoT.

On-going activities	Capabilities
Reverse engineering	Product design prototyping and short-run production
Rapid prototyping	
Finite element analysis	
3D printing of tools and medical implants	Additive manufacturing/3D printing
SMART Bins/Farm/Campus project	Automation, Sensor Networks, Big Data analytics and IoT
Building energy management system/Smart Grid/Solar power project/Smart Manufacture and Assembly	Energy Management (Renewable Power and Power Management); Vision (Machine Vision and Quality Systems); Automation and Robotics
Mainstreaming 4IR + CE technologies/principles into extant curricula and pedagogical approaches	Knowledge concerning 4IR + CE technologies and principles. Curriculum development and re-development for new existing qualifications detailing the use of 4IR technologies in driving CE
Development of new courses/4IR + CE competencies for	
Development of online short courses on 4IR+ CE (MOOC)	Information Community Technology unit/Sustainability/Green Economy/CE/Lean Production/Entrepreneurship/e-Waste/construction/Smart Manufacturing and assembly/IoT competencies

Source: Authors' compilation (2021).

concerning a phenomenon to be captured from the discussant's worldviews. Seeber et al. (2017) highlight the growing relevance of brainstorming sessions in facilitating an organization's ability to make quick-paced decisions to keep up with the demands of the ever-changing and dynamic business environment occasioned by fast technological advancements. This relevance is not peculiar to business organizations only as Al-Samarraie and Hurmuzan (2018) acknowledge the existence and use of three different brainstorming variants within the HEI context. These variants include the traditional, nominal, and electronic brainstorming typologies.

Similarly, brainstorming was used in this study to elicit the perspectives of different stakeholders at SAUoT concerning the role of the 4IR technologies in enabling optimal CE implementation performance within the university and its host community where poor waste management has continued to pose a significant challenge. The brainstorming session was expected to provide feedback on the following:

1. The potential of 4IR-enabled CE implementation to contribute to the attainment of sustainable university aspirations at the institution;
2. An identification of factors (opportunities and challenges) likely to influence the attainment of improved CE implementation through the adoption of 4IR technologies, and;
3. The ability of the extant strategic management frameworks at the university to facilitate effective governance of 4IR technologies identification and deployment toward improving CE implementation performance.

The participants to the brainstorming session were drawn from different operational units in the institution in a purposive manner. The population comprised of representatives from different academic faculties, university leadership, procurement, finance, facilities and information technology departments, the research and teaching and learning support units as well as the student representative body. For brainstorming sessions to provide for succinct for idea generation, the engagement of a skilled and knowledgeable facilitator remains imperative (Obi et al., 2021) as they enable the sustenance of success factors like discussion encouragement, goal setting, and groupthink (Seeber et al., 2017). In this instance, one of the authors served as the facilitator for the brainstorming session whilst another took notes. This session which had a total of 18 participants including two of the authors took place in May 2019, lasted for an estimated hour and half. The conversations were recorded with the knowledge and permission of the participants and subsequently transcribed. The transcripts were reviewed by three of the authors in a manner suggestive of multiple investigation triangulation (Patton, 1999) for the purposes of completeness. The contents of the transcript was further analyzed using thematic analysis using themes considered congruent with the three previously mentioned aspects. The analyzed data was subsequently shared with participants to validate the accuracy of the information provided therein. All participants agreed that the excerpts presented served as a true reflection of the brainstorming session.

PRESENTATION AND DISCUSSION OF FINDINGS

As previously stated, the findings from the brainstorming session shall be provided for under three main thematic areas, namely: 4IR-enabled CE implementation and the attainment of sustainable university aspirations; establishment of opportunities and challenges, and the ability of extant strategic management frameworks to facilitate effective governance of 4IR technologies identification and deployment toward CE implementation performance. Whereas, the opportunities comprised of the pathways available for the operationalization of the 4IR + CE concept as it pertains to the present capabilities, and the changes in the environment which SAUoT can leverage on these capabilities to cater for; the challenges consisted of the perceived barriers negating the implementation of the concept at SAUoT.

Theme 1: 4IR-Enabled CE Implementation and the Attainment of Sustainable University Aspirations

All discussants concurred that the juxtaposition of the 4IR technologies and CE were imperative for the SAUoT if it truly wanted to remain relevant in the comity of higher education institutions. It was observed that these technologies were instrumental to the radical transformation being witnessed in the acquisition of knowledge among staff and students. They suggested a comprehensive articulation of the inherent pro-4IR technologies capabilities and/or expertise for facilitating CE knowledge and practice among relevant stakeholders within the university community as a first step toward engendering improved adoption of such technologies. It is expected that this will not only allow for increased CE awareness but also encourage improved CE implementation across multiple scales between the university and the community. It was agreed that the SAUoT serves as the living laboratory for operationalizing the deployment of different 4IR technologies toward achieving this purpose. This concurs with postulations raised in similar literature as it concerns the nexus between digital technologies and circular economy implementation (Hoosain et al., 2020; Liu et al., 2021), the role of HEIs in driving sustainability performance in regional and national contexts through transfer of appropriate technologies and expertise (Soares et al., 2020; Thomas and Pugh, 2020; Garcia-Alvarez-Coque et al., 2021), and improved CE implementation performance across multiple scales between HEIs and regional and economic sectoral contexts (De Medici et al., 2018; Qu and Shevchenko, 2019; Qu et al., 2020; Rokicki et al., 2020; Stephan et al., 2020).

Theme 2: Establishment of Factors Influencing Improved CE Implementation Through the Adoption of 4IR Technologies

Discussions under this theme are delineated according to opportunities and challenges as elicited from the brainstorming session.

Opportunities

Discussants identified aspects through which SAUoT could leverage on 4IR technologies and CE to not only improve on their service offerings, but also to leverage on extant capabilities within the institution to support regional (provincial) socio-economic and environmental development strategies. Aspects identified include:

a. The development of waste minimization and management strategies through improvements in recycling and efficiencies in resource utilization;
b. Expansion of the institutional ICT infrastructure to cater to growing needs;
c. Creation of knowledge management opportunities;
d. Alignment of research centers toward 4IR + CE implementation-oriented research themes;
e. Provision of geriatric-oriented solutions;
f. Development of appropriate management techniques for the human-machine interactions in the emerging new world of work;
g. Development of an effective Human resource platform to cater for skills and diversity in the new world of work;
h. Re-tooling of future graduates to ensure that they imbue 4IR + CE relevant skills through the deployment of these technologies during their tutelage period at the institution in teaching and learning activities;
i. Creation of transition platforms which enable easy passage of students into research frontiers on 4IR + CE;
j. Development of short courses for residents of the institution's host community on 4IR technologies + CE, and;
k. Accentuation of digital skills proficiency acquisition among staff and students.

Fortunately, these opportunities share interesting similarities with the opportunities which several universities have since tapped into in other climes; See Ellen MacArthur Foundation (2017) and Ramakrishna et al. (2020).

Challenges

Also, discussants identified different challenges which will influence institutional uptake of the 4IR technologies + CE. These challenges include:

a. Fears concerning technological unemployment and organized labor concerns
b. Shift in attitudinal mindsets of most of the university population (organizational culture)/people issues/etc.
c. Management of access to information and comprehension of information
d. Inadequate nature of ICT infrastructure;
e. Absence of industrial hub within the institution's environs;
f. Regulatory encumbrances to new multidisciplinary academic qualification development on 4IR technologies + CE, and;
g. Absence of 4IR + CE content in the extant curricula at SAUoT.

These challenges can be categorized under a single heading: contextual realities. Discussants whilst admitting to the utility of the 4IR + CE advancements to SAUoT's strategic objectives admitted that contextual variables may hinder the successful participation of the institution in the unfolding 4IR era. For instance, the issue of unemployment was raised during the session and several discussants reiterated that the South African economic context was plagued by high unemployment rates. They feared that the introduction of 4IR technologies like AI might exacerbate the current unemployment situation and lead to avoidable tensions with organized labor unions within and beyond the university.

Theme 3: Ability of Extant Strategic Management Frameworks at the University to Facilitate Effective Governance of 4IR Technologies

Within the HEI context, strategic management frameworks comprise of the governance architecture for facilitating policy implementation. Leal Filho et al. (2021) admit to the significant contributions of these governance structures and instruments such as well-articulated sustainable development plans, policies, and programmes in engendering sustainable development implementation in universities.

Accordingly, for universities to effectively utilize the emerging 4IR technologies for a variety of purposes, including CE implementation, they must possess management frameworks that enable quick-paced adaptations to the dynamic evolution of these technologies. This has been espoused in various studies (Xing et al., 2018; Oke and Fernandes, 2020). Besides from this ability to adapt and adopt emerging technologies in a quick-paced, dynamic, and proactive manner, other studies have identified factors ranging from behavioral intentions of university stakeholders (Skoumpopoulou et al., 2018) to socio-cultural and contextual variables (Karim and Rampersad, 2017; Adams et al., 2018; Sabi et al., 2018). However, Mendoza et al. (2019a,b) attest to the lack of CE implementation frameworks within HEI contexts whilst Ramakrishna et al. (2020) advocate for the institutionalization of proactive frameworks for facilitating successful adaptation, and adoption of 4IR technologies toward enabling optimal CE implementation in HEIs. They highlighted the inability of the extant managerial and governance frameworks in universities to cope in the 4IR era.

A consensus was reached among participants concerning the mostly reactive orientation of the strategic management frameworks in the institution. Perhaps this orientation is responsible for the inability of universities to compete with the pace of technological development and innovation obtainable in conventional (private sector) organizations (Adams et al., 2018; Smuts et al., 2020). The reactive nature of the strategic management framework in HEIs is buttressed by the *ad-hoc* and unprepared nature of most of these institutions to transition to online delivery platforms at the outbreak of the COVID-19 pandemic (Mossa-Basha et al., 2020; Reister and Rook, 2021). Discussants lamented the long and tedious process of decision-making in the institution, a clear depiction of the relaxed nature of the management/governance framework at the university and posited that it would prevent the institution from engaging with emerging 4IR technologies in an agile manner, leveraging its internal capabilities.

Based on the foregoing, the shortcomings of current institutional strategic management and governance frameworks in managing the optimal deployment of 4IR technologies for improved CE implementation in HEI contexts can be discerned. Therefore, to contribute toward overcoming this obstacle, this study proposes the adoption of a dynamic capabilities' theoretical framework for developing an appropriate framework for actualizing this objective. The rationale for this proposition is rendered in section Preparing Universities for 4IR + CE Futures: A Case for a Dynamic Capabilities Framework.

PREPARING UNIVERSITIES FOR 4IR + CE FUTURES: A CASE FOR A DYNAMIC CAPABILITIES FRAMEWORK

To gain competitive advantage, organizations need to continually position themselves to provide better products or services to their clientele in a timely manner. As such, they are expected to gauge happenings in their environment and respond to any changes or transitions noticed, leveraging on the capabilities that they have within the organization. Organizational sustainability is premised on this ability to respond to changes in the operational environment (Awuzie and McDermott, 2019). However, most organizations have faltered because of their inability to keep up with the changes in their environment when compared to their competition.

In what can best be described as an oxymoron, universities have been referred to as slow reactors to change whilst being the purveyors of knowledge (Marshall, 2010). But this slow adaptation change is predicated on the prevalence of discipline-centric knowledge silos therein. These silos prevent the multi, inter- and trans-disciplinary (MIT) exchange of epistemes which are often responsible for the co-production of new knowledge (Awuzie, 2019). Such new knowledge is required for the operationalization of 4IR technologies and CE implementation interactions. Also, these discipline-centered knowledge/capabilities have been labeled as ordinary capabilities. For these ordinary capabilities to make positive contributions to the rapid technological advancements resulting from 4IR + CE transitions, an appropriate strategic management approach must be adopted and subsequently deployed. The dynamic capabilities approach is proposed in this study as a strategic management framework which will support the attainment of this feat at universities using the SAUoT exemplar.

The term "dynamic capabilities" connotes those capabilities-often described as non-imitable- possessed by organizations (business organizations) which facilitates their ability to sense, seize, and transform their business models in a way that enables them to generate and exploit internal and external organization-specific competencies in addressing the organization's changing environment (Teece et al., 1997; Augier and Teece, 2008; Teece, 2018a). According to Augier and Teece (2008), the theory of dynamic capabilities derives its root from the theory of the growth of firms as postulated by Edith Penrose. Other relevant theoretical underpinning which gave rise to the theory of dynamic capabilities include: the nature of the firm (Coase, 1988), the resource-based view of the firm (Wernerfelt, 1995), the behavioral theory of the firm (Argote and Greve, 2007) as well transaction cost economics (Williamson, 2010). These theories focused on leveraging in-house and external capabilities to optimize the firm's productive opportunities and create competitive advantage for the firm.

Teece (2018b) dichotomizes the available capabilities within organizations. According to him, two main categories of capabilities exist in firms: ordinary capabilities and microfoundation-based capabilities. Whereas, the former comprises of the plethora of processes which enable the deployment of people, facilities and equipment to carry out routine business of the organization, the latter comprises of the low-level dynamic capabilities like processes for new product development which allow organizations to integrate and reconfigure, add or remove resources to achieve a positive response to environmental (marketplace) changes. These microfoundation capabilities form the main thrust of the dynamic capabilities' framework.

The dynamic capabilities approach is predicated on organizational routines as well as managerial skills and enables the choice of the right mix of capabilities that are required to provide a response to the changes within and beyond the firm's boundaries. This means that it is concerned with selection of the right capabilities to sense changes in its operating environment, seize such identified opportunities and transform their working processes to take advantage of such opportunities. In a nutshell, the dynamic capabilities approach seeks to enable firms to understand how global changes are likely to influence changes in their internal structure and how they can realign their environments whilst improving on their present capabilities (Augier and Teece, 2008). According to Augier and Teece (2008) the dynamic capabilities framework, contributes to the growth of firms in three distinct but interrelated ways: identification and capture of new strategic opportunities, alignment and arrangement of necessary organizational assets, and (re) inventing business models and new organizational forms as required by the changes. Therefore, the firm serves as an incubator for technological and organizational resources that are difficult to replicate by rival firms. The approach governs the rate at which ordinary capabilities change to serve the strategic interest of the organization hence supporting the proposition that the speed and degree of fostering alignment of an organization's resources with the needs of its clientele is dependent on the strength of the organization's dynamic capabilities framework (Teece, 2018b).

Although the literature is replete with instances of the dynamic capabilities' framework application in conventional for-profit organizations, an emergence of its utility in organizations such as universities has been noted. For example, Yuan et al. (2018) in their study on the role of dynamic capabilities in enabling university technology transfer and subnational development relying on a sample of 829 Chinese universities, 3,908 university-year observations across 30 Chinese provinces over a 6-year period, justified the utility of the dynamic capabilities perspective of university technology transfer process in sensing, seizing and reconfiguring future areas of research development. In furtherance to this justification, they argued that through the reconfiguration process, universities can develop strong dynamic capabilities thereby easing their ability to adjust to environmental changes. Reconfiguration in this instance means the ability of universities to adopt a flexible disposition though the constant redesign of their business models, asset realignment and upgrading of routines (Teece, 2018a). Such acts enable them to improve on value capture from their solutions in such a manner that enables a proper alignment-fit to their environment whilst allowing them to contribute to shaping this ever-changing environment (Yuan et al., 2018).

In another contribution, Teece (2018a) opines that the adoption of the dynamic capabilities approach will assist university leaders/managers with a platform for deploying better management strategies to universities, especially in the face of the recent technological explosion being experienced across the globe. Deployed within the context of universities, the framework enables university managers to scan and interpret their environments both internal and external, generating new innovative approaches to grabbing opportunities and tackling challenges hence positioning the institution for relevant transformations which can impact on subnational performance. This is what SAUoT's management intends to achieve within the facets of CE, 4IR, sustainability and a combination thereof.

These opportunities captured during the brainstorming session epitomizes an aspect of the sensing component of the dynamic capabilities' framework-technological possibilities, see **Figure 2**. As it pertains to the other aspect of the sensing component- technology development, a range of technological capabilities are available to the SAUoT already as itemized previously. There is a need to manage these capabilities to seize these opportunities through a redesign of the existing business model at the institution. Excerpts from the brainstorming session indicate that this process is ongoing. For instance, the transition from discipline-oriented research units and groups into inter-, multi-, and transdisciplinary research centers is step in the right direction. The evolution of these centers will allow for the cospecialization- a term described by Teece (2018b) as the extra value accruing from a set of two or more assets when they are jointly deployed toward providing a particular solution. This is an advantage that the SAUoT can enjoy through the operationalization of these centers. Yet, there is need for 4IR and CE tenets along with the associated technologies to be mainstreamed into these centers.

Technological unemployment poses a significant risk to the operationalization of the 4IR technologies in driving CE at SAUoT. Buttressing this downside of technological innovation, Loi (2015) argues that the technologies like the ones introduced under the 4IR have the tendency to disenhance individuals than they are likely to enhance them. This argument continues to resonate just as it did during the brainstorming session. The discussants were divided on the ability of the institution to upskill the staff in accordance with the levels of digital proficiency required for them to contribute meaningfully to the sustenance of the 4IR + CE agenda at SAUoT.

This study has thus far justified the utility of dynamic capabilities-driven frameworks for driving the 4IR + CE implementation initiative at SAUoT. SAUoT possesses the capability to engage optimally with technologies associated with the emerging 4IR era in fostering CE within its immediate environment and beyond. However, there is need for these capabilities to be strategically harnessed with the aid of the dynamic capabilities framework to achieve optimal contributions to the CE concept. As an immediate implication of this proposition, SAUoT has set up an alternative governance

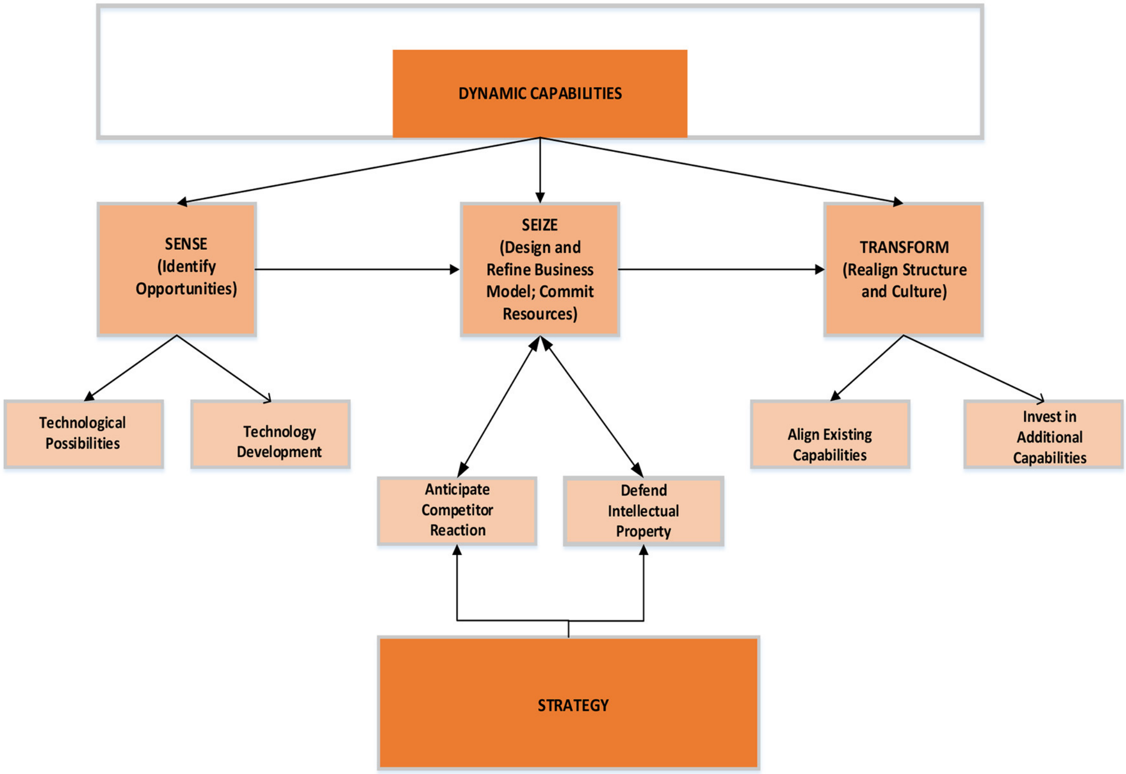

FIGURE 2 | Alignment between dynamic capabilities and strategy (Teece, 2018b).

structure, labeled the 4IR + CE taskforce with membership drawn from relevant sections of the institution with the mandate to adopt an agile approach to the identification of opportunities for deploying relevant 4IR technologies for improving CE implementation performance within the institution and its host community. Furthermore, the taskforce is expected to coordinate all activities relating to 4IR deployment in a manner that encourages collaboration and an extinction of silos. The operations of the taskforce are aligned with the dynamic capability framework. It must be reiterated that the taskforce is still in the nascent stages of its operational lifecycle. As such, its provenance in articulating in-house capabilities, sensing changes associated with a dynamic operating environment and carrying out seamless deployment of 4IR technologies toward CE implementation has not been validated. This is considered one of this study's limitation. However, further studies are encouraged to validate the utility of the underpinning theory in framing agile, adaptable, and proactive strategic management frameworks for managing 4IR + CE implementation in HEIs, with particular focus on developing country contexts.

CONCLUSION

History of human civilizations make it abundantly clear that societies progress by embracing advances in knowledge and innovations. In recent decades, universities are playing an important role in facilitating the transformation of respective societies and communities. The emergence of 4IR technologies provide a glimpse into future innovations. Universities in high-income countries especially in Europe and USA began to leverage the nexus of 4IR technologies and CE. They are embracing them in respective education and research programs. In addition, some universities are leading the innovations in these domains of strategic importance.

Within the African continent, the SAUoT is proactively embedding the culture of fourth industrial revolution technologies and circular economy vision. This is evidenced from the systematic analysis via the dynamic capabilities' framework method. Examples of SAUoT include structured electronic waste or E-waste recycling program, 3D Printing or additive Manufacturing, smart solar energy or renewable energy test beds, automation and robotics, smart farming, energy efficient and smart buildings, smart waste collection bins, water conservation, and idea-gym for innovation and entrepreneurship for students and staff. Curriculum and pedagogy are slated to be updated with subjects and projects which strive to succinctly articulate the critical roles of 4IR technologies in facilitating optimal CE performance and, by extension, climate change mitigation.

It is expected that experiences of SAUoT's approach to managing 4IR technologies deployment toward CE implementation through knowledge development and practice will be shared with other universities in South Africa, Africa in general, and rest of the world in subsequent publications. Obviously, a 4IR-catalyzed CE future is emerging, and universities need to embrace them holistically to not only prepare future-ready graduates but engender the introduction of innovative solutions relating to resource efficiency across multiple scales.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

All authors contributed equally to the development of the paper.

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