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Article

Hybrid lean practices with industrial revolution 4.0 for sustainability in South African higher education institutions: Preliminary approach

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Abstract: Institutions of higher learning are crucial to sustainability. They play a crucial role in preparing the next generation of leaders who will successfully execute the Sustainable Development Goals of the United Nation. This research therefore intends to present a preliminary conceptual approach in examining how industrial revolution 4.0 (I.R. 4.0) technologies, and lean practices affect sustainability in South Africa's Higher Education Institutions (HEIs). The study shall employ survey questionnaire to collect data from the employees of the institutions. This preliminary study reveals that hybrid IR 4.0 technologies and lean practices as enablers of sustainability has not gained enough attention in the HEIs. Existing literature show the important role plays by performance variance of lean practices to improve sustainable performance when deployed from industry to education sector. The report validates the HEI's future course, which has been incorporating new technology into its services processes recently. Using the created items, researchers may utilize empirical analysis to look into the combined effects of lean practices and IR 4.0 technologies on sustainability in HEIs. The following conclusions may be drawn: HEIs are essential for the application of sustainability principles; curriculum focused on sustainability and culture change are critical for attitude development; and the political climate and stakeholder interests impact the implementation of sustainability.

Keywords: I.R. 4.0 technologies; lean practices; six sigma practices; sustainability

1. Introduction

In the era of digital transformation, cultivating dynamic competences has become even more crucial; nevertheless, the literature has not fully explored the role that dynamic skills and practices play in sustainable development (Saha et al., 2024). Also, organizations that enhance their brand, reputation, and ethical issues have been seen to embrace the concept of sustainability (Akanmu et al., 2023). Although there are structural and contextual obstacles facing the educational system in Sub-Saharan Africa (Bozalek and Ng'ambi, 2015), there are also countless opportunities brought about by new technology. Even though South Africa is an independent country, it is nonetheless susceptible to the problems brought about by and carried over from previous colonial educational systems. However, it may take use of the advantages offered by 21st-century technology (Maphalala and Adigun, 2021). In order to address the issues facing the educational sector through information and communication technologies (ICT), South Africa has implemented a number of policies, including the National Plan for Higher Education (Department of Education [DoE], 2001) and The White Paper for Post-School Education and Training (Department of Higher Education and Training [DHET], 2013). It is interesting to see how ICT has impacted teaching and learning practices in higher education. The use of ICT (e.g., e-learning)

in the teaching and learning process, is an enhanced digitalized multimedia online learning environment that complements traditional face-to-face instruction (Biehl and Prescott, 2013). No matter where they are in the world or how far apart they are from one another, e-learning allows students and instructors to share information and course materials. Stated differently, e-learning has promise in mitigating educational disparities and fostering a more welcoming and inclusive learning environment.

Bill Smith, an engineer, created the Six Sigma business development program at Motorola in the middle of the 1980s (Snee, 2010). According to Pyzdek and Keller (2010), statisticians employ the Greek symbol σ, or sigma, to quantify the variability in any process. A goal of 3.4 faults per million chances is suggested by the term Six Sig-ma, according to Linderman et al. (2003). Thus, by concentrating on outputs that are vitally important to students and university employees, Lean Six Sigma aims to identify and eradicate the root causes of errors or flaws in organization settings (Snee, 2000). The success of six sigma depends on the approach of: defining, measuring, analysing, improving, and controlling (DMAIC), which is a methodical process or improvement roadmap (Antony and Banuelas, 2002). DMAIC arranges how many different tools are used in Six Sigma projects. People can acquire expertise in addressing scientific problems as they get more proficient with these instruments and work on an increasing number of projects (Arumugam et al., 2014).

The study's objective is to present relevant past literature on lean techniques in relation to how academic managers and engineers apply IR 4.0 to the Higher Education sector. The results of the hybrid practices will have a significant effect on theories and practices of HEIs. The impacts of lean practices, and industrial revolution 4.0 on operational performance have all been the subject of separate prior studies. Researchers are still in the early phases of investigating the combined effects of these updated strategies in order to achieve sustainability in the sector. By putting out a model that conjectures the combined impacts of these influence on sustainable performance under certain environmental situations that have not yet been considered, the study seeks to fill this gap in the literature. The model's primary focus is on RSA's HEI.

According to Ogunlela and Tengeh (2021), the last few years have seen a global acceleration of digital disruption. There is a claim that this technology revolution will drastically change lives, jobs, and the way people connect with one another. The lines separating the physical and biological realms may become hazier as a result of the Fourth Industrial Revolution (4IR). While the exact impact is unknown, many predict significant changes in the fields of education and the economy. Due of the tight connection between the university entrepreneurship drivers and the economy, the 4IR's preparation and influence will continue to be critical to the survival of entrepreneurial institutions. In South Africa, the government takes the lead in assisting HEIs to become more entrepreneurial so they can contribute to knowledge creation in a competitive manner, which in turn spurs economic growth (Tengeh and Rorwana, 2017).

It has not been business as usual since the first COVID-19 positive case was found in South Africa on 5 March 2020 (Mhlanga, 2021). Nearly every economic sector saw a halt in business (Zakaria et al., 2023). According to the report of Mhlanga (2021), the COVID-19 pandemic made it possible for blended learning to be

introduced after the pandemic. This can assist to increase access to education in South Africa, where it was previously restricted by geographic location, particularly at the university level. The study did find, however, that implementing blended learning comes with difficulties because of the widening digital gap, high levels of inequality, financial limitations, and a skills deficit. Therefore, in order for blended learning to be effective, it is crucial to make sure that there is a platform for policy that addresses issues with inequality, a skills gap, and the widening digital divide.

Numerous research papers and projects by different business practitioners have drawn attention to sustainable performance in the manufacturing and service industries while incorporation of theories and practices of sustainable development in HEIs is still unclear (Leal Filho et al., 2022). Within educational approach, the theory and practice of sustainability have emerged as crucial issues in the fast-paced commercial world. The conversation on sustainability in the education sector has to happen sooner rather than later. While it was first primarily focused on societal and occasionally environmental challenges, it is now clear that HEIs all over the world are finding it more relevant. Sustainability issues have also received more attention recently in all fields, with the educational sector seeing a rise in prevalent social behaviors (Franco et al., 2019). Numerous learning institutions have seized the chance to adopt sustainable practices in relation to continuous growth, expansion, material selection, customer relations, supply chain management, operational practices, environmental costs, strategic action and plan and product quality. Research has shown that there is a dearth of studies explaining the limits of lean practices in this context. The emerging trend of industrial revolution 4.0 (IR 4.0) provides the platforms that academic and industrial sectors require to further their usage of these problem-solving methodologies, as many corporations have adopted lean practices. Thus, this study presents the introduction as a gateway to the research, followed by a theoretical review of the past studies in HEIs, lean practices and IR 4.0 as regards to sustainability. The proposed questionnaire, framework and hypotheses are equally out-lined while the concluding part posits the future implication of the study.

2. Theoretical review

The concept of Lean practices has gained popularity recently, however higher education institutions (HEIs) still struggle to use Lean activities and the Lean concept is still not widely accepted (Simonyte et al., 2022). This study in addition aims to discuss best practices for lean implementation and identify global experiences within HEIs.

2.1. Sustainability in HEIs

Institutions of higher learning are crucial to sustainability. They play a crucial role in preparing the next generation of leaders who will successfully execute the Sustainable Development Goals (SDGs) of the UN (Žalėnienė and Pereira, 2021). Since education is a key tool for communication and the foundation of the "sustainability mindset", it is the engine propelling the establishment of sustainability. The notion encompasses "a comprehensive method of comprehending, surpassing technical expertise and comprehending the fundamentals of a robust ecosystem and a

flourishing community." Traditional business practices have changed significantly during the last several decades (Ali et al., 2022; Bibi and Shaukat, 2023). Most businesses have put environmental policies into place (Ahmad et al., 2019). For instance, Green human resource management (GHRM) is the use of environmentally friendly HRM methods in a company context (Shaukat et al., 2023). The sustainable mentality pushes us to move away from traditional management discipline silos by emphasizing self-awareness, environmental studies, entrepreneurship, management ethics, and systems thinking (Kassel et al., 2016). Systems thinking, for example, is frequently cited as one of the abilities required to comprehend sustainability more fully. This is so because sustainability equally incorporates the social, environmental, and economic facets. The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP, 2015) states that "Economies that sustain people's livelihoods and improve their general quality of life are formed by and in turn influence people and the character of the society in which they live. In this instance, fostering a comprehensive approach to issue analysis requires the application of systems thinking (UNESCAP, 2015).

Many studies examined the effects of higher education on sustainability in recent years (Feilner, 2019; Findler et al., 2019a; Leal Filho et al., 2018). Despite the fact that neither public nor private institutions emphasize sustainability, Alam et al. (2021) claimed that the mushrooming of private universities has led to a problem in this area. In generally, universities are seen as "changing agents" and "catalysts" in the emergence of sustainability-related issues (Shields, 2019). In general, the contents of education as well as the related process and results are impacted by sustainability-based education (Gatti et al., 2019). Fehlner (2019) emphasized that higher education and sustainable development are positively correlated. The graduates of higher education are far more likely to have well-paying jobs and to create stable, affluent communities. Higher education also fosters the development of novel concepts and technological advancements, which form the cornerstone of sustainability. In spite of this, the value that HEIs add to society is probably underappreciated (Fehlner, 2019).

In the business world, sustainable performance is attained when an organization upholds environmental rules while creating ongoing values for its stakeholders and stockholders (Brent and Labuschagne 2004). According to Hassan et al. (2018), a company's sustainable performance value consists of a few key components, the most significant of which are satisfying the needs of the society and environment as well as its shareholders and customers. Sustainable performance refers to actions that extend an organization's useful life in a socially beneficial way, support the ability of the ecosystem to regenerate and remain viable, support life, and support a society's capacity to sustain itself in the face of major crises while upholding decent welfare, individual liberty and involvement of both current and future generations of humans (Dunphy, 2011). According to Hassan et al. (2018), a constructive and inventive corporate culture is created via the execution of transactions and business towards sustainable company, which results in sustainable performance.

In the same vein, a high performance settings that optimize resource utilization for the benefit of the environment, society, and economy may be developed with a built-in healthy culture (Dunphy, 2011). Economic, social and environmental sustainability are the three categories that make up sustainable performance.

According to the European Commission, sustainable development policies placed a strong emphasis on the need for social cohesion, environmental preservation, and economic growth to coexist (Pei et al., 2010). According to Guan et al. (2010), sustainable management is a contemporary style of management that focuses on the cooperative integration of the economy, society, and environment through procedures like purchasing, manufacturing, and packaging, storing, using, and disposing of end-of-life products that are made possible by technological advancements. The ultimate goal is to achieve sustainable development that is socially, economically, and environmentally beneficial.

Institutions of higher learning have a significant influence on mentality formation. Bowen (2018) states that the influence of a college degree lasts for an average of fifty to sixty years in an adult's life after graduation. This influence can last for generations in civilization. Institutions of higher learning are crucial to the implementation of education for sustainability because: an institutional culture of sustainability raises awareness among university staff, local community, and broader audiences. Employee training and development are essential components in reaching the environmental goals specified in an organization's environmental strategy (Dong et al., 2021). By encouraging a successful and efficient implementation of environmentally friendly concepts in the workplace, including employee empowerment into a business' framework is a dependable strategy to guarantee long-term success or sustainability (Ullah et al., 2021). High education institutions are responsible for forming the next generation of professionals, which will have a decisive impact on their various professional contexts and social engagements. By implementing sustainable campus practices (e.g., reducing greenhouse emissions, promote biodiversity, efficient use of energy, and reduce the ecological footprint), teaching and research centers can improve sustainability through project development and incorporation of sustainability principles across the disciplines.

2.2. Sustainability in HEI of South Africa

At the forefront of study is examining strategies for promoting sustainable performance (Akanmu and Hassan, 2023). Recent study, however, urges further investigation into the dynamic phenomenon of "sustainability" in order to ultimately contribute to the 2030 UNESCO sustainability goal (Xie et al., 2024). Higher education institutions in South Africa have faced numerous challenges in recent years, including poverty among specific racial groups, which has prompted calls for free education, decolonization, massification, and politicalization of education (Kekana and Kubheka, 2016; Mabelebele, 2015). Government subsidies (50%) and student tuition fees (25%) together provide the funding for public higher education institutions in South Africa (de Beer et al., 2016; DHET, 2013). Certain institutions also have internal revenue-generating mechanisms. HEIs are obliged to adhere to the King IV report's provisions, which adopt a "triple bottom line" baseline for assessing organizational performance, notwithstanding their heavy reliance on public money. People of color have historically not been accepted into the South African educational system (Ramdass, 2009). Many laws and regulations were passed during the early days of democracy to promote inclusive relationships in all areas of society. Even if learning

has been easier according to the new democratic principles, the system is nevertheless plagued by ghosts of the past (Badat, 2010; DHET, 2013).

According to Kappo-Abidemi and Kanayo (2020), the mandate has put pressure on the government to offer free education for everyone in South Africa, which has resulted in unrest at HEIs during the past five years. The department is finding it difficult to keep up with the students' seemingly never-ending desire for free education (Masweneng, 2017). Additionally, through their unions, workers have expected things like turning all contract or temporary non-skilled workers into permanent positions, which can occasionally lead to impasse. The surge of students at HEIs poses infrastructure difficulties that necessitate government assistance. Alongside the demands of these internal stakeholders, host communities of HEIs often have to put up with demonstrations and disturbances.

Universities have the power to impact students by setting an example (Littledyke et al., 2013). Since the organizations making the biggest efforts in higher education have high academic knowledge, research interest, and a willingness to adopt and research advancements, including those related to SDGs, investing in higher education is essential to developing a culture of sustainability (Rosati and Faria, 2019). The environment, economy, society, and stakeholder awareness of sustainability aspects are all significantly impacted by the development of a sustainability culture on campus through various activities like institutional framework and assessment, research, education, experiences, operations, and outreach (Findler et al., 2019b).

Climate change has proceeded more fiercely and swiftly in the world because of the delicate and susceptible environment (Asadullah et al., 2020; Hassan et al., 2018). Thus, in order to address the crisis that is engulfing the world, it is imperative that crucial sustainable development (SD) measures and activities be taken (Akanmu et al., 2023; Czvetkó et al., 2021). A favorable climate was established by many global symposia engaging various stakeholders and participatory governance in order for the 17 SDGs to be accomplished based on methodical and quantifiable progress (United Nations, 2020). Africa will be able to lessen its reliance on fossil fuels, minimizing the related negative environmental effects and addressing one of the largest concerns of SD in the area by shifting toward clean energy generation and energy source diversification.

A key factor in creating sustainable societies in the present and future is sustainability at universities. Therefore, many universities in the world are currently adopting various strategies to ensure sustainability. To help India progress toward attaining complete sustainability, a focus on sustainability education is made (Priyadarshini and Abhilash, 2020). According to Miotto et al. (2020), the Indian School of Business, for example, supports the creation of competitive initiatives and strategies based on sustainable management, which will benefit society and institutions alike and boost their legitimacy. Nousheen et al. (2020) reported that Pakistan was among the initial nations to embrace the UN 2030 Agenda for Sustainable Development. Commencing in 2017, the country initiated an educational strategy with an emphasis on Education for Sustainable Development (ESD) for the first time.

In furtherance, recognizing the role of HEIs in the transition to sustainability, eight university grant-funded institutions signed the Hong Kong Declaration. The

proclamation sought to integrate sustainability into the curriculum and the processes of teaching and learning. Additionally, it supported university operations that are more environmentally friendly by reducing energy consumption, waste, water use, and greenhouse gas emissions. It also gave colleges a way to be held responsible for their deeds (Xiong and Mok, 2020). Also, urban planning strategies and laws are being put into practice in Cambodia with the goal of regulating land use sustainably. This is done to make sure that the country's fast urban population increase does not have a detrimental effect on the environment (Lord, 2020). In the same vein, the Philippines aims to apply sustainability to research in HEIs by means of more participatory governance. This is because HEIs serve as living laboratories and help develop more sustainable forms of management, which will have a positive effect on the surrounding environment (Blanco, 2021).

In furtherance, Halili et al. (2021) reported that from a Malaysian viewpoint, the adoption of education 4.0 at universities has been slow to start and is still in its early phases. Because industrial revolution 4.0 (IR 4.0) has a significant influence on education, the report poses to assist policymakers at universities in embracing their efforts to achieve IR 4.0 education transformation and increasing efforts for a good learning environment. The study concludes that Malaysian universities must adapt and contribute to the country's economic growth. In order to stay relevant to contemporary demands, the institution plays a vital role in educating students for industry 4.0. In IR 4.0, there is a rise in the introduction of new goods and services as well as the development of new employment.

Similarly, Muftahu (2024) examined the effects of IR 4.0 on entrepreneurial education and higher education by analyzing the national development plans of Nigeria and Malaysia and assessing their applicability to IR 4.0. This issue is not at all connected to the students themselves, but rather to the inadequate strategy used by colleges to provide their students with the entrepreneurial abilities required in the highly competitive industrialized world of today. The study showed that, to equip students for the demands and difficulties of IR 4.0, both nations must emphasize the benefits of education. These reports illustrate that there is a need for similar investment in sustainability of HEIs in Africa as a whole specifically in South Africa for a global competitive advantage especially with the inclusion of Lean practices which is missing in the previous studies as illustrated in the **Table 1**.

Table 1. Developing countries initiating IR 4.0 into HEIs sustainability.

Source/Author(s)	Country	Problem Statement	Scope of Study	Result
Priyadarshini and Abhilash (2020)	India	Many universities in the world are currently adopting various strategies to ensure sustainability	Creating sustainable societies in the present and future from universities	To help India progress toward attaining complete sustainability, a focus on sustainability education is made.
Nousheen et al. (2020)	Pakistan	The education provided by universities is essential to bringing about societal transformation and paving the way for a sustainable future.	The UN 2030 Agenda for Education for Sustainable Development (ESD)	To improve students' attitudes toward sustainable development, there is a need and opportunity of education for sustainable development across a variety of academic disciplines, particularly in Pakistani institutions' education programs.

Table 1. (*Continued*).

Source/Author(s)	Country	Problem Statement	Scope of Study	Result
Xiong and Mok (2020)	Hong Kong	The global appeal for sustainability initiatives in HEIs was met with good and effective responses from eight public universities in Hong Kong that are supported by the University Grant Committee (UGC).	Integration of sustainability into the curriculum and the processes of teaching and learning	The study supported university operations that are more environmentally friendly by reducing energy consumption, waste, water use, and greenhouse gas emissions.
Halili et al. (2021)	Malaysia	The adoption of education 4.0 at universities has been slow to start and is still in its early phases	Industrial revolution 4.0 (IR 4.0) in Education	In IR 4.0, there is a rise in the introduction of new goods and services as well as the development of new employment.
Muftahu (2022)	Nigeria	Inadequacy of the strategies used by colleges to provide their students with the entrepreneurial abilities required in the highly competitive industrialized world of today	Applicability of IR 4.0 in higher education	To equip students for the demands and difficulties of IR 4.0, both nations must emphasize the benefits of education.
Lord (2020)	Cambodia and Vietnam	The social, economic, and environmental infrastructure of many cities in Southeast Asia is no longer sustainable due to the rapid pace of urbanization in the region.	Transition to Resilient and Sustainable Urban Futures	Trans-disciplinary research is necessary to comprehend how to improve urban governance capabilities for changes toward urban sustainability.
Blanco (2021)	Philippine	The durability of institutional capacities, which are mostly generated from training and education, has had setbacks and deficiencies.	Application of sustainability in HEIs by means of more participatory governance	HEIs serve as living laboratories and help develop more sustainable forms of management.

2.3. Lean practices in HEIs

Lean practices can be used to enhance teaching strategies, administrative procedures, and other aspects of higher education institutions, according to a systematic review of the pertinent literature on these approaches in higher education (Cudney et al., 2020). These approaches' introduction and use may raise the standard of higher education and provide value that consistently raises student satisfaction.

Organizations can benefit from enhanced tools and procedures through the integration of Lean and Six Sigma processes (Akanmu and Nordin, 2022a). Offering online education to students is one of the innovative ways that higher education institutions are now managing rising expenses and the requirement for constant improvement (Bandyopadhyay, 2014). Continuous improvement is made possible by Lean Six Sigma, which replaces conventional methods with aggressive management strategies including Lean service management, Six Sigma quality management, and quality function deployment (QFD) (Bandyopadhyay, 2014). These methods support increasing instructional efficacy, which raises student potential (Hopen and Cudney, 2016). Numerous investigations on Six Sigma and Lean methodologies in higher education have been carried out.

In order to address the many expenses related to nonconformity to process requirements in higher education and enhance the quality of higher education, Kanakana et al. (2015) developed a framework utilizing Lean Six Sigma. Using four criteria, the study determined the expenses associated with subpar quality. The expenses incurred when a student had to retake a course were known as internal failure costs. Losses like missed possibilities for government grants and business investment

are examples of external failure costs. The expenditures of mentoring, counseling, training, and tutorials were included in the prevention costs. Activities like quality checks and document proofreading are included in appraisal fees. The approach used records from an industrial engineering department in the management system information unit of Tshwane University of Technology, South Africa, during 2011 and 2012 to determine expenses. Given that these measures were required to lower costs and raise the standard of higher education, this research recommended a number of changes, including staff quality evaluation, a reduction in the staff to student ratio, the availability of financial assistance, and a shift in the way lectures are delivered to better engage students.

Alhuraish et al. (2016) posit that lean concept is an approach that seeks to reduce waste and expenses associated with production. Similar to this, lean practice is a corporate approach or strategy that improves customer satisfaction, process performance, and triple bottom line performance (i.e., social, economic, and environmental) (Snee, 2010). When the Toyota system was being produced, lean practice was included. To enhance quality and delivery on time, just-in-time procedures were incorporated into the system. The Toyota production system (TPS) is credited with originating the lean idea (Nordin et al., 2014). The TPS aimed to decrease waste and increase quality by eliminating non-value added components. Yang et al. (2017) mentioned that various techniques are combined to generate hybrid lean practices. In a similar vein, the cluster of lean techniques include employee engagement in complete preventative maintenance, productive maintenance, just-in-time delivery, human resources management, and regulated processes.

Also, the significance of downstream cooperation and consumer engagement has been demonstrated by recent research (Martinez-Jurado and Moyano-Fuentes, 2014). Other subcategories of lean techniques include product design, supplier and customer relations, production planning and control, process and equipment, and human resources. These components are almost applicable to all industries (Bergmiller, 2006). Thus, for lean processes to be implemented successfully, forward cooperation with customers and backward coordination with suppliers are critical. Dues et al. (2013) state that in this manner, the products are manufactured, packaged, and delivered specifically to meet operational and environmental objectives. Among the objectives for reaching lean management performance are the environment, sustainable development, and ecological performance traits.

Furthermore, Motorola developed six sigma in the 1980s as a way to reduce variances and mistakes throughout the product development process. Six sigma emphasizes the significance of statistical methods and data analysis techniques in developing ideal business processes that reduce output variability and attain 99% efficiency rates (Antony et al., 2017). Six sigma has been referred to as a “parallelmeso” structure because it functions at both the micro (worker behaviour) and the macro (organizational processes) levels concurrently (Schroeder et al., 2007). To be more precise, the six sigma processes use a combination of organized procedures, individual specialists, and output requirements (performance measurements) in order to reduce mistakes and variances. In addition, the six-sigma paradigm consists of the following essential phases: define, measure, analyze, improve, and control (DMAIC) (Gutpa et al., 2019). The experts pinpoint the probable issues, anticipated objectives, and

pertinent elements of the six sigma projects; this provides the remaining DMAIC stages.

Data collection to determine current quality and output method to identify problem scope are the first steps in the measure phase. After comprehending the outcomes of the processes, the "analysis" step looks to understand the practices, methods, and processes required to obtain the desired results. After determining the root cause, the "Improve" step implements process and/or procedure modifications to address the fundamental cause, eliminating mistakes and output variability and reaching 99% efficiency rate. Finally, the control phase lays out the strategies and procedures to guarantee that the advancements made in earlier stages is continued (Gupta et al., 2019). Most significantly, statistical approaches are used at each phase of six sigma to inform subsequent actions and conclusions.

2.4. Industrial revolution 4.0 in HEIs

The disruptive effects of technological innovations are causing significant changes in business operations, according to Oke and Fernandes (2020); however, little is known about the acceptability and implications of the fourth industrial revolution (4IR) in South Africa's education sector. Despite the fact that research indicates that 4IR can improve student learning and revolutionize the workplace, an evaluation of the learning environment is necessary to identify the factors that promote and hinder the spread of 4IR. In light of this, it seems that the education industry, particularly in Africa, is ill-prepared for 4IR, despite some signs of possibility for capitalizing on this much-anticipated development. Saha et al. (2023) posit that the adoption and implementation of Industry 4.0 (I4.0) technologies improves organizational sustainability performance by helping to deliver organizational objectives more effectively. As a result, innovative practices and I4.0 technologies work together to significantly improve organizational sustainability performance (Akanmu and Nordin, 2022b; Akanmu et al., 2022).

Digital technology is spreading exponentially throughout numerous industries, but its consequences for pedagogy, ethics, and epistemology are still up for debate, particularly in the education sector given the current 4IR. Despite the fact that many industries still lack basic understanding about 4IR, the term is becoming popular and gaining popularity in a variety of economic sectors. Thus, policymakers, industry practitioners, and academics are increasingly paying more and more attention to 4IR, which is seen as a fusion of various technologies and considered to blur the boundaries between the physical, digital, and biological domains (World Economic Forum, 2018).

Furthermore, the past 30 years have seen a significant change in power from power sources to automated manufacturing, information technology, and communication in the industrial revolution. The industrial revolution may be characterized as centered around three key categories: people, processes, and technology. Each of these groups is responsible for pushing development and starting a mutually reinforcing cycle. Industrial Revolution 4.0, according to Ahuett-Garza and Kurfess (2018), is the digital system made possible by the effective integration of information technology, methodologies, and production processes.

In the age of Industry 4.0, higher education establishments are confronted with difficulties in preparing students for the quickly evolving workforce (Mustapha et al., 2024). These institutions may get a deeper understanding of student needs and results, as well as the efficacy of teaching and learning practices, by utilizing the unprecedented volumes of data at their disposal (Akanmu and Bahaudin, 2018). In order to investigate the state of data use in higher education today—that is, how data is being utilized to guide decisions and enhance results—there is a need to incorporate lean practices that are in consonance with IR 4.0. In order to fully realize the potential of data use in higher education, academics and practitioners need to devote more time to this area. Muftahu (2022) added that, technological advancements have brought about inevitable changes in today's world. Many changes are being brought about by the IR 4.0, in terms of education, employment, and even lifestyles. Employees in HEIs now require additional skills in addition to technological know-how, including as problem-solving, creative thinking, and communication, as a result of the disruptions brought about by disruptive technologies (Nazir, 2019).

In the same vein, the adoption of technology is rather low in the education sector due to factors including cost, perceived restricted use, and lack of training, and its efficacy is not well demonstrated (Tymon, 2013). Gaining a sufficient grasp of the various 4IR components, using the existing classifications in the literature, is the first step towards comprehending the roles and usefulness of 4IR in supporting teaching and learning methods. The main objective of Industrial Revolution 4.0 (IR 4.0) is to improve the responsiveness and efficiency of any services system. IR 4.0 technologies, which function on the concepts of vertical and horizontal integration of production systems, are influenced by real-time data interchange across several partners in a performance value chain (Fatorachian and Kazemi, 2018). The nine pillars of digital innovation are as follows, according to Rüßmann et al. (2015): (1) internet of things, (2) simulation, (3) horizontal and vertical system integration, (4) autonomous robots, (5) cybersecurity, (6) cloud, (7) additive manufacturing, (8) augmented reality, and (9) big data and analytics.

3. Methodology

The survey questionnaire in this study is employed as a data gathering tool from the administrative staff of University of Johannesburg (UJ). A developed online questionnaire with a link attached will be provided through email. The questionnaire will be sent to the representative of each administrative department to have a look first. Then, a meeting can be held to validate the items of the questionnaire. When the questions have been validated by these representatives, then a large scale distribution of the online survey to other employees can be done. The administrative system of the university includes: the finance division, the human resources (HR) division, the IT division, the student administration system, the research and development division, the quality assurance system, and the library. Using the active UJ Administrative employees as the targeted population, a non-probability sampling shall be employed and the G-Power analysis shall determine the eventual sample size. In a similar vein, the Smart PLS by Ringle et al. (2015) is employed in this study as the tool of analysis. Smart PLS is a powerful and multivariate technique that entails special case of

specified version of number of other analyses approaches. Notably, PLS is considered (Urbach and Ahlemann, 2010):

1) Fewer sample size is required than other methods in PLS;
2) Normal data input distribution is not required in PLS;
3) PLS is applicable to a complex structural equation mode with a larger number of constructs;
4) PLS handles both reflective and formative constructs; and
5) PLS can easily achieve predictions

Therefore, it is essential to carefully craft the questionnaire items so that they accurately reflect the variables used to measure the study framework's variables. The questionnaire items are produced, modified, or incorporated from previous research (Zikmund et al., 2010). Items measuring lean practices (i.e., employee involvement, just in time, statistical process control, continuous flow, pull system, customer involvement, employee involvement, supplier involvement, and setup time reduction), IR 4.0 technologies, and sustainability performance are divided into four sections. The survey instrument is created with the help of relevant literature.

3.1. Dimensions of sustainability performance

The social, environmental and economic performance is used to gauge sustainability performance. Three factors in all are taken from the research of Brent and Labuschagne (2004). For the firms, the last three years are set aside as the evaluation period. The elements evaluating sustainability performance are shown in **Table 2** below.

Table 2. Items for measuring sustainable performance.

Items	Code
Our company has achieved in the last three years:	
Performance of Economic Sustainability Lower production costs	PES1
Higher earnings	PES2
Lower expenses for teaching development	PES3
Lower energy expenses	PES4
Lower expenses for inventories	PES5
Decrease in the cost of rework and rejection	PES6
Reduction in the cost of acquisition of teaching and research materials	PES7
Reduction in the expense of waste management	PES8
Performance in Social Sustainability	
Better working conditions	PSS1
Increased workplace safety	PSS2
Better health of the workers	PSS3
Better labor relations	PSS4
Higher morale	PSS5
Less workload pressure	PSS6
Performance in Environmental Sustainability	

Table 2. (*Continued*).

Items	Code
Decrease in solid waste	PEnS1
Decreased amounts of liquid waste	PEnS2
Diminished emissions of gas	PEnS3
Decrease in energy wastage	PEnS4
Reduced use of poisonous, dangerous, or harmful products	PEnS5
Improved state of the company's environment	PEnS6

3.2. Dimensions of lean practices

The first set of Shah and Ward's (2007) suggested constructs for lean practices is used in the development of the construct domain specification and item creation. **Table 3** lists several constructs: continuous flow, just-in-time supply, supplier development, employee and supplier involvement, set-up time reduction, customer involvement, total productive maintenance, and statistical process control.

Table 3. Items for Measuring Lean Practices.

Items	Code
Supplier Involvement	
Our institution maintains constant communication with the suppliers.	SI01
Our institution gives suppliers input on their performance in terms of quality and delivery.	SI02
Our institution makes every effort to establish enduring relationships with its suppliers.	SI03
Just In Time	
Every one of our major suppliers is involved in the development of new products.	JTO1
Just-in-time deliveries to our company are made by our suppliers	JT02
We have a supplier certification scheme in place.	JT03
Supplier Development	
Every year, our institution's supplier aims to reduce costs.	SD01
Our primary supplier is located near to our institution.	SD02
We have a mechanism in place to notify suppliers of critical concerns.	SD03
Our institution strives to have fewer suppliers in each area.	SD04
Key suppliers are in charge of managing the stockpiles.	SD05
Suppliers are evaluated based on the entire cost of the purchase rather than the price per unit.	SD06
Customer Involvement	
Our institution maintains good ties with its clients.	CI01
Clients provide feedback on our institution's delivery and quality performance.	CI02
Our institution incorporates clients into the process of developing and refining both new and current services.	CI03
Clients take part in the process of developing new and improved services.	CI04
The clients communicate their needs, both current and prospective, to our business.	CI05

Table 3. (*Continued*).

Items	Code
Continuous Flow	
The same processing criteria are used to classify our items into groups.	CF01
We use the same routing rules to classify our items into groups.	CF02
Our system is categorized to deliver consistent product flows.	CF03
The performance layout is determined by our services.	CF04
Total Productive Maintenance	
Every day, our organization sets aside time to schedule tasks linked to equipment maintenance.	TPM01
We maintain all of our equipment in top shape	TPM02
Our organization does daily maintenance on all equipment.	TPM03
Our organization shares equipment maintenance details on its website with its staff members.	TPM04
Statistical Process Control (SPC)	
Most of the equipment and processes covered by SPC are handled by our organization.	SPC01
Statistical methods are employed by our organization to manage process volatility.	SPC02
Our organization shows failure rates using charts as a tool.	SPC03
Fishbone diagrams are used by our organization to determine the root causes of quality issues.	SPC04
Prior to the release of a new technology, our organization studies process capabilities.	SPC05
Employee Involvement	
According to our organization, employees are crucial in resolving issues.	EI01
The institution is motivated by its employees through a suggestion program.	EI02
The attempts to enhance the process and/or product are led by our personnel.	EI03
Our organization offers its staff cross-functional training.	EI04
Set Up Time Reduction	
For our personnel, our organization offers a variety of setup reduction measures.	STR01
Our organization is always striving to reduce setup time.	STR02
Our organization's equipment setup takes a long time.	STR03

3.3. Dimensions of industrial revolution 4.0 technologies

Since most firms have not yet investigated the advanced capabilities of IR 4.0 technologies, Tortorella and Fettermann (2018) mentioned that they are unsure about the potential future advantages of these technologies. According to Kamble et al. (2018), the industrial industries are just beginning to implement IR 4.0 technology, but it is gradually gaining traction. As a result, items are intended to assess the extent of IR 4.0 technology deployment rather than the degree of implementation success. The measurement items for IR 4.0 Technologies according to Kamble et al. (2020) research are shown in **Table 4**:

Table 4. Items for measuring industrial revolution 4.0 technologies.

Items	Code
Our institution intends to use cloud computing.	IR01
Our institution intends to use big data analytics.	IR02
Our institution intends to use the internet of things.	IR03
Our institution intends to use additive manufacturing.	IR04
Our institution intends to use robotic systems.	IR05
Our business intends to use augmented reality.	IR06

As a result, the framework for this study is created based on the theoretical underpinnings of the critical issues, as shown in **Figure 1** below. Hypothetically, performance can be at its peak due to the model testing of the connections among the variables if the university management integrate the relevant factors. Theoretically, the study model that was built helped to bridge the knowledge gap between sustainability and lean methods, which had been discussed in previous studies (Farias et al., 2019; Klein et al., 2021).

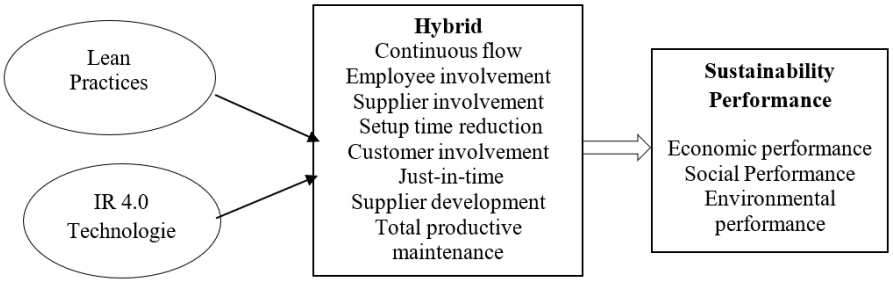

Figure 1. Conceptual framework development for the research.

The hypotheses of the study are developed using the theories of contingency and practice-based view (PBV) that are taken from the theoretical backdrop. The theory of contingency, according to Sousa and Voss (2008), offers recommendations on how to choose certain sets of operations management strategies that work well in a given organizational setting. Stated differently, Bromiley and Rau (2014) argue that performance variances are explained depending on the usage of a specific practice, and PBV is adopted because some companies do not utilize all of the advantageous current practices.

4. Discussion

According to Klein et al. (2023), by supporting local, regional, and national advancements as well as the sustainability of HEIs, lean practices can contribute in optimizing the use of university resources and improve their administration. Therefore, the following highlights the formation of the study's hypotheses based on the previous research:

4.1. Lean practices and sustainability performance

4.1.1. Supplier involvement and sustainability performance

Previous research (Vachon, 2007; Zhu et al., 2010), has demonstrated that supplier engagement in an organization has a major impact on sustainability performance. An organization's environmental and financial sustainability performance is enhanced when it collaborates with its suppliers (Vachon and Klassen, 2006). According to Vachon (2007), effective development, adoption and the implementation of lean practices towards social responsibility are facilitated by collaborative relationships with suppliers. Zhu et al. (2010) also reflect on the significance of the link between supplier engagement and sustainability performance. According to the report, services organizations' efforts to enhance their sustainability performance are hindered when suppliers do not collaborate with them.

More precisely, the research conducted by Limon et al. (2020) demonstrates a favorable association between the environmental sustainability practices and the lean practices of HEIs. This indicates that lean initiatives affect waste and residue awareness, material reuse, water and power consumption reduction, and the separation of recyclables from organic waste, even if indirectly. In accordance with these aforementioned past studies, it is proposed that:

Hypothesis 1: there is a significant and positive relationship between supplier involvement and sustainability performance

4.1.2. Just-in-time (JIT) and sustainability performance

Just-in-time (JIT) and autonomy (i.e., automation with human touch) are the two pillars needed to sustain the Toyota Production System, claim Bicheno and Holweg (2009). Zelbst et al. (2014) further noted that JIT is a component of lean processes that requires accurate and timely information exchange in order to be successfully applied. Accurate inventory data are crucial to lean production when big buffers and safety supplies are eliminated. According to Zelbst et al. (2014), a digitalized sustainable supply chain offers precise and fast information on the locations and stock levels. Furthermore, JIT offers machine intelligence to differentiate between anomalous and typical activity. In order to prevent making faulty goods, a machine will shut down if an issue cannot be sustained (Buer et al., 2018). The use of JIT practices enables a machine to possess intelligence, hence promoting autonomy. According to Thoben et al. (2014), machines are capable of reporting and analyzing deviations more quickly, identifying their causes, and kicking off actions automatically.

The economic success of HEI is also impacted by its lean procedures. The evaluation of lean methods provided favorable support for the elements of quality, resources and valued skills, creativity and efficiency and effectiveness (Wijayanto et al., 2020). This is understandable as lean management philosophy and improved quality, resource optimization, activity time improvement for efficiency, and cost reduction to create more value are shared goals (Al-Aomar and Hussain, 2018). In addition, JIT is a lean six sigma tool that, along with statistical process control, six sigma, analytic tools, kaizen events, cellular manufacturing, visual management, value stream mapping, standard works, supplier relationship and plant layout reconfiguration, helps organizations reduce waste. JIT has an influence on lessening the social and environmental impact of organizations, according to Chiarini (2014). Cherrafi et al. (2016) added that numerous organizations have embraced the instrument to achieve greater environmental and social development. In light of the foregoing discourse, this research proposed that:

Hypothesis 2: just in time and sustainability performance have a positive and significant relationship

4.1.3. Supplier development and sustainability performance

According to Krause et al. (2000), supplier development is “any activity undertaken by a purchasing organization to improve either supplier performance, supplier capabilities, or both, and to meet the buying firm’s short- and/or long-term supply needs”. Traditionally, the goal of supplier development has been to increase the suppliers’ economic viability and their performance in terms of quality, cost and transportation. According to the triple bottom line theory, supplier development entails

achieving economic, socio-ethical, and environmental objectives (such as stopping dysfunctional behavior or ensuring fair pay) (Busse et al., 2016). Examples of these objectives include waste reduction and energy efficiency. Likewise, supplier development concerning social and environmental objectives denotes an implicit "enlightened self-interest" on the part of the customer and is closely linked to the buyer's interests about economic objectives (Busse, 2016).

Foerstl et al. (2014) state that in response to stakeholder concerns for effective, sustainable organizational conditions, supplier development has lately attracted scholarly interest. Prior studies (Blome et al., 2014; Sancha et al., 2015) focused on environmentally friendly procedures that assist suppliers in reducing the adverse effects of the environment on social activities. In view of the assertions made by Busse et al. (2016) that both sustainability measures and stakeholder reactions are in the purchasers' enlightened self-interest and by Hoffmann et al. (2014) that sustainability measures may impact stakeholder reactions. This "externality" is beneficial to society as a whole and aligns with Michael and Elser's (2019) introduction of the "educational value," which is the fourth bottom line of sustainability. Furthermore, it restates the HEIs' ability to be change agents and lessen the barriers to education for sustainable development (Hay and Eagle, 2020). Thus, the following hypothesis is put forth:

Hypothesis 3: there is a positive and significant relationship between supplier development and sustainability performance

4.1.4. Customer involvement and sustainability performance

Chen et al. (2012) shown in a previous study that consumers are eager to support environmentally conscious businesses and are prepared to work with manufacturers to achieve environmental sustainability. The study demonstrates that, in cases where these tech-savvy consumers acquire newly created technical features of a good or service, there is a strong correlation between user engagement and sustainable performance. The state of the economy, society, and environment has an impact on an organization's sustainability performance (Chen et al., 2012).

Additionally, Andic et al. (2012) found that an organization's competitive edge and financial success are determined by the level of consumer interaction. Additionally, Eltayeb et al. (2012) found a strong correlation between sustainability performance and consumer participation. When a new product is released, customer engagement is always crucial since producers must properly identify and communicate the features of the items (Chan et al., 2012). According to Ellram et al. (2008), an organization's ability to function sustainably may be attributed to the connection between its consumers and manufacturers. According to Simpson et al. (2007), there is a noteworthy correlation between the degree of customer collaboration and the environmental and social sustainability performance. Thus, this research postulated that:

Hypothesis 4: there is a positive and significant relationship between customer involvement and sustainable performance

4.1.5. Continuous flow and sustainability performance

The goal of lean techniques, according to Benavent et al. (2005), is to improve customer satisfaction across the board by using continuous process flow. Every business should establish continuous improvement methods in order to integrate all

components of the organizational process, including management styles and activities, in an efficient manner. According to Baker (2003), a high degree of customer satisfaction should be the ultimate goal for any firm. Such a strategy, according to Maldonado et al. (2020), is seen as continuous improvement cycles that provide incremental organizational changes at each cycle, resulting in new improvement cycles that are organized and continuous. In contrast to the traditional "wait-and-see" strategy, it involves a collaborative effort between the "staff" and the "line" employees to interact and work with the leaders toward a shared objective that centers on providing high-quality service or results through continuous improvement with a constant focus on the customer.

Furthermore, continuous sustainable flow is fuelled by critical innovation and quality-conscious clients, according to Escrig-Tena (2004), even though there are many other factors that can help enhance and facilitate continuous improvement practices in an organization, such as an efficient information system and top management support. Research (e.g., Fotopoulos and Psomas, 2010; Yusuf et al., 2007) show that an organization's productivity, long-term competitive position, and sustainable performance are all significantly and favorably impacted by continuous flow. On the other hand, Burli et al. (2012) found no evidence of a substantial relationship between sustainable performance and continuous flow. Therefore, this research postulated:

Hypothesis 5: there is a significant and positive relationship between continuous flow and sustainability performance

4.1.6. Total productive maintenance and sustainability performance

Lean practice, according to Shah and Ward (2002), is the cooperative integration of several complementary practice packages that fall into four categories: human resources management, JIT, total productive maintenance and total quality management. In an organization, certain lean tools are more appropriate than others. Tools including total productive maintenance, value stream mapping, task standardization, 5S, and team-based issue resolution, as well as quality management programs, are independent of process features. However, businesses may align their operations to avert paradoxical effects if they embrace comprehensive preventative maintenance and strive for environmental and social sustainability. According to Desiderio et al. (2022), social activities pertaining to social sustainability are associated with comprehensive preventative maintenance. As such, quality and safety concepts ought to be complementary.

Longoni and Cagliano (2015) state that cross-functional executive involvement and employee participation with environmental and social objectives and practices impact the strategic alignment of the lean practices (such as JIT, TPM, HRM, and TQM). Specifically, TPM's impact on lean processes is consistent with sustainability in terms of both the environment and society. Preventive maintenance therefore has a favourable impact on the use of lean practices in line with environmental and social sustainability.

Furthermore, Desiderio et al. (2022) noted that several industries with sophisticated production models have investigated TPM approaches in an effort to enhance their organizational environmental and social performance. For example,

TPM is designed by operation executives to monitor social and environmental indicators and detect and address safety, environmental, and health hazards. TPM is therefore made with reducing material waste and energy loss. Thus, this investigation suggests:

Hypothesis 6: there is a significant and positive relationship between total preventive maintenance and sustainability performance

4.1.7. Statistical process control and sustainability performance

According to Kumar et al. (2006), lean methods utilize statistical approaches and tools that may elevate businesses to a higher process or performance level while also playing a significant part in decreasing wastes and non-value added activities across organizational levels. According to Laureani and Antony (2017), in order to achieve optimal results and boost precision and velocity, lean methodologies necessitate the utilization of statistical process control techniques. Lean practices have evolved into a comprehensive and adaptable system for optimizing, attaining, and maintaining successful businesses, as demonstrated by Neuman and Cavanagh (2000). This system is powered by a common concept of what constitutes a satisfied client, careful attention to controlling and enhancing business performance, and methodical application of fact, data, and statistical analysis.

The aspects of statistical process control are among the least used by any industry, claims Azizi (2015). The practices that require financial capabilities in order to train the belt team are challenges in low-margin industries that are always seeking for ways to cut costs; these practices rely on statistical technique knowledge and are deemed too sophisticated and complex for the industry. Initially, the industry gives these techniques little thought, but as statistical process control increases, so does their acceptance, demonstrating their suitability for the industry. In light of the above mentioned reports, it may be suggested experimentally that:

Hypothesis 7: there is a positive and significant relationship between statistical process control and sustainability performance

4.1.8. Employee involvement and sustainability performance

One of the lean methods is employee involvement, which includes training, empowerment, and participation from employees. According to Yusuf et al. (2007), in order for workers to participate in an organization's financial breakthrough, decision-making, and problem-solving processes, they must be motivated. This shows that each employee is capable of participating in organizational affairs and is informed about the state of the business's finances both now and potentially in the future. As a result, workers can get more deeply involved in the organization's core activities and enhance its long-term effectiveness.

Practice motivates every individual, bringing them closer to the organization's aims and objectives. An essential component of lean processes is employee participation. In order to help the employees achieve sustainable performance, a model of lean processes that incorporates employee engagement should be designed. Furthermore, with employee support, lean techniques have a good relationship with organizational sustainable performance (Akdere, 2006). Since they are viewed as the organization's most valuable asset, employees may provide values to the company if they receive enough training, empowerment, and collaborative opportunities. One of

the key factors in any organization's ability to successfully adopt lean processes is employee participation. According to the same perspective, Arawati (2005) found a strong correlation between sustainability performance and employee participation. Thus, it is possible to suggest that:

Hypothesis 8: there is a positive and significant relationship between employee involvement and sustainability performance

4.1.9. Setup time reduction and sustainability performance

Any industry that wants to be well-organized must constantly apply lean techniques that minimize setup times (Dora et al., 2014). The sector's features are somewhat impacted by the adoption of lean practices. Reducing setup times in the industry is impacted by the mandatory cleaning procedure that must be followed correctly to guarantee education safety and prevent contamination. Businesses with a large percentage of specialized equipment are the ones who choose the setup time reduction strategy, emphasizing how important it is to maintain the dependability and availability of the equipment (Dora et al., 2014). Nevertheless, the setup-time reduction approach is not often implemented, even with the company's qualities.

Furthermore, internal collaboration and cooperation across the enterprises save setup time and result in overall effective sustainable performance (Green et al., 2012). Economic objectives may be met by implementing lean techniques and effectively integrating the setup time reduction. Reducing setup time has the potential to boost profitability and grant competitive market shares to a number of firms (Chien and Shih, 2007). Economic failure is caused by a lack of internal practices, such as reducing setup time, according to Zhu et al. (2010).

Additionally, Eltayeb et al. (2011) discovered a strong correlation between environmental sustainable performance and internally integrated set-up time reduction. The environmental management system has an impact on the production and time waste reduction performance of the operations. Zhu et al. (2012) further assert that integrated sustainable design methods within an organization boost profit, revenue, and employee wellbeing. Similarly, Zhu et al. (2010) discovered that social sustainability performance (i.e., high employee involvement, increased happiness, participation, safer working environment, and motivation and social commitment) is significantly impacted by internal coordination mechanism such as having employees attend to setup time reduction, exposure of cross-functional cooperation and environmental issues. Therefore, this analysis suggests that:

Hypothesis 9: there is a positive and significant relationship between setup time reduction and sustainability performance

4.2. Industrial revolution 4.0 technologies and sustainability performance

Kolberg and Zuhlke (2015) claim that lean techniques provide enormous opportunity for integrating cutting-edge and automotive technology. According to Sanders, Elangeswaran, and Wulfsberg (2016), IR 4.0 technologies help industrial organizations meet the current issues in lean practices. Meudt et al. (2017) added that, value stream mapping, which is the first stage in implementing lean methods and six sigma, can be done with great accuracy because to the real-time information made possible by IR 4.0 technology.

Technologies like the value stream map, robotic systems (RS), cloud computing (CC), additive manufacturing (AM), cyber-physical systems (CPS), big data analytics (BDA), the internet of things (IoT), and augmented reality (AR) are used in a number of processes that deliver goods and services to clients from the very beginning. According to Meudt et al. (2017), these technologies are used to analyze the current issue and create the future condition in order to achieve a reduction in waste. Tortorella and Fettermann (2018) suggested that, IR 4.0 technologies would improve sustainability within an organization. Consequently, the following theory is put forward:

Hypothesis 10: there is a positive and significant relationship between IR 4.0 technologies and sustainability performance

4.3. Implication to the industry

The results of this study will have a big impact on policy makers, practitioners, and managers of engineering practices. Numerous beneficial insights exist on how lean and six sigma processes improve a company's overall sustainability performance. The report recommends HEIs in SA to integrate Lean practices, six sigma and IR 4.0 into their production processes. This is because industry policy makers are now considering restructuring techniques and plans that are in line with technology advancements. The overall success of lean practice is traced by engineering managers to the critical assessment of performance and data analysis to make sure that the goal of achieving quality improvement is being maintained. Once six sigma is employed, there are safeguards and check and balance to ensure continuous efficiency through the life of any process. Thus, the six sigma certification educates engineering managers to work as team with other departments within a company in order to identify the causes of defect within a process and how to devise statistically-driven and effective techniques to reduce or to completely eliminate them.

Furthermore, the lean practices have evolved to introduce methodologies that are helpful and necessary to avert dangerous mistake for managers as it is known that engineering is a unique niche of business where mistakes can often be deadly. Thus, the business knowledge is tied with all types of Engineering such as Electrical, Industrial, Civil, Mechanical, Automotive, Structural, Computer, Agricultural and Mechatronic. The statistical tools and concepts are utilized to identify defects or variations in a process. Notably, a group of engineers in 1980s developed these practices for their company, Motorola. This indicates the roots of lean six sigma process in the engineering sector of business. The whole motive behind these practices is to find, diagnose and fix defects or errors while increasing the efficiency and quality of services and products exceed the expectations of the customer and consequently leads to sustainability.

As the globe becomes more interconnected with the internet of things and other smart technologies, local facilities and services may eventually lose their geographic advantage due to the Industrial Revolution 4.0, which is altering business processes and increasing competitiveness. Because of these difficulties and the pressing necessity to transform the current workforce into intelligent workers while adjusting to the already encroaching technological advances, managers' tasks will thus alter. In

any industry, increase in customer satisfaction and bottom-line profit is a necessary measure of success. Engineering managers have been long responsible to guide and coordinate the creation of products and processes followed to manufacture those products. By giving the managers, the tools and creating a mind-set needed to build positive quality-driven change in a workplace, they can help better the industry that employ them. Engineering managers therefore need to prepare themselves for the challenges and equip their employees to accept technological evolution.

5. Conclusion

This study suggests that practitioners should organize their actions, identify obstacles, and consider success factors while adopting Lean practice at HEIs. The study suggests that the primary obstacle that HEI management need to address is the intricacy of the community and its procedures. They should also guarantee that the key success factors—strong leadership practices, senior management commitment, effective communication, and teamwork—are present and provide Lean training for workers and Lean facilitators. This preliminary study offers insightful information about the execution and upkeep of Lean efforts at higher education institutions; yet, respondents would be needed for a thorough analysis.

The influence of technology on the processes of teaching and learning in higher education cannot be overstated. Through the numerous e-learning platforms offered by HEIs, the purpose, deployment, and usage of technology for learning have supported educational achievement, equality, and social justice regardless of geography, distance, or time. Crucially, successful e-learning implementation and use in HEIs depend on a number of variables, including users' expectations of how well the e-learning platforms and devices work, users' expected roles and the amount of effort they put into using the technology, the realization of personal and social benefits, and the availability of organizational and technical support when needed. The experiences, attitudes, and impressions that users have of e-learning are shaped by the aforementioned. The study found that there are several issues with using the e-learning platform at the HEIs under investigation. These issues include a lack of ICT infrastructure, inconsistent Internet access, a lack of technical support, and insufficient training opportunities for using the e-learning platform at the university. This study concludes that the academic community's morale has been negatively impacted by these issues taken together. They are now unable to effectively assess the information that students have acquired via the e-learning platform, and they lack the motivation to work towards developing interactive content or course materials for virtual learning.

Currently HEIs are always looking for innovative ways to carry out their tasks, maintain their competitive edge, and enhance their overall performance. By integrating operational processes, continuous improvement programs like six sigma and lean methods assist institutions in maintaining their competitiveness, achieving high performance levels, and making quick or seamless process changes. By eliminating wasteful tasks and offering new goods and services, these approaches, when combined with IR 4.0 technologies, concentrate on generating greater value for the clients. For example, the six sigma methodology is incorporated into services processes to evaluate and eliminate errors and flaws in business operations by focusing

on outcomes that are significant enough to maintain an organization's social, environmental, and financial performance. In a similar vein, hybrid lean six sigma has improved the triple bottle line outcome while combining the best aspects of both unique approaches to boost organizational performance via customer satisfaction.

Studies have revealed that while many Higher Institutions are still in the early stages of smart system adoption, incorporating IR 4.0 technology into hybrid lean six sigma is among the least embraced strategies by the institutions. It makes sense that these procedures need financial resources, which presents challenges, particularly for low-margin businesses that depend heavily on statistical expertise and are always looking for methods to cut expenses. Thus, more research in the education sector is necessary due to the very advanced and complicated nature of these unique integrated systems.

There are certain limitations on the research. One of them is that, this study is only a preliminary approach with hypotheses development while an effort to collect data is ongoing for a large scale empirical analysis. Also, although gathering a sizable number of participants are expected from the university, the study does not cover all universities in South Africa. In addition, the study only focuses on the administrative staff of the university; thus, future studies can extend the research into academic staff in order to uncover the challenges of sustainability in teaching and research. Additionally, the subsequent study will validate the proposed framework after completing the ongoing data collection. Assessing educational outcomes like student performance, engagement, and satisfaction together with teacher job satisfaction and instruction quality can yield important insights into how these organizational enhancements really help end users.

Future implication

The advantages and future uses of IR 4.0 technologies exceed its drawbacks by a wide margin. Therefore, it is essential that institutions address the issues covered in this essay. In the proposed institution to be examined, where issues with faculty, infrastructure, training, and curriculum development, together with user attitudes, have prevented IR 4.0 technologies from reaching its full potential:

1) Government organizations and university officials should work to increase broadband Internet access on campus.
2) The foundation of IR 4.0 activities is a fast and high-speed Internet connection. Thus, through the university's e-learning site, a public-private partnership might be formed to guarantee that instructors and students engage in unrestricted and constructive teaching and learning experiences.
3) In order to maintain positive user experiences, the university's technological platform should be user-friendly. Academics should also receive training on content development and student evaluations for virtual teaching.
4) Academics should be updated and trained on new changes made to the university's platforms on a regular basis. Technical support should be immediately provided to academics and students when needed.

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MDA and ACB; data curation, MDA; writing—original draft preparation, MDA; writing—review and editing, MDA and ACB; visualization, ACB; supervision, ACB; project administration, ACB; funding acquisition, ACB. All authors have read and agreed to the published version of the manuscript.

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