Article

Social Inclusivity, Integration and the Fourth Industrial Revolution in South African Universities: Evidence from Vaal University of Technology

Watson Munyanyi
https://orcid.org/0000-0003-1727-8351
University of Johannesburg
wmunyanyi@hotmail.com

Gloria Mothibi
https://orcid.org/0000-0001-8356-4925
Vaal University of Technology
mgmtraining46@gmail.com

Abstract

Introduction: The swift strides of the fourth industrial revolution (4IR) and its entrenched emerging technologies are expected to increase significantly, leading to significant technological transformation and socio-economic change. The emerging 4IR technologies could bring substantial economic growth and welfare benefits in sub-Saharan Africa and social and economic disruption. There are emerging concerns that the rising pace of 4IR could widen inequality if counterbalancing policies are not adopted. This implies that coping with the 4IR transformation may require a holistic approach encompassing sustainable social solutions and not just technological ones. To meet and extend their understanding of the curriculum's objectives and improve their overall comprehension, students need to be able to use various digital tools. This study examines the role of the adoption of 4IR technologies in fostering social inclusivity and integration in the South African context.
Methodology: Drawing from the technological integration models, the current study argues that 4IR plays a crucial role in transforming the inclusivity and integration of learners, such as those living with disabilities and those from previously disadvantaged backgrounds. Technology integration models are theoretically constructed models that are meant to assist educators in planning technology integration more profoundly. Research was conducted on 203 students from different faculties selected using simple random sampling. Data was collected using an online questionnaire powered by Google Forms and analysed through structural equation modelling in SmartPLS 4.
Results: An evaluation of the results obtained in this study reveals a positive contribution of 4IR towards the general concept of inclusion as defined by the extent of accommodating different disabilities and backgrounds in social activities. The analysis also demonstrated the importance of 4IR in integrating

Southern African Business Reviiew
#14967 | 25 pages

https://doi.org/10.25159/1998-8125/14967
ISSN 1998-8125 (Online)

learners in mainstream classrooms and significant strides in eliminating special needs classes.

Conclusion/- and Recommendations: The paper concludes with recommendations for developing 4IR adoption strategies by universities in South Africa to bring about attitudinal change and formulate genuinely inclusive and integrated practices.

Keywords: 4IR; fourth industrial revolution; social inclusivity; integration; technology

Introduction

The digital revolution in Africa has evolved into an immensely potent weapon for effectively and efficiently connecting Africa to the world's markets, even though it initially took the form of mobile phones and internet access (Signé 2023; Marwala 2021; Petersen, Tanner and Munsie 2019). As argued by Mhlanga (2023), African companies must adapt, change, and innovate even more during enormous and unexpected disruptions like Covid-19. The current and emerging environment in which evolving technologies and trends, such as the Internet of Things (IoT) and artificial intelligence (AI), are altering how we live and work is known as the fourth industrial revolution (or 4IR). The fourth industrial revolution (4IR)'s rapid advancements and firmly established new technologies are anticipated to accelerate dramatically, bringing about profound technological and socio-economic change (French et al. 2023). Three significant trends have come together at the beginning of the decade: the rapid adoption of 4IR technologies, the disruption of the job market for both remote and in-person work, and the widespread demand for greater inclusivity, equity, and social justice (Mindell and Reynolds 2022; Vyas 2022). Emerging 4IR technologies, such as AI, the Internet of Things (IoT), Robotics and Quantum computing, have the potential to cause significant social and economic upheaval as well as economic development and welfare advantages in sub-Saharan Africa. Several implications for skill development, education, reimagining educational systems, and innovative strategies are also provided by 4IR (Kayembe and Nel 2019).

Several implications for skill development, education, reimagining educational systems, and innovative strategies are also provided by 4IR (Ilori and Ajagunna 2020; Tsiligiris and Bowyer 2021). Chalmers, MacKenzie and Carter (2021) argue that there are growing worries that the rapid adoption of 4IR would increase inequality if counterbalancing policies are not implemented. This suggests that addressing the 4IR revolution may require a comprehensive strategy, including sustainable and technological social solutions. Technology use has produced a variety of beneficial outcomes, including social inclusion, more accessible access to information, help with daily tasks, and healthcare applications (Andrade and Doolin 2016; Kirkpatrick 2016). Inequality is blatant in South Africa's educational system (Chakabwata 2022), and there is a chance that new technologies for education will only be accessible to the wealthier segment of the population, leaving the poor behind and reinforcing inequality (Buheji et al. 2020; Ainscow 2020). The Covid-19 problem, which expedited the 4IR, clarified that technology is no longer merely "neutral" regarding diversity, equity, and inclusion. Many organisations are proactively utilising technology to achieve higher levels of diversity, equity, and inclusion, although those that haphazardly adopt new technologies are facing challenges in achieving this objective (Luo and Zahra 2023; Srinivasan and Eden 2021; Aderibigbe 2021).

The 4IR, also known as Industry 4.0, a term primarily used in the business world, is a collective term for technologies of value chain organisations (Hermann et al. 2016; Erboz 2017). 4IR, by definition, is an embodiment of digitalised industrial production processes that result in completely smart and interconnected factories and organisation activities (Ruzarovsky et al. 2020). Industry 4.0 is predominantly concerned with creating digitised systems and network integration via intelligent systems with machine-oriented tasks. Butler-Adam (2018) opines that the 4IR will affect education through robotic tutors, curricula, teaching, and learning. Covid-19 has significantly impacted educational programmes delivery by accelerating the rate at which educators integrate digital tools into their programming (Nantais et al. 2021). To meet and extend their understanding of the curriculum's objectives and improve their overall comprehension, students need to be able to use various digital tools. There are disparities in access to and usage of digital technologies, and these have emerged from the cost of technological devices, internet connectivity and insufficient knowledge and skills to use the necessary devices, which continue to impede low-income students (Mhlanga and Dunga 2023; Haleem et al. 2022; Matli and Ngoepe 2022). In addition, there have been difficulties in implementing infrastructures that facilitate the adoption of 4IR technologies in certain areas.

The objective of this paper is to investigate and analyse the dynamics of social inclusivity and integration within the context of the Fourth Industrial Revolution (4IR) in South African universities, with a specific focus on the Vaal University of Technology. The study aims to examine the extent to which the transformative technologies and socio-economic changes associated with the 4IR impact the inclusivity of diverse social groups within the university setting. Through empirical evidence and case studies at the Vaal University of Technology, the paper seeks to identify challenges, opportunities, and effective strategies for fostering social inclusivity and integration in the rapidly evolving landscape of higher education influenced by the Fourth Industrial Revolution. The findings aim to contribute to the discourse on shaping inclusive policies and practices that align with the demands and possibilities presented by the 4IR, ultimately fostering a more equitable and integrated university environment in South Africa. This study examines the role of the adoption of Fourth Industrial Revolution technologies in fostering social inclusivity and integration in the South African context.

Technological Integration Model

According to Kimmons and Hall (2017), different groups adopt various technological integration models since the specific settings of individual stakeholders are too varied for a single model to handle. This study is grounded on the Technological Pedagogy Content Knowledge (TPACK), a theory developed to explain the set of knowledge that educators need to teach their students effectively and use technology (Koehler and Mishra 2009). The technology integration model is a theoretical framework that has been developed to assist educators and researchers in incorporating technology in meaningful ways. One of the fundamental questions that educationists, when faced with challenges, must answer is how technology can be integrated into student life besides through curriculum development. Technology integration models are theoretical frameworks created to support educators, researchers, and others in the education field in thinking critically about technology integration. This framework builds on Lee Shulman's (1986, 1987) construct of pedagogical content knowledge (PCK) to include technology knowledge. The development of TPACK by educational researchers Mishra and Koehler is critical to effective teaching with technology, as it integrates knowledge of content, pedagogy, and technology. This provides educators with a framework to design and implement meaningful learning experiences that leverage technology appropriately to enhance student learning. Pencils, pendulums, and chalkboards are examples of traditional pedagogical technologies characterised by their specificity, stability, and transparency of function (Simon 1969). Three essential elements—content, pedagogy, and technology—and their connections and interactions are at the heart of effective technology-assisted instruction. Vast differences in the degree and calibre of educational technology integration are due to the interactions between and among the three elements, which take different forms in various situations.

The foundation of the TPACK framework comprises three knowledge bases: content, pedagogy, and technology. This model was chosen because it provides insights that support the development of strategies to more effectively and efficiently promote the kinds of pedagogical reforms that reformers hope to see in schools, helps us understand and explain how technology integration occurs, and allows us to make better decisions about how to utilise technology resources. The TPACK framework also presents several opportunities for fostering social inclusivity and integration research. It provides possibilities for analysing and developing new ways to examine a complicated phenomenon like technology integration. Several studies have used the TPACK framework to understand the role of technology in social inclusion. This model was employed by Koh (2017), who explored social inclusivity in higher education, focusing on how instructors in diverse disciplines utilise technology to address the needs of students with varying backgrounds and abilities. The findings from this study indicate that pedagogical strategies informed by TPACK are of paramount importance in promoting inclusive practices. In another study, Reinders, H., and Wattana (2015) investigated the application of the TPACK framework in language education to support students from culturally and linguistically diverse backgrounds. The results of the study indicate that TPACK-informed instructional approaches facilitated more inclusive learning experiences, allowing students to engage with course content effectively, regardless of their linguistic background. Graham, Borup and Smith (2012) examined the role of TPACK in online higher education to promote social inclusivity. Their research emphasised the importance of instructors' TPACK competencies in designing inclusive online courses that accommodate diverse learner needs and foster collaboration among students from various backgrounds.

Social Inclusivity

The term social inclusion is used in various disciplines to describe the bonds that bring people together concerning cultural diversity. It improves how individuals and groups participate in society, improving the ability, opportunity, and dignity of those disadvantaged based on their identity (Kubota et al. 2022; Nurhayati 2020). From an evolutionary perspective, social inclusion can be seen as an adaptive goal that helps the individual adapt to the environment. The Covid-19 pandemic put the spotlight on deep-rooted systemic inequalities, and as such, it is essential to understand how marginalised groups such as women, persons with disabilities, sexual and gender minorities, and ethnic and racial minorities can be socially included (Jeanne et al. 2023; Häfliger, Diviani and Rubinelli 2023). As higher education institutions seek to take on more responsibility for addressing social justice, ensuring that diversity and equality become the norm very soon, a critical pathway is to adopt an integrated approach to diversity, equity, and inclusion in the workplace and a renewed commitment to tangible change. Allowing equal access and opportunities in educational institutions under fair and equitable conditions is simply the right thing to do, and it has been noted that inclusive companies declare fairness and opportunity for all as part of their corporate values and codes of conduct. As such, ensuring racial justice, gender parity, disability inclusion, LGBTI equality, and inclusion of all forms of human diversity needs to be the "new normal" set to emerge from the Covid-19 crisis (Ferraro, Hemsley and Sands 2023; Calver et al. 2023). Kayembe and Nel (2019) assert that because recent technical developments can be used to bridge the gap between the rich and the poor and between various races, technology can help alleviate social exclusion issues.

Additionally, the 4IR enables educational institutions to promote collaborations with other stakeholders, including public and private businesses, through enhanced connectivity and digital platforms. This facilitates the sharing of resources, expertise, and innovative ideas, fostering mutually beneficial partnerships that drive research, development, and the implementation of cutting-edge technologies. These collaborations leverage the diverse strengths of each stakeholder, leading to interdisciplinary approaches and real-world applications that address complex societal challenges and prepare students for the dynamic demands of the digital age. The President of the Republic of South Africa has set up a commission on the 4IR, comprising various people, including academics from various educational institutions, an initiative previously championed by private stakeholders such as IBM and Microsoft.

The 4IR Commission was established in April 2018, and its key purpose was to advise the government on policies and strategies to harness the opportunities presented by 4IR (Carrim 2022). According to Sutherland (2020), upon becoming President of South Africa, Cyril Ramaphosa 4IR into his national economic strategy and the commission was tasked to explore ways to leverage emerging technologies such as artificial intelligence, robotics, and the Internet of Things to drive economic growth, promote innovation, and address social challenges in South Africa. The commission aimed to ensure that South Africa could effectively navigate and benefit from the transformative changes brought about by the 4IR while mitigating potential risks and ensuring inclusivity and sustainability.

Integration

In this study, integration relates to both social and technological integration. Social integration and technology integration are two interconnected concepts that profoundly impact each other in today's digital age. Technology plays a vital role in enhancing social integration by connecting people across different geographical locations. Social media platforms, video conferencing tools, messaging apps, and other digital communication tools facilitate interactions among individuals, communities, and societies. Through these technologies, people can exchange ideas, share experiences, collaborate on projects, and form new relationships, breaking down barriers of distance, time, and physical limitations. Technology can facilitate social integration by connecting people, promoting inclusivity, enhancing relationships, and enabling cultural exchange.

Social integration is the process during which newcomers or minorities are incorporated into the social structure of the host society. Social, economic, and identity integration are three main dimensions of newcomers' experiences in the society receiving them. As the promotion of social inclusion has increasingly been formulated not only as an aim of social policy but also as a targeted outcome of specific programs and interventions aimed at improving health and well-being, the urge to develop measures of social inclusion on an individual level has emerged (Cordier et al. 2017). These students' social integration is essential for acquiring the abilities that improve their lives and make them happy. A person's self-concept and social integration are reflected in how others perceive their attitude, feelings, skills, appearance, abilities, and knowledge (Ashman and Conway 2017). It is a psychological approach to understanding how a person observes himself as an individual. With the rapid evolution of education, there has been concern over technological integration over and above social integration (Van Wart et al. 2019). Technology integration, according to Inan and Lowther (2010), is the use of technology for learning tool development, instructional preparation, and delivery. Khusheim (2022) states that the social integration of special needs students is seen as a vital phenomenon for developing skills that improve the quality of their lives and give them satisfaction. Technology in education has been redefined due to numerous aspects concerning its use. The rate at which educators incorporate digital technologies into their programming has risen due to the Covid-19 epidemic and its impact on instructional programming (Nantais et al. 2021). The Covid-19 pandemic pushed educators, irrespective of their techno-pedagogical preparedness, into an instructional environment where technology became a necessary medium in the form of remote learning and a hybrid of remote and face-to-face instruction (Gomez et al. 2022).

Conceptual Model

This study seeks to determine whether the 4IR practices adopted by universities influence integration and social inclusivity using structural equation modelling (SEM) techniques. The conceptual model in this study is influenced by the TPACK theory, a framework that highlights the importance of integrating technology, pedagogy, and content knowledge in educational settings. It emphasises the need to have a deep understanding of how technology can be used effectively to enhance teaching and learning (Jammeh, Karegeya and Ladage 2023). The TPACK theory provides a framework to navigate the integration of digitised systems, robotic tutors, and AI-based curricula into their teaching practices. It emphasises the importance of balancing technological, pedagogical, and content knowledge to create meaningful and effective learning experiences for students. The conceptual model developed in the study exhibits the relationships analysed in this study.

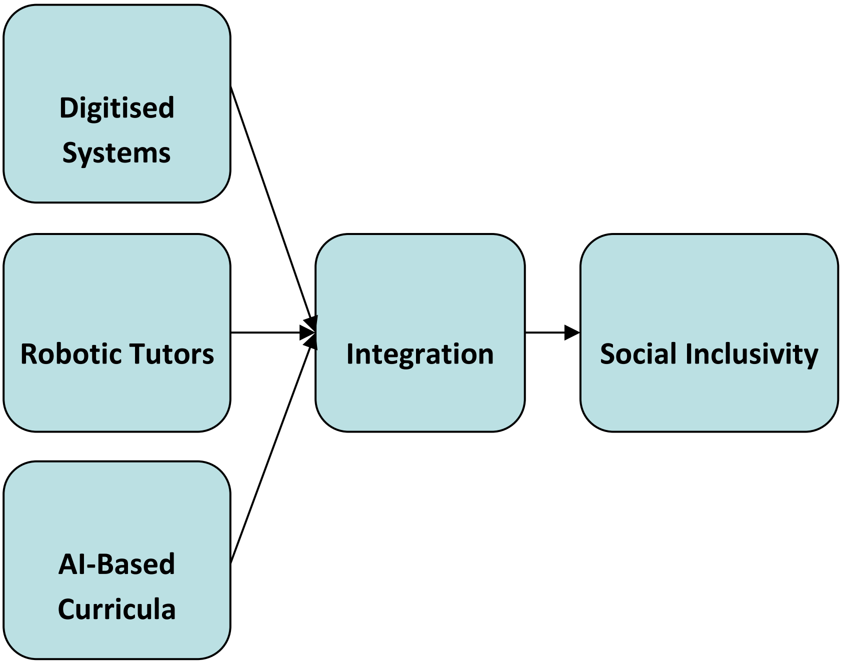

Figure 1. Conceptual Model

The model is used to test the following hypothesis:

H1: Digitised systems in education and pedagogy have a positive and significant influence on social and technological integration among students at the University of Technology

H2: Robotic tutors positively and significantly influence social and technological integration among University of Technology students.

H3: AI-Based Curricula in education and pedagogy positively and significantly influence social and technological integration among University of Technology students.

H4: Social and technological integration positively and significantly influences social inclusivity among University of Technology students.

Research Methods

The data used in this study were obtained through a questionnaire survey, and the questionnaire was developed from previously validated research instruments. The questionnaire is a modified version to assess how 4IR practices could influence integration and, in turn, social inclusivity among higher education students. The questionnaire used in this study was divided into six sections, with Section A focusing on the demographic characteristics of the respondents. Section B solicited information on Digitised Systems, Section C on Robotic Tutors, and Section D AI-Based Curriculum. Sections E and F focused on Integration and Social Inclusivity, respectively. A five-point Likert Scale questions ranging from “Strongly Agree” to “Strongly Disagree”. Also, participants were asked to choose from options of “always”, “sometimes”, and “never” practised in the practices section. A pilot survey, which included 50 participants, was conducted during the study's early stages to assess the questionnaire's validity, and the necessary revisions were made. The participants in the pilot survey were not included in the main study. The participants involved in the survey were undergraduate students from the University of Technology.

Regarding data collection, a questionnaire administered using Google Forms was chosen, leveraging the ease of accessibility and convenience offered by online survey platforms. This method allows participants to respond at their own pace, enhancing the likelihood of thoughtful and considered responses. The data collection period spanned 15 days, from the 25th of May to the 8th of June 2023, providing a sufficiently comprehensive timeframe for a diverse range of students to participate. To reach the targeted student population effectively, a strategic approach was adopted. Social media class groups, particularly on widely used platforms like WhatsApp and Telegram within the university community, served as primary channels for disseminating the survey link. Leveraging these platforms acknowledged their popularity among students and increased the visibility of the survey. Alongside the survey link, a clear and concise message was shared, outlining the objectives and emphasising the significance of the research. This introductory message aimed to inform participants about the study's purpose, fostering an understanding of its relevance within the university context.

Moreover, to uphold ethical standards, the survey introduction included a checkbox for participants to provide explicit consent before engaging in the study. This step ensured that respondents were fully aware of the research's nature and voluntarily agreed to contribute their insights. This approach aligns with ethical guidelines and emphasises the researchers' commitment to respecting the rights and autonomy of the participants. By employing these specific data collection strategies, the research team aimed to maximise participation, ensure informed consent, and generate a dataset that reflects the diverse perspectives of the student body at Vaal University of Technology. The combination of online self-administration targeted social media outreach, and transparent communication contributes to the robustness and validity of the quantitative data collected for the study.

Structural equation modelling (SEM) was utilised to map the hypothesised model, allowing the testing of the complex predictive relationships among the variables. SEM is a commonly used multivariate technique in investigating the direct and indirect effects of relationships between observed and latent variables (Wright 1934; Graf and Knepple Carney 2021). The theory of SEM simplifies complex relationships between variables by utilising a path model or analysis to explain effects resulting from observed and latent variables (Kang and Ahn 2021). In SEM, an observed variable is a variable that has been directly measured and contributes to the composition of a latent variable. On the other hand, latent variables are unobserved variables that cannot be measured directly. This data analysis technique summarises linear structural relationships into measurement and structural regression models in SmartPLS 4.

Confirmatory factor analysis (CFA) is a standard method that is used to evaluate the measurement model, and the process specifies the number and types of observed variables associated with one or more hypothetical constructs and evaluates how well the observed variables measure the constructs (Lam and Maguire 2012). A structural regression (S.R.) model is a path model with latent variables which combines the principles of path and measurement models. The ultimate objective is to account for measurement errors of observed variables when evaluating a path model, which is the core model widely applied in SEM. In implementing PLS-SEM in this study, two steps were performed; the first step focused on assessing the measurement model (Hair et al. 2019). This was done to confirm the reliability and validity of the model, mainly based on C.R. (composite reliability) and Cronbach alpha values, factor loadings, and AVE. The second step sought to assess the structural regression model, which involved testing the initial hypotheses and drawing conclusions, and the two steps were done in SmartPLS4.

Results

Demographic Characteristics of the Students

This study solicited data on the profiles of the respondents who participated in this study. According to Eime, Harvey, Charity and Nelson (2018), it is essential in research to understand the demographic differences among research participants so as to align the resultant policies and strategies' recommendations to specific market segments as presented in the research. The demographic characteristics of the students involved in the study, the frequencies, and the percentage distribution are displayed in **Table 1** below.

Table 1: Demographic Characteristics of the Students (n=203)

Characteristics	Item	Frequency (%)
Gender	Male	88 (43.35)
	Female	115 (56.65)
Age	Below 18 years	21 (10.34)
	18 – 25 years	108 (53.20)
	26 – 30 years	68 (33.50)
	Above 30 years	6 (2.96)
Faculty	Applied and Computer Sciences	38 (18.72)
	Human Sciences	36 (17.73)
	Engineering and Technology	38 (18.72)
	Management Sciences	48 (23.65)
	Arts and Built Environment	19 (9.36)
	Agriculture and Natural Resources	24 (11.82)
Current residency type	On-campus accommodation	147 (67.16)
	Off-campus accommodation	56 (32.84)

The results presented in Table 1 show that most of the participants (115, 56.65%) are male, while 88 (43.35%) are female. These results corroborate the general sentiment that the enrollment of women in South African universities has surpassed that of men. According to Mabokela (2023), an analysis of enrollment data by gender validates that South African universities have made significant strides to improve the admission of women into higher education institutions. Regarding age, most respondents were between 18 and 25 years (108, 53.20%), which is highly expected of undergraduate students, while a minority was found within the over 30 years category (6, 2.96%). The faculty of Management Sciences provided the most respondents (48, 23.65), followed by a tie between the faculty of Applied and Computer Sciences and Engineering and Technology at 38 (18.72%) respondents each. Arts and Built Environment provided the least number of respondents in this study. However, what is important to note is that all the faculties were represented in the current study, making it a university-wide study. Most respondents stay on campus (147, 67.16), and only 56 (32.84%) stay off campus.

Descriptive Statistics

To improve the clarity of the results obtained, the descriptive statistics were analysed, and the results were recorded on the means, standard deviations, skewness, and kurtosis relating to the measurement constructs. According to Lee (2020), descriptive statistics summarise the information relating to the study datasets' characteristics and distribution of values. The results obtained from the analysis are presented in **Table 2** below.

Table 2: Descriptive Statistics.

	Min	Max	M	SD	Skewness	Kurtosis
Digitised systems	1.00	4.00	4.02	0.58	0.75	0.65
Robotic tutors	2.00	5.00	3.74	0.53	0.38	0.61
AI-Based Curricula	1.00	4.00	3.22	0.36	0.30	1.80
Integration	1.00	5.00	4.43	0.82	0.54	−0.25
Social Inclusivity	2.00	4.00	4.01	0.65	-1.52	-1.25

The results for the five constructs indicate that the means for the variables were all above 3, indicating some strength in the level of agreement with the statements provided in the questionnaire. In addition, the standard deviations for the constructs were around 0.5 points around the means, indicating that the responses provided were not very far from the mean. The skewness and kurtosis statistics were also recorded. Skewness measures the level of symmetry, or lack thereof, in a data set, while kurtosis measures how tailed the data is relative to a normal distribution. The values for the skewness and kurtosis tests ranged from −12.52 to 0.75 and from −1.25 to 1.8, respectively, suggesting that the mentioned variables had a sufficiently normal distribution. According to George and Mallery (2010), values for skewness and kurtosis that lie between -2 and +2 are considered acceptable in proving normal univariate distribution.

Internal Consistency and Reliability

In this study, the internal consistency of the measurement instrument was assessed using Cronbach's alpha, and it was expected that the Cronbach's alpha (α) values should be at least 0.7 (Clark and Watson 1995). The composite reliability measure was employed to assess the reliability of the measurement instrument. According to Hair et al. (2014), a composite reliability measure of 0.70 or greater should be achieved to confirm reliability. Further, the convergent validity and discriminant validities were examined to test the validity of the constructs. The average variance extracted (AVE) was also used to assess the convergent validity, with a minimum threshold of 0.50 (Hair et al. 2011). Detailed results of outer loadings, reliability, and convergent validity are provided in **Table 3.**

Table 3: Psychometric Characteristics of Constructs.

Constructs	Indicator	Outer Loadings	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Digitised systems	**DS1**	0.876	0.886	0.934	0.781
	DS2	0.869			
	DS3	0.845			
	DS4	0.941			
Robotic tutors	**RT1**	0.856	0.817	0.918	0.616
	RT2	0.752			
	RT3	0.851			
	RT4	0.832			
	RT5	0.721			
	RT6	0.754			
	RT7	0.711			
AI-Based Curricula	**ABC1**	0.741	0.740	0.868	0.569
	ABC2	0.745			
	ABC3	0.708			
	ABC4	0.784			
	ABC5	0.790			
Integration	**INT1**	0.853	0.758	0.859	0.695
	INT2	0.849			
	INT3	0.821			
	INT4	0.870			
Social Inclusivity	**SI1**	0.691	0.854	0.911	0.720
	SI2	0.687			
	SI3	0.681			
	SI4	0.794			
	SI5	0.692			

The results presented in Table 3 show that all the constructs attained a composite reliability value of more than 0.70, indicating that the constructs are reliable. The lowest composite reliability was 0.859, obtained on integration, while the highest was 0.934, obtained on the Digitised Systems construct. In addition to the above, all the factor loadings are above 0.50; hence, they are acceptable, and all the constructs met the minimum threshold on AVE, with the lowest AVE of 0.569 being recorded on AI-Based Curricula. These satisfactory results gave no reason to delete any items from the scale, and we considered the internal consistency of the measurement instrument to be good.

Convergent Validity

According to Krabbe (2017), convergent validity measures how closely related a scale is to other variables and measures of the same construct, and these should also not correlate with dissimilar, unrelated variables. Researchers such as Anderson and Gerbing (1988) and Hair et al. (2009) have suggested that convergent validity should be evaluated by looking at the standardised factor loadings and the acceptable value of the factor loading for interpretation purposes being at least 0.5. in addition to the factor loading, many studies have employed the Fornell and Larcker (1981) criterion for assessing convergent validity (Yu et al. 2021; Zahoor et al. 2022). According to Fornell and Larcker (1981), convergent In this case, the AVE value should not be lower than 0.5 to be acceptable, indicating that the latent construct explains no less than 50% of the indicator variance (Fornell and Larcker 1981; Malhotra 2011). The results in Table 3 indicate evidence for convergent validity because the C.R. values for all the constructs are greater than 0.7, all the standardised factor loadings are above 0.5, and the AVE values are 0.5 or greater.

Discriminant Validity

According to Taiminen et al. (2000), discriminant validity measures the extent to which a test measures aspects of a phenomenon that differ from other aspects assessed by other tests. To examine discriminant validity, this study employed again the Fornell and Larcker criterion, an approach that compares the square root of the AVEs with the correlations of a construct with other constructs. According to this approach, discriminant validity is confirmed whenever the square root of the AVEs is greater than the correlations between constructs (Fornell and Bookstein 1982; Sarstedt et al. 2014). The results of the Fornell–Larcker test for assessing discriminant validity are presented in **Table 4** below.

Table 4: Results of the Fornell–Larcker Test for Assessing Discriminant Validity.

	AVE	DS	RT	ABC	INT	SI
DS	0.781	**0.884**				
RT	0.616	0.329	**0.785**			

	AVE	DS	RT	ABC	INT	SI
ABC	0.569	0.218	0.247	**0.754**		
INT	0.695	0.272	0.269	0.126	**0.834**	
SI	0.720	0.130	0.159	0.387	0.218	**0.849**

Note: AVE = Average Variance Extracted; $n = 203$; D.S. = Digitised systems, R.T. = Robotic tutors, ABC = AI-Based Curricula, INT= Integration and S.I. = Social Inclusivity.

The results presented in Table 4 show that the discriminant validity was confirmed for all the constructs. This is because all the values of the square root of AVE are greater than all the inter-construct correlations. The lowest value was 0.754, obtained as the square root of the AVE for ABC against the highest inter-construct correlation coefficient of 0.387 between S.I. and ABC.

Measurement Model Goodness-of-Fit

The goodness of fit of the measurement model is evaluated using a range of indices to assess the relationship between the observed data and the empirical data from the model. Model fit indices are typically used as thresholds or hypothesis testing to reject or retain the proposed model (Maydeu-Olivares, Fairchild, and Hall 2017). In this study, the measurement model goodness of fit was tested by comparing their chi-square indices ($\chi2$) and degrees of freedom (df) to see if they attain the acceptable model fit. In addition, model fit indices such as the Tucker-Lewis index (TLI), Comparative fit index (CFI), Goodness of Fit index (GFI), Adjusted Goodness of Fit index (AGFI), and root-mean-square error of approximation (RMSEA) were conducted to check the goodness of fit for the model in this study. The results are presented in **Table 5** below.

Table 5: Fitness Indices of the Initial and Final Model

Fit indices	RMSEA	CFI	TLI	GFI	AGFI
Final model	0.066	0.914	0.928	0.908	0.821
Accepted value	$< 0.06^a$	$\geq 0.900^b$	$\geq 0.900^b$	$> 0.900^c$	$> 0.800^d$
Remarks	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

a Hu and Bentler (1999), b Hair et al. (2009), c Thakkar (2020), d Gefen et al. (2000)

The resultant indices from a maximum likelihood estimation confirmed that the measurement model had an acceptable model. Fit indices for the model, including GFI = 0.908, AGFI = 0.821, and CFI = 0.908, indicate acceptable model fit. In addition, the other index (RMSEA = 0.066) also revealed an appropriate model fit. Therefore, considering the given indices and significance, the current structural model was confirmed.

Structural Path Analysis

After conducting the CFA, evaluating the structural model and testing the hypothesised relationships became necessary. The variance inflation factor (VIF) was estimated to test for multicollinearity among the constructs. The common practice is that VIF values should be below a threshold of 5 to indicate that multicollinearity does not exist. Multicollinearity exists when different variables reflect a related variation or when an explanatory variable is strongly related to a linear combination of the other independent variables, prompting skewed or deluding results in a statistical model (Shrestha, 2020; Lindner, Puck and Verbeke 2022). The VIF values are presented in **Table 6**, where all values are not more than 5, indicating the absence of multicollinearity between any of the variables in the model.

Table 6: Variance Inflation Factor (VIF).

Construct	VIF
Digitised Systems	1.223
Robotic Tutors	1.456
AI-Based Curricula	1.470
Integration	1.295
Social Inclusivity	1.181

In SmartPLS, the bootstrapping procedure was used to evaluate the relationships among the research variables, and the results are presented in Table 6. The value of β refers to the effect of an exogenous variable on the endogenous variable. The t-statistic measures the difference between the two sets expressed in units of standard error. The P-value measures the probability of observation at extreme t-values; therefore, a low p-value implies “significance”.

Table 7: Summary of Hypothesis Testing

Path	Path Coefficients (β)	t-Value	*p*-Values	Result
DS → INT	0.412	2.365	0.000	Significant
RT → INT	0.312	3.326	0.001	Significant
ABC → INT	0.369	3.365	0.001	Significant
INT → SI	0.212	4.114	0.000	Significant

First, for H1, it was established that there is a significantly positive relationship between digitised systems and social and technological integration ($\beta = 0.413$; $p = 0.000$). This implies that as institutions continue introducing digitised systems, learners' integration levels also improve. Learners who operate in digitised systems find it easy to navigate through their learning, and resources are obtainable easily and cheaply. This reduces anxiety and uncertainty about their current and future learning conditions, thereby increasing integration. Secondly, for H2, the results indicate that robotic tutors significantly and positively influence integration ($\beta = 0.312$; $p = 0.001$). The result indicates that robotic tutors can enhance integration among university learners. As such, the proposed hypothesis was supported and hence maintained. Thirdly, regarding the relationship between AI-Based Curricula and Integration, a positive and significant relationship exists between the variable proposed in H3 (0.369; $p = 0.001$). Lastly, a positive and significant relationship was obtained concerning H4, the influence of integration on social inclusivity (0.212; $p = 0.001$). All the proposed hypotheses were accepted as they were significant and positive. These findings are partly consonant with those of Nwosu, Bereng, Segotso and Enebe (2023) and Uleanya (2023), who opened scholarly discourse on 4IR in higher education in Southern Africa.

Conclusion and Discussion

From the study, it can be derived that the advent of the fourth industrial revolution and its subsequent incorporation into the education system has brought about improved pedagogical practices and inclusivity and integration. The rate and pace of information dissemination have experienced a substantial increase, leading to greater accessibility and affordability of education. An evaluation of the results obtained in this study reveals a positive contribution of 4IR towards the general concept of inclusion as defined by the extent of accommodating different disabilities and backgrounds in social activities. The analysis also demonstrated the importance of 4IR in integrating learners in mainstream classrooms and significant strides in eliminating special needs classes. The 4IR movement has allowed South African education institutions to create an environment of social inclusivity and integration. The technological solutions employed in higher education have potentially established best practices at scale and empowered new practices that were previously implausible. Although the Covid-19 pandemic may be said to have posed a significant distortion on the daily life activities of individuals worldwide, it has significantly transformed the education sector. Higher education learning requires extensive engagement of the students, especially in self-directed learning, requiring a higher degree of self-motivation. The findings of this study reaffirm the potential of robotic tutors to foster inclusivity and facilitate integration within the student learning process. Robotic tutors offer unique advantages, including personalised instruction, immediate feedback, and the ability to adapt to diverse learning styles, which can contribute significantly to creating inclusive educational environments.

Moreover, their integration into educational settings has the capacity to enhance accessibility for students with diverse needs and backgrounds, ultimately promoting equity and improving overall learning outcomes. This result is consistent with the findings in existing studies by Smakman and Konijn (2020), Leyzberg, Spaulding and

Scassellati (2014) and Kanero, Oranç, Koşkulu, Kumkale, Göksun and Küntay (2022) who concluded that as robotic technology continues to advance, the efficacy of robot tutors and their benefits to learners concerning learning outcomes exceed that of human tutors. These studies prove that learners demonstrated inclusive and integrated learning experiences when robots provided tutorials.

4IR technologies should be integrated into new curricula to ensure sustainable enhancement of collaborative skills relevant to the Fourth Industrial Revolution (4IR) among students. South African educational institutions ought to restructure their programs in alignment with the 4IR paradigm, as advocated by Penprase (2018), in order to offer interdisciplinary programs that meet the evolving needs of the digital age. The study results indicate that an AI-based curriculum framework can enhance learning quality. According to Su and Zhong (2022), developed economies like China, the United Kingdom, and the European Union have significantly incorporated A.I. into curricula to standardise learning at all levels. Progressively, institutions must embrace strategies that combine greater use of new technological tools to improve the student experience, leveraging diversity, equity, and inclusion as core institutional strengths. There is also a need for corresponding policy interventions to support students during the growth of 4IR adoption into pedagogical practices. Undoubtedly, the fourth industrial revolution has brought about more inclusive, integrated, and even personalised learning among higher education students. However, as argued by Jeong et al. (2020), Gehle et al. (2017), and others, progress in implementing these initiatives has been slowed down by a lack of resources. Over the last few decades, significant developments in AI and robotics to supplement the existing pedagogical structures have been initiated, but the majority have not fully materialised. The South African higher education 4IR initiatives could also suffer the same plight. Existing literature has shown that early childhood development is critical to the South African education system (Draper et al., 2023; Richter et al., 2019). However, most of the studies relating to 4IR technology and social inclusivity and integration have focused on secondary and higher education (Mkansi and Landman 2021; Coetzee et al. 2021). As such, there is a need to unlock the potential of AI in higher education by focusing future directions for researchers and educators on areas of e-learning tools or platforms as teaching material.

Practical Recommendations

Regarding social inclusivity and integration in the Fourth Industrial Revolution (4IR) era, educators and institutions should prioritise providing digital literacy training and ensuring equitable access to technology and the internet. This can help bridge the digital divide and ensure that all students have the necessary skills and resources to participate in the 4IR. Educators should adopt inclusive teaching practices that cater to diverse learning needs and styles. This can involve using differentiated instruction, universal design for learning (UDL), and culturally responsive teaching methods to create an inclusive learning environment. Institutions, policymakers, and educators should collaborate with community organisations, businesses, and other stakeholders to promote social inclusivity and integration. This can involve partnerships that provide mentorship, internships, and job opportunities for underrepresented groups. Academics should conduct research to understand the impact of 4IR technologies on social inclusivity and integration. This can involve studying the effects of emerging technologies on marginalised communities, exploring best practices for inclusive technology design, and evaluating the effectiveness of interventions aimed at promoting social inclusivity. Institutions, policymakers, and academics should also address the ethical implications of 4IR technologies to ensure that they do not perpetuate inequalities or exclude marginalised groups. This can involve discussions on data privacy, algorithmic bias, and the responsible use of emerging technologies. These recommendations aim to foster a more inclusive and integrated society in the 4IR era, where all individuals have equal opportunities to participate, contribute, and benefit from technological advancements.

References

Aderibigbe, J. K. 2021. "The Dynamism of Psychological Contract and Workforce Diversity: Implications and Challenges for Industry 4.0 HRM." *Redefining the Psychological Contract in the Digital Era: Issues for Research and Practice*, 247–259. https://doi.org/10.1007/978-3-030-63864-1_13

Ainscow, M. 2020. "Promoting Inclusion and Equity in Education: Lessons from International Experiences." *Nordic Journal of Studies in Educational Policy* 6 (1): 7–16. https://doi.org/10.1080/20020317.2020.1729587

Buheji, M. K. da Costa Cunha, G. Beka, B. Mavric, Y. L. De Souza, S. S. da Costa Silva, M. Hanafi, and T. C. Yein. 2020. "The Extent of Covid-19 Pandemic Socio-Economic Impact on Global Poverty. A Global Integrative Multidisciplinary Review." *American Journal of Economics 10* (4): 213–224. https://doi.org/10.5923/j.economics.20201004.02

Calver, J., K. Dashper, R. Finkel, T. Fletcher, I. R. Lamond, E. May, N. Ormerod, L. Platt, and B. Sharp. 2023. "The (In) Visibility of Equality, Diversity, and Inclusion Research in Events Management Journals." *Journal of Policy Research in Tourism, Leisure and Events*, 1–25. https://doi.org/10.1080/19407963.2023.2228820

Carrim, N. 2022. "4IR in South Africa and Some of its Educational Implications." *Journal of Education (University of KwaZulu-Natal)* 86: 3–20. https://doi.org/10.17159/2520-9868/i86a01

Chalmers, D., N. G. MacKenzie, and S. Carter. 2021. "Artificial Intelligence and Entrepreneurship: Implications for Venture Creation in the Fourth Industrial Revolution." *Entrepreneurship Theory and Practice* 45 (5): 1028–1053. https://doi.org/10.1177/1042258720934581

Chakabwata, W. 2022. “An Intersectional Study of the Funding Experiences of South African University Students After Majority Rule.” *Advances in Educational Marketing, Administration, and Leadership*, May, 242–258. https://doi.org/10.4018/978-1-7998-9567-1.ch012.

Cho, E. 2016. “Making Reliability Reliable: A Systematic Approach to Reliability Coefficients.” *Organizational Research Methods* 19 (4): 651–682. https://doi.org/10.1177/1094428116656239

Coetzee, J., B. Neneh, K. Stemmet, J. Lamprecht, C. Motsitsi, and W. Sereeco. 2021. “South African Universities in a Time of Increasing Disruption.” *South African Journal of Economic and Management Sciences* 24 (1): 1–12. https://doi.org/10.4102/sajems.v24i1.3739

Cohen, J., P. Cohen, S. G. West, and L. S. Aiken. 2013. *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences.* Routledge. https://doi.org/10.4324/9780203774441

Draper, C. E., C. J. Cook, R. Allie, S. J. Howard, H. Makaula, R. Merkley, M. Mshudulu, N. Rahbeeni, N. Tshetu, and G. Scerif. 2023. “The Role of Partnerships to Shift Power Asymmetries in Research with Vulnerable Communities: Reflections from an Early Childhood Development Project in South Africa.” *Journal of Cognition and Development*, 1–19. https://doi.org/10.1080/15248372.2023.2215863

Ferraro, C., A. Hemsley, and S. Sands. 2023. “Embracing Diversity, Equity, and Inclusion (DEI): Considerations and Opportunities for Brand Managers.” *Business Horizons* 66 (4): 463–479. https://doi.org/10.1016/j.bushor.2022.09.005

Gefen, D., D. Straub, and M. C. Boudreau. 2000. “Structural Equation Modeling and Regression: Guidelines for Research Practice.” *Communications of the Association for Information Systems* 4 (1): 7. https://doi.org/10.17705/1CAIS.00407

Gomez, F. C., J. Trespalacios, Y. C. Hsu, and D. Yang. 2022. “Exploring Teachers’ Technology Integration Self-Efficacy Through the 2017 ISTE Standards.” *TechTrends*, 1–13. https://doi.org/10.1007/s11528-021-00639-z

Graf, A. S. and A. Knepple Carney. 2021. “Ageism as a Modifying Influence on COVID-19 Health Beliefs and Intention to Social Distance.” *Journal of Aging and Health* 33 (7–8): 518–530. https://doi.org/10.1177/0898264321997004

Häfliger, C., N. Diviani, and S. Rubinelli. 2023. “Communication Inequalities and Health Disparities among Vulnerable Groups During the COVID-19 Pandemic- A Scoping Review of Qualitative and Quantitative Evidence.” *BMC Public Health* 23 (1): 1–18. https://doi.org/10.1186/s12889-023-15295-6

Hair, J. F., W. C. Black, B. J. Babin, and R. E. Anderson. 2009. *Multivariate Data Analysi*s 7th Edition. Pearson Prentice Hall.

Hair, J. F., J. J. Risher, M. Sarstedt, and C. M. Ringle. 2019. "When to Use and How to Report the Results of PLS-SEM." *European Business Review* 31 (1): 2–24. https://doi.org/10.1108/EBR-11-2018-0203

Haleem, A., M. Javaid, M. A. Qadri, and R. Suman. 2022. "Understanding the Role of Digital Technologies in Education: A Review." *Sustainable Operations and Computers* 3: 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

Hu, L. T. and P. M. Bentler. 1999. "Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria Versus New Alternatives." *Structural Equation Modeling: A Multidisciplinary Journal* 6 (1): 1–55. https://doi.org/10.1080/10705519909540118

Ilori, M. O., and I. Ajagunna. 2020. "Re-Imagining the Future of Education in the Era of the Fourth Industrial revolution." *Worldwide Hospitality and Tourism Themes* 12 (1): 3–12. https://doi.org/10.1108/WHATT-10-2019-0066

Jammeh, A. L., C. Karegeya, and S. Ladage. 2023. "Application of Technological Pedagogical Content Knowledge in Smart Classrooms: Views and its Effect on Students' Performance in Chemistry." *Education and Information Technologies*, 1–31. https://doi.org/10.1007/s10639-023-12158-w

Jeanne, L., S. Bourdin, F. Nadou, and G. Noiret. 2023. "Economic Globalization and the COVID-19 Pandemic: Global Spread and Inequalities." *GeoJournal* 88 (1): 1181–1188. https://doi.org/10.1007/s10708-022-10607-6

Kanero, J., C. Oranç, S. Koşkulu, G. T. Kumkale, T. Göksun, and A. C. Küntay. 2022. "Are Tutor Robots for Everyone? The Influence of Attitudes, Anxiety, and Personality on Robot-Led Language Learning. *International Journal of Social Robotics* 14 (2): 297–312. https://doi.org/10.1007/s12369-021-00789-3

Kang, H. and J. W. Ahn. 2021. "Model Setting and Interpretation of Results in Research Using Structural Equation Modeling: A Checklist with Guiding Questions for Reporting." *Asian Nursing Research* 15 (3): 157–162. https://doi.org/10.1016/j.anr.2021.06.001

Kayembe, C. and D. Nel. 2019. "Challenges and Opportunities for Education in the Fourth Industrial Revolution." *African Journal of Public Affairs* 11 (3): 79–94.

Kubota, H., H. Raymond, V. Caine, and D. J. Clandinin. 2022. "Understanding Social Inclusion: A Narrative Inquiry into the Experiences of Refugee Families with Young Children." *International Journal of Early Years Education* 30 (2): 184–198.

Lam, T. Y. and D. A. Maguire. 2012. "Structural Equation Modeling: Theory and Applications in Forest Management." *International Journal of Forestry Research*, 2012. https://doi.org/10.1155/2012/263953

Lee, S. Y. and X. Y. Song. 2004. "Evaluation of the Bayesian and Maximum Likelihood Approaches in Analyzing Structural Equation Models with Small Sample Sizes." *Multivariate Behavioral Research* 39 (4): 653–686. https://doi.org/10.1207/s15327906mbr3904_4

Leyzberg, D., S. Spaulding, and B. Scassellati. 2014. "Personalizing Robot Tutors to Individuals' Learning Differences." *Proceedings of the 2014 ACM/IEEE International Conference on Human-Robot Interaction,* March. https://doi.org/10.1145/2559636.2559671

Lindner, T., J. Puck, and A. Verbeke. 2022. "Beyond Addressing Multicollinearity: Robust Quantitative Analysis and Machine Learning in International Business Research." *Journal of International Business Studies* 53 (7): 1307–1314. https://doi.org/10.1057/s41267-022-00549-z

Luo, Y. and S. A. Zahra. 2023. "Industry 4.0 in International Business Research. *Journal of International Business Studies* 54 (3): 403–417. https://doi.org/10.1057/s41267-022-00577-9

Marwala, T. 2021. *Leading in the 21st Century: The Call for a New Type of African Leader*. Jonathan Ball Publishers.

Matli, W. and M. Ngoepe. 2022. "Extending Information Poverty Theory to Better Understand the Digital Access and Inequalities among Young People Who are not in Education, Employment or Training in South Africa." *Higher Education, Skills and Work-Based Learning 12* (3): 419–436. https://doi.org/10.1108/HESWBL-05-2020-0107

Mhlanga, D. and H. Dunga. 2023. "Demand for Internet Services Before and During the Covid-19 Pandemic: What Lessons are We Learning in South Africa?" *International Journal of Research in Business and Social Science (2147–4478)* 12 (7): 626–640. https://doi.org/10.20525/ijrbs.v12i7.2781

Mindell, D. A. and E. Reynolds. 2022. *The Work of the Future: Building Better Jobs in an Age of Intelligent Machines.* MIT Press.

Mkansi, M. and N. Landman. 2021. "The Future of Work in Africa in the Era of 4IR–The South African Perspective." *Africa Journal of Management* 7 (sup1): 17–30. https://doi.org/10.1080/23322373.2021.1930750

Nurhayati, S. 2020. "Social Inclusion for Persons with Disabilities Through Access to Employment in Indonesia." *Prophetic Law Review* 2 (1): 1–21. https://doi.org/10.20885/PLR.vol2.iss1.art1

Nwosu, L. I., M. C. Bereng, T. Segotso, and N. B. Enebe. 2023. "Fourth Industrial Revolution Tools to Enhance the Growth and Development of Teaching and Learning in Higher Education Institutions: A Systematic Literature Review in South Africa." *Research in Social Sciences and Technology* 8 (1): 51–62. https://doi.org/10.46303/10.46303/ressat.2023.4

Petersen, A., C. Tanner, and M. Munsie. 2019. "Citizens' Use of Digital Media to Connect with Health Care: Socio-Ethical and Regulatory Implications." *Health* 23 (4): 367–384. https://doi.org/10.1177/1363459319847505

Richter, L. M., M. Tomlinson, K. Watt, X. Hunt, and E. H. Lindland. 2019. "Early Means Early: Understanding Popular Understandings of Early Childhood Development in South Africa. *Early Years* 39 (3): 295–309. https://doi.org/10.1080/09575146.2019.1613346

Shrestha, N. 2020. "Detecting Multicollinearity in Regression Analysis." *American Journal of Applied Mathematics and Statistics 8* (2): 39–42. https://doi.org/10.12691/ajams-8-2-1

Signé, L. 2023. *Africa's Fourth Industrial Revolution*. Cambridge University Press. https://doi.org/10.1017/9781009200004

Smakman, M. and E. A. Konijn. 2020. "Robot Tutors: Welcome or Ethically Questionable? *Robotics in Education: Current Research and Innovations* 10: 376–386. https://doi.org/10.1007/978-3-030-26945-6_34

Srinivasan, N. and L. Eden. 2021. "Going Digital Multinationals: Navigating Economic and Social Imperatives in a Post-Pandemic World." *Journal of International Business Policy* 4 (2): 228–243. https://doi.org/10.1057/s42214-021-00108-7

Su, J. and Y. Zhong. 2022. "Artificial Intelligence (AI) in Early Childhood Education: Curriculum Design and Future Directions." *Computers and Education: Artificial Intelligence 3*: 100072. https://doi.org/10.1016/j.caeai.2022.100072

Thakkar, J. J. 2020. "Applications of Structural Equation Modelling with AMOS 21, IBM SPSS." *Structural Equation Modelling,* 35–89. https://doi.org/10.1007/978-981-15-3793-6_4

Tsiligiris, V., and D. Bowyer. 2021. "Exploring the Impact of 4IR on Skills and Personal Qualities for Future Accountants: A Proposed Conceptual Framework for University Accounting Education." *Accounting Education* 30 (6): 621–649. https://doi.org/10.1080/09639284.2021.1938616

Uleanya, C. 2023. "Scholarly Discourse of the Fourth Industrial Revolution (4IR) and Education in Botswana: A Scoping Review." *Education and Information Technologies* 28 (3): 3249–3265. https://doi.org/10.1007/s10639-022-11298-9

Van Wart, M., A. Ni, L. Rose, T. McWeeney, and R. Worrell. 2019. "A Literature Review and Model of Online Teaching Effectiveness Integrating Concerns for Learning Achievement, Student Satisfaction, Faculty Satisfaction, and Institutional Results." *Pan-Pacific Journal of Business Research* 10 (1): 1–22.

Vyas, L. 2022. "'New Normal' at Work in a Post-COVID World: Work–Life Balance and Labor Markets." *Policy and Society* 41 (1): 155–167. https://doi.org/10.1093/polsoc/puab011

Wright, S. 1934. "The Method of Path Coefficients." *The Annals of Mathematical Statistics* 5 (3): 161–215. https://doi.org/10.1214/aoms/1177732676