Research Paper

Fostering sectoral competitiveness and adaption: 4IR in architecture curricula of South African tertiary institutions

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Abstract

Conceptualisation and design functions in the built environment is set to be revolutionised by system innovations propagated by the 4th Industrial Revolution (4IR). Related technological advances constitute a gamechanger in building design and construction, altering the nature of skills requirements for roleplayers in the architecture industry. As system innovations may significantly disrupt the sectoral status quo of service providers and consumers, so too may the proliferation of advanced Building Information Modelling (BIM) and parametric design technology alter the modus operandi of architecture professionals. In the developing country context, the need exists to ensure the relevant roleplayers are empowered with the required skills to ensure timely and continuous sectoral adaptation to retain competitiveness. The objective of this research is to evaluate the content inherent to knowledge transfer in the architecture curricula of South Africa's tertiary education institutions, with the aim of determining the exposure of prospective professionals to technology-related system innovations. A qualitative research methodology is utilised where the curricula of selected institutions are evaluated based on their incorporation of themes relating to 4IR. Findings suggest a considerable incorporation of 4IR themes, specifically the multidisciplinary theme, with the practical and theoretical themes incorporated to a lesser extent. While sectoral adaptation may be fostered due to the current curricula design, it is recommended that computer-based applications and theoretical synergies on smart and sustainable human settlements be incorporated, in addition to generic competencies to support long-term adaptability to 4IR.

Keywords

4th Industrial Revolution, resilience, built environment, architecture, tertiary education

1. Introduction

Industry 4.0 and related applications will catalyse system and social innovations, the latter relating to the proliferation of new business models, consumption patterns, and wholly altered means of production (Avelino *et al*., 2014). Determinations of the future of work (WEF, 2018) ought to be utilised to inform adaptation and transformation in sectors vulnerable to disruption in the long term. One such sector is the built environment, which includes the conceptualisation, design, and fulfilment of property developments. Architectural activities in particular, with which technological applications are significantly integrated, will be further influenced by revolutions in BIM technology, AI-systems, cloud technology, and integrated sensors in the design process (Lucas, 2016).

Adaptation and transformation is required to mitigate potential skills gaps in the future that would place downward pressure on sector productivity and output. Said adaptability may be fostered through the proliferation of knowledge-based interventions in the nature of education and skills transfer to students and professionals in the related fields. In the developing country context, where the adaption of new technologies in production processes lag behind global peers (Uaiene, 2011), the pronounced need exists to empower relevant roleplayers with the required skills to ensure timely and continuous sectoral adaptation. The retention of competitiveness is important for roleplayers in the South African property sector, the value-chain of which sees significant public and private sector investment, while also constituting an important contributor to economic output growth (Bock, 2015). The urban milieu in South Africa is characterised by significant inequality and fragmentation on the back of apartheid spatial planning approaches (Abrahams & Everatt 2019). Transformation of this morphology is central to interventions in the built environment (DHS 2021). Education approaches ought to empower students in this context of spatial transformation, which includes architectural functions on the urban community scale. Therefore, sectoral adaptation to external disturbances, such as 4IR and related technological applications, is central to achieving the long-term development objectives of South Africa and its built environment, as well as supporting property sector productivity.

The aim of this paper is to evaluate presiding education approaches in South African tertiary institutions in facilitating the effective transfer of knowledge to prospective architecture students in the context of 4IR and related applications. The inherent objective is to determine whether students are being equipped with the relevant skills in this context to foster sectoral adaptation and long-term competitiveness in the face of this disturbance. In undertaking this research, the curricula of an appropriate sample of tertiary architecture institutions is analysed to determine their integration of themes related to 4IR. In this regard, a qualitative research method is applied. Following this introduction is a review of relevant literature, the overview of the research methodology utilised, an extended discussion of the findings of the analysis and their consequence for architecture education and sectoral adaptation, as well as a conclusion.

2. Literature review

This literature review provides an overview of 4IR and what it entails, the potential implications of 4IR on architecture, and places 4IR in the context of architecture education in South Africa.

2.1. What is 4IR?

4IR is an abbreviated term to represent the whole of the current industrial revolution the world is experiencing. In 2011, at the Hanover Fair, the German Government introduced the idea of 4IR, and soon after, in 2013, put forward the recommendations for implementation (Li *et al*., 2017). However, the term 4IR took off after the publication of Professor Klaus Schwab's book, The Fourth Industrial Revolution, at the annual Davos meeting of the World Economic Forum (WEF) (Lee *et al*., 2018). To unpack the meaning of 4IR, we must first understand what revolution means. Revolution means a significant change or improvement in the way people do things (Cambridge University, 2021). Similarly, Schwab (2016a) professes that the word revolution means abrupt and radical change. These significant changes are evident in the history of the world, from the agrarian revolution to a series of industrial revolutions. The first industrial revolution saw the mechanisation of processes, the second industrial revolution saw mass production, and the third industrial revolution saw the automation of process through computers and electronics (Prisecaru, 2016; Schwab, 2016a; Li *et al*., 2017). 4IR builds on the preceding industrial revolutions. Using the hardware technologies from the third industrial revolution and the electricity and telecommunication technologies from the second industrial revolution, 4IR focuses on a data-driven industrialised internet.

4IR can be termed the Second Information Technology Revolution due to the massive uptake of digital technologies beyond hardware (Lee *et al*., 2018). 4IR introduces the concepts of Cyber-Physical Systems (CPS), Internet of Things (IoT), Big Data, Artificial Intelligence (AI), BlockChain, Autonomous Vehicles, 3D Printing and other new technological concepts (Schwab, 2016b; Lee *et al*., 2018). Li *et al.* (2017) suggest that 4IR has brought forward the industrialised internet through extensive network systems. Prisecaru (2016) suggests that 4IR has brought the need for clean energy and blurs the boundaries between the physical, digital and biological world. Schwab (2016b) cements that 4IR in its scope, scale and complexity is nothing like humans have experienced before changing how we work, live and interact with each other. Although 4IR is challenging to pin down as a one catch definition, perhaps, a simple way of understanding 4IR is the movement of current processes into the digital realm, merging the cyber world with the physical and biological.

4IR, driven by technological advancement, proliferates through all parts of human life, including the economy, society and politics (Prisecaru, 2016; Schwab, 2016b; Li *et al*., 2017; Lee *et al*., 2018). With significant drivers, 4IR also has a significant impact on the world's economy and society. Several authors comment on how 4IR will affect job opportunities for people as machines take over (Prisecaru, 2016; Li *et al*., 2017; Lee *et al*., 2018). However, very much like the other industrial revolutions, this one will also bring opportunity in the form of new jobs. Moreover, unlike the other industrial revolutions, 4IR is not following a linear path but rather an exponential one, revealing that this course is far different from previous revolution trajectories.

2.2. Architecture and 4IR

As the world moves into 4IR, typical of the construction industry, it lags compared to other sectors (Stewart *et al*., 2004; Hong *et al*., 2018). Several barriers are evident in implementation; low level of IT awareness, high cost of implementation, lack of perceived return on investment, resistance to change by staff, lack of IT leadership, reluctance by management to invest in innovation, mindset, and a host of other reasons (Stewart *et al*., 2004; Pillay *et al.*, 2018; Nnaji & Karakhan, 2020; Olaniran & Pillay, 2020). Although barriers exist within the construction industry, there is uptake by some professionals, especially architects. Menges (2015) solidifies that the relationship between architecture and construction is often non-linear and ambivalent, and the architect's imagination has spurred on the invention of new construction technologies. However, architecture takes many cues from other fields, which expand design possibilities (Menges, 2015).

Not too different from the past cues, architecture will be disrupted by 4IR. Numerous new technologies are currently disrupting the architectural profession. *Generative design* is data-driven by AI, parametric design and restrictions given by the designer. Through inputting certain assumptions into the system, architects can generate exhaustive design options with algorithms that would have been difficult to perceive through traditional methods (Souza, 2020). As the world progresses and adopts 4IR technologies, it inevitably will proliferate into the space of architectural design and construction, with one affecting the other. With the introduction of c*yber-physical systems* into manufacturing processes, this phenomenon is becoming a reality in the architecture and construction industries (Menges, 2015). *3D printing* has brought the digital cyber building into a physical reality, progressing from mere prototyping of designs at a small scale (Hager *et al*., 2016).

As sensors become cheaper to produce, the uptake of *sensor technology* in buildings other than commercial and industrial applications is evident. The use of sensors to create big data ultimately assists building designers to adapt and learn from how people use buildings and interact with them, eventually making buildings responsive to their users (Van Berkel, 2020). *Big data* will play a significant role in the architectural profession, significantly if the data can positively affect human life. New *materials* will be inevitable due to the extensive information sets available for analysis by researchers and inventors. Like the second and third industrial revolutions, where new materials such as Poly Vinyl Chloride (PVC) were invented, 4IR will see new synthetic materials invented, especially in the fields of nanotechnology (Daemmrich, 2017). These materials will proliferate the construction industry, making it a priority of understanding by the architects who use them to design their buildings. Perhaps one of the most significant disruptions to the architectural industry in terms of 4IR was the introduction of *virtual and augmented reality*. The process of being able to step inside a building before it has been physically built has advanced the profession light years ahead. Beyond the obvious uses in designing buildings, virtual reality technology can assist clients in perceiving their buildings long before they are physically built on site.

In light of these new technologies and applications in the architectural space, architects will contribute to the conceptualisation, planning, design, and implementation of *smart and sustainable cities* and urban environments (Lucas, 2016; Debacker *et al*., 2017). With the increased emphasis on the integration of technological applications in the design and development of cities, as well as to foster an ecologically conscious built environment in light of holistic climate change adaptation, architects will occupy a crucial role in theorising and applying dramatic change in design approaches. The effective integration of the technological disruptions inherent to 4IR will allow architects to contribute to shaping the future of urban environments.

2.3. Architecture education in South Africa

The world is in a state of transformation as 4IR infiltrates all parts of life. This phenomenon will more than likely affect the education sector due to the demand for new skills. 4IR will reinvent education systems and strategic approaches to foster innovation and creativity. Gleason (2018) elaborates that a drastic reconsideration of the curriculum is required to enable students to understand technologies role and function to adapt to it, analyse and predict the networked systems of technology, environment, and socio-political systems. In the built environment, skills that connect to critical thinking and analysis; complex problem-solving; analytical thinking and innovation; creativity, originality, and initiative; system analysis and evaluation; active learning and learning strategies; and emotional intelligence (Kamaruzaman *et al*., 2019). The transformation of the education system through evaluating and redesigning curricula in response to 4IR and related disruptions, is critical in students meeting future sectoral and workplace requirements (Halili, 2019).

With this rapid change in education systems and syllabus, the Department of Higher Education (DHET) in South Africa must keep a careful eye on the new curriculums for quality assurance through the Higher Education Quality Committee (HEQC) under the surveillance of the Council for Higher Education (CHE) and the South African Qualifications Authority (SAQA). To this end, the SAQA has developed a framework to identify qualifications by a rating from one to ten. This structure is called the National Qualification Framework (NQF), in is illustrated in Table 1. The levels on the NQF table below represent the different qualifications congruent with the NQF Level.

Table 1. NQF levels (tertiary education)

NQF Level	Qualification
10	PhD
9	Master's Degree
8	Honours Degree; 4 years + Bachelor's Degree
7	3rd year of Bachelor's Degree; Advanced Diploma
6	2nd year, Advanced Certificate, Diploma
5	1st year (maximum 96 credits), Higher Certificate

Source: SAQA (2015)

The South African Council for the Architectural Profession (SACAP) is the statutory council responsible for registering professionals and building inspectors and regulating the architectural profession in South Africa in terms of Act 44 of 2000. The SACAP also regulates the curricula of universities with specific competencies (SACAP, 2021). The SACAP identifies ten professional competencies that architectural professionals must possess to practice. These competencies are assessed by academic qualification and practice-based experience, which is reflected in the matrix of Complexity Factors and Complexity Ratings of Building Types (SACAP, 2021). The ten core competencies include architectural design, environmental relationships, construction technology, the structure of buildings, contextual & urban relationships, architectural history and theory, building services & related technologies, contract documentation and administration, computer applications, office practice legal aspects and ethics (SACAP, 2021).

The SACAP has applied a system that allows different levels of education and registration to perform duties congruent with the NQF framework. Ten universities in South Africa currently offer accredited courses in architecture. This includes the Cape Peninsula University of Technology, Nelson Mandela Metropolitan Municipality, Durban University of Technology, Tshwane University of Technology, University of Cape Town, University of the Free State, University of Johannesburg, University of KwaZulu-Natal, University of Pretoria, and University of the Witwatersrand. Among these institutions, one offers programmes at NQF level six, ten at NQF level seven, six at NQF level eight, and nine at NQF level nine (SACAP 2021).

3. Research methodology

Central to the research methodology is a case study analysis of the architecture curricula of three institutions identified in section 2.3. Inherent to this analysis is to determine the extent to which 4IR themes are integrated into said curricula and whether knowledge on related themes is being transferred to architecture students in tertiary education institutions in South Africa. The sample selection is guided by the NQF levels of the architecture programmes offered at the different institutions. To achieve standardisation, the sample consists of three institutions selected from those that offer an accredited undergraduate architecture programme at NQF level seven. The data source used in the evaluation is the yearbooks of the identified institutions. Ethical considerations maintain these institutions remain anonymous. However, the data and references utilized in the analysis can, upon request, be availed.

The analysis centers on each module in the curricula of the institutions being evaluated on their integration of 4IR themes. This qualitative method of analysis is supported by Boud and Falchikov (1989) providing that two elements are adhered to, namely that (i) clear criteria is delineated and used as the benchmark in the analysis, and (ii) the analysis is centred on determining whether the delineated criteria is met. The criteria used in the analysis of this paper are relevant 4IR themes that will impact architecture functions. These themes are identified in the literature review, and include a multidisciplinary, practical, and theoretical theme. The sample curricula will be evaluated on their incorporation of these 4IR themes.

The first criterium is the *multidisciplinary theme*. It is evident that new technology inherent to 4IR will affect the activities of diverse stakeholders in the built environment, in addition to architecture. Through emphasizing multidisciplinarity in the knowledge transfer process, curricula can develop students to take part in the diffusion of expertise, innovations, information, and new ideas associated with advanced technology application among the numerous roleplayers in the built environment. This may support adaptation to changes, both stakeholder and sector specific, as a result of 4IR. Therefore, the curricula will be evaluated on their learning outcomes associated with multidisciplinarity in the built environment and exposure of architecture students in this regard.

The *practical theme* is the second criterium. As the impact of 4IR proliferates, advanced technological applications will alter production processes across sectors, including the built environment, and subsequently change the activities of architects. This is specifically relevant to the infusion of computer-based design and modeling applications that will be critical for future architects. The curricula of the institutions will thus be evaluated based on their knowledge transfer and development of computer and software utilization skills of students in the architecture context. Associated skills may support continuous adaptation as applications change over time.

The third criterium is the *theoretical theme*. Potential applications of 4IR and related technology has increased the focus on creating smart and sustainable cities, including with reference to advanced architectural design and implementation within the urban community context. Inherent to this vision is sustainable development, ecological design, and the infusion of new technologies in conceptual and design perspectives. Accordingly, the curricula will the evaluated based on their knowledge transfer related to the changes that occur in architectural approaches as human environments and needs change, and related theoretical concepts.

4. Findings and discussion

This section provides an overview of the findings of the curriculum analysis for the three identified institutions. The discussion is navigated by three subsections, namely the curricula overview and 4IR inclusion, the inclusion of multidisciplinary, practical, and theoretical themes, and the consequences for sectoral adaptation.

4.1. Curricula overview and 4IR inclusion

Table 2 delineates the NQF level and number of modules and credits of each curriculum, in addition to the modules and credits that are specifically linked to themes related to 4IR. The latter is determined by the application of the criteria relevant to the multidisciplinary, practical, and theoretical themes inherent to 4IR.

Table 2. Inclusion of 4IR in sample curricula (number of modules and % of credits)

Institution	NQF level	Modules	Credits	4IR inclusion	
				Modules	Credits (%)
Institution A	7	21	432	15	74%
Institution B	7	35	404	21	78%
Institution C	7	31	388	16	61%
Average					71%

As illustrated in the above table, although the sample curricula is the same NQF level, there is some difference in the number of modules between the institutions. Institution B has 35 modules that totals 404 credits, while Institution C has 31 modules with 388 credits. Institution A, while having the least number of modules, has more credits that the preceding institutions with 432 in total. In terms of the inclusion of 4IR themes in the curricula, the institutions are comparable. Institution B has the highest number of modules linked to the delineated 4IR themes (21), which may be attributed to the institution also having the highest number of modules in general. Institution C has 16 modules linked to 4IR, the second most in total. However, despite having considerably less modules than the other two institutions, Institution A has 15 modules relevant to 4IR themes, one less that Institution C. Therefore, proportionally, more relevant modules are identified in Institution A than the other two.

While the number of modules is important to consider in this analysis, it is the number of credits that the identified modules represent that provide a holistic indication of the positioning of the curricula toward 4IR themes. Institution B has the highest proportion of total credits linked to 4IR themes of the sample (78%), followed closely by Institution A (74%) and, lastly, Institution C (61%). On average, between the institutions, 71% of all curriculum credits are linked to themes relevant to 4IR, which are the multidisciplinary, practical, and theoretical themes.

4.2. Inclusion of multidisciplinary, practical, and theoretical themes

Table 3 indicates a detailed breakdown of the nature and extent of the inclusion of the three identified 4IR themes in the curricula of the three institutions. These findings are presented as percentages of the total credits connected to the multidisciplinary, practical, and theoretical themes.

Table 3. Extent of 4IR inclusion (% of credits)

Institution	Multidisciplinary	Practical	Theoretical
Institutional A	58%	9%	6%
Institutional B	20%	48%	7%
Institutional C	49%	8%	4%
Average	42%	22%	6%

Evident from the table is that the multidisciplinary theme is the most prominent associated with 4IR that is integrated into the sample curricula, with an average of 42% of credits between the institutions connected to this 4IR theme. The practical theme represents an average of 22% of credits, while 6% of credits are linked to the theoretical theme relevant to 4IR.

In studying the findings of related to each institution, it is evident that the majority of credits (58%) in Institution A is linked to the multidisciplinary theme inherent to 4IR. This curriculum incorporates relevant topics that include architectural design and space-making through collaborative engagement with other stakeholders in the built environment, including civil and structural engineers, and urban and regional planners; advanced knowledge transfer in building technologies, materials, regulations, structures, service provision, and the diverse stakeholders relevant to these functions; and the synergies between design and conceptual, aesthetic, sustainability, and technical building systems and objectives. Institution C places a similar emphasis on multidisciplinarity in its curriculum, with 49% of credits linked to this 4IR theme. In addition to a similar cross-pollination between architectural design and construction methods, materials, technologies, and approaches to that of Institution A, the former exposes students to the unique social, economic, and environmental contexts in which architecture is applied in conjunction with urban and regional planning functionalities and stakeholders. This curriculum specifically incorporates the multidisciplinarity that exists between urban and regional planning, its related regulations, and the activities of the architect. In comparison with the rest of the sample, Institution B has significantly less credits linked to multidisciplinarity, although some focus is also placed on fostering an effective relationship between the architect and other built environment professionals (i.e. engineers, spatial planners) within a project management context, through the integration of housing studies, planning regulations, and structural and civil engineering outcomes.

In terms of incorporating the practical theme inherent to 4IR, Institution B has a significant number of credits linked to this variable, 48%, compared to 9% in Institution A and 8% in Institution C. Emphasised under this theme in Institution B is outcomes related to computer-based architectural design approaches, including teaching and learning on programming, and advanced graphic and reprographic techniques that are technology-based, with the objective of fostering visual analysis, interpretation, and literature through exposure to diverse media. A possible factor that contributes to the practical theme being more pronounced in Institution B compared to the rest of the sample, is curriculum design. Institution B integrates computer-based design applications with other, more theoretical architectural design outcomes within the same modules. While considerably less than Institution B, Institutions A and C also incorporate practical themes relevant to 4IR, as students learn about visual design representation and rendering using computer applications and industry-guided software, including AutoCAD, Revit, Viz, and CorelDraw.

Institution C also has a module specifically aimed at the ongoing development of computer literacy among the student body.

The three sample institutions have a similar incorporation of the theoretical theme inherent to 4IR: 7% of credits in Institution B is connected to this theme, while being 6% in Institution A and 4% in Institution C. Relevant theoretical topics incorporated into the curriculum of Institution B include the paradigm of sustainable development and the need for ecological design approaches, changing state of design production as it is continually infused and altered by technological change, and factors that change the built environment – and thus architectural activities – over time. Institution A incorporates the changing city and the evolution of the human experience in physical and temporal space over time, and the architect's role, among other stakeholders, in optimising this evolution. Institution C integrates theoretical topics relevant to 4IR in its curriculum through transferring knowledge on how new ideas, inventions, and events will shape the future of architecture and the role of the architect in the built environment.

4.3. Consequences for sectoral adaptation

Based on the findings of the analysis, there is a considerable incorporation of themes related to 4IR in the architecture curricula of tertiary education institutions in South Africa, with an average of 71% of credits linked the either the multidisciplinary, practical, and theoretical themes. Among these, the multidisciplinary theme is the most prominent (amounting to an average of 42% of credits in the architecture curricula), followed by the practical (22%) and theoretical (6%) themes.

Proportional to the other two themes, students of architecture in South African tertiary education institutions experience extensive exposure to knowledge on the role of the architect in a multidisciplinary project team, where specific skills are needed to successfully navigate among the diverse stakeholders in the built environment. This emphasis on multidisciplinarity is especially important for the architect, whose role is shaped by advances in building technology, new construction materials, and improved engineering capabilities. Continuous engagement, in addition to actual knowhow related to the specifics of the associated disciplines, will enable continuous adaption of new approaches and techniques, both of emerging and currently unknowable technology and their applications. The current infusion of this theme of 4IR may enable sector-wide adaptation and adaptability to future technological disturbances, and education approaches should continue to foster knowledge exchange between architecture students and engineering and urban and regional planning functionalities to maintain sectoral competitiveness.

While multidisciplinarity is the most prominent 4IR theme, the practical theme and computer-based learning through exposure to architectural design software and computer literacy outcomes is also, on average, an important part of architecture education in the tertiary institutions of South Africa. It is noted that this varies significantly among the sample institutions. Based on the findings deduced from the analysis, some institutions seek to foster ongoing skills development through focussing on fundamental computer literacy and programming functionalities, going beyond merely utilising computers in the learning process. This enables holistic learning and adaptability to current and emerging software applications in the architecture sphere, but also future applications that may transcend the desktop, veering into the realm of augmented and virtual reality. However, there is scope for improvement in the incorporation of the practical 4IR theme in tertiary architecture education in the form of wholly infusing the theoretical with the practical in curriculum design. Computer-based learning ought to be key part of the curricula, reflecting its status as an already central component of 4IR and related technology applications, which will increase in prominence as diverse software applications proliferate.

The inclusion of theoretical themes inherent to 4IR in architecture curricula in South Africa is severely limited. As elucidated in the section 2.3, architects, as a prominent member of the built environmental stakeholders, will occupy an important part in transforming cities into smart and sustainable environments through contributing to the paradigm shift in the design and development of these environments. The exploration of these theoretical themes in the context of architectural principles and design is important in infusing the vision of smart and sustainable communities in the learning outcomes and approaches of architecture students. Related knowledge transfer may contribute to the development in students of critical problem-solving skills and innovation in constantly changing human environments in which architecture functionalities are exercised. Increasing expose to the theoretical theme of 4IR will enable architecture students to fulfil their role in the spatial transformation of South African cities and towns, in addition to fostering long-term adaptability in diverse and ever-changing spatial contexts.

In the regulatory context, the core competencies delineated by the SACAP – which guide the accreditation of tertiary architecture programmes in South Africa – includes topics which have significant synergies with the delineated 4IR themes. This includes topics on multidisciplinarity (environmental relationship, construction technology, structure of buildings, contextual and urban relationships), the practical (computer applications), and the theoretical (architectural history and theory) themes. While this guides the incorporation of relevant 4IR themes in architecture curricula to empower students for ongoing technological disruption, the inclusion of generic competencies such creative problem solving, critical thinking, emotional intelligence, ethical behaviour, and communication may contribute to the development of the auxiliary, soft skills needed in the workplace of the future. These skills may prove to be of specific importance in securing sectoral competitiveness and adaptability as the effect of 4IR spreads in the built environment.

5. Conclusion

4IR has brought several changes affecting how people live, work and interact with each other. Furthermore, the proliferation of technology into every aspect of life has disrupted how humans currently interact with the world. This disruption is only the beginning of the most significant disruptions to society humankind would have seen. However, not everyone is prepared to take on the challenges of this new revolution, and this begs the questions of how education plays a role in transforming human learning. From the literature, it is evident that architecture as a profession is severely affected by the impacts of 4IR, especially in the realm of architectural designs and construction technology. It is, therefore, prudent that education leaps forward in this case. From the case study analysis, it is evident that there is considerable incorporation of themes related to 4IR in the architecture curricula of South Africa's tertiary institutions. This is particularly pronounced in the context of the multidisciplinary theme, while to a lesser extent in reference to the practical and theoretical themes. This constitutes a motive to redesign the curricula to incorporate increased knowledge transfer on computer-based technological applications and the vision of smart and sustainable human settlements in architecture education. In addition, it is recommended that regulatory outcomes emphasise generic competencies (including creative problem-solving, innovation, etc.), which would be beneficial to architecture students, while fostering sectoral competitiveness and adaptation to the potential disruption posed by 4IR, and other narratives of change yet to be conceived. A future avenue of research includes comparative analyses of 4IR themes in curricula among diverse disciplines in the built environment, as well as across implementation contexts, i.e. curricula and institutions in developing and developed countries. Data availability is a limitation applicable to this study, as the analysis of the curricula is determined by the available detail in the yearbooks of the sample institutions.

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