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Introducing Construction 4.0 into Construction Management Curricula

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Abstract
The rise of the Fourth Industrial revolution has forced many, if not all industries to embrace the transformation and adopt its concepts and technologies. Innovation that resulted from Industry 4.0 technologies gave rise to Construction 4.0, and the construction industry is adopting these Construction 4.0 technologies, as they are extremely beneficial. The adoption of Construction 4.0 has created a skills gap as the current and future workforce does not have the necessary skills for a Construction 4.0 environment. A quantitative study was conducted among recent construction management graduates of Nelson Mandela University between 2019 to 2021, to determine how Construction 4.0 can be integrated into the construction management curricula. The findings indicate the construction industry is slow to adopt Industry 4.0 concepts and technologies and it faces challenges in terms of increasing Construction 4.0 awareness; the current skills gap needs to be addressed and qualifications need to be restructured to include digital skills, and more digital training programmes need to be adopted on site. Conclusions include that universities and theconstruction industry both need to make progress in terms of adopting Industry 4.0 concepts and technologies so thatthey are current and can fully embrace the new innovations and trends that will be beneficial to them. Recommendations include: the relevant Construction 4.0 technologies need to be introduced into construction management curricula; students should develop the related skills, and vacation work should be a requirement, which will enable students to apply what they learn in the lecture environment in the workplace.

Keywords
Construction Management, Curricula, Industry 4.0.

1. Introduction
Construction Management curricula have played a vital role in the success of construction professionals in the construction industry, as they provide a foundation, providing graduates with the knowledge and skills that they will need in the workplace.

Industry is continuously evolving, and new information and technologies are discovered every day, but unlike other industries, the construction industry is the slowest to adjust. For example, the construction industry is historically reported as the second lowest sector to have adopted information technology (Perera et al., 2020).

The 4th industrial revolution (Industry 4.0) follows three previous industrial revolutions, namely Industry 1.0 (water and steam power), Industry 2.0 (electricity), and Industry 3.0 (internet, electronic devices). According to Perera et al. (2020) "Industry 4.0 is characterised by the seamless integration of cyber-physical environments propelled by an array of technologies that enable the development of a digital and automated industry as well as the digitisation of the value chain."

Construction 4.0 has been described as the digitalisation of the construction industry, introducing building information modelling (BIM), autonomous construction, advanced building materials such as nanomaterials, augmented and virtual reality, and more. Osunsanmi, Aigbavboa and Oke (2018) propose that construction professionals should adopt Industry 4.0 to improve the overall performance of the industry in South Africa.

Innovation generates new opportunities that allow for improvements within the construction industry. Becker et al. (2011) suggest that for construction professionals to benefit from innovative technologies and emerging business environments, they must both recognise opportunities and possess the prerequisite education and training needed to capitalise thereon. Therefore, Construction Management curricula must be current in terms of what is happening in the industry, to prepare students for the industry.

Given the abovementioned, the aim of the study was to evolve a framework for digitalisation of construction management curricula, the objectives being to:

- determine the degree of adoption and experience of Industry 4.0 technologies in construction;
- determine the digital skills construction managers will require in the future;
- determine the incidence of vacation work during graduates' studies;
- identify which modules need attention, and
- identify which Industry 4.0 technologies can be integrated into such modules.

2. Review of the literature

2.1 Industry 4.0

According to Dima (2021), "Industry 4.0 originated in 2011 from a project in the high-tech strategy of the German government that promoted computerisation of manufacturing." It is in that same year that the term Industry 4.0 was introduced publicly.

Carvalho and Cazarini (2020) refer to Industry 4.0 as an industrial model that characterises the Fourth Industrial Revolution. The advanced manufacturing model is represented by intelligent, virtual, and digital performance in large scale industries and emerges as a disruption to the previous three industrial revolutions. The focus of Industry 4.0 on interconnectivity through the Internet of Things (IoT), machine learning, and the processing of real-time data.

Phuyal, Bista and Bista (2020) state that this industrial revolution connects IoT and the industrial internet to manufacturing systems to interact with the machines to enable sharing of their information, and to make intelligent decisions based on the systems' algorithms.

Zhang and Yang (2020) cited by Phuyal, Bista and Bista (2020) opine that Industry 4.0 includes artificial intelligence, automated robots, flexible manufacturing automation systems, additive manufacturing, and augmented reality.

2.2 Students', graduates', and professionals' knowledge regarding Industry 4.0

Industry 4.0 is not a new concept, but most people in different parts of the world are still not aware of it and its significance.

A review of accredited programmes in the United States of America determined that construction management students receive little exposure to the vast amount of mobile technologies used in the industry (Radden, Collins and Kim, 2017). In a similar vein, a study conducted by Osunsanmi, Aigbavboa and Oke (2018) in South Africa determined that construction professionals have a low level of awareness with respect to Construction 4.0 principles.

One of the challenges that Construction 4.0 is facing is increasing awareness thereof. The construction industry needs to clearly communicate the benefits of Construction 4.0 technologies to migrate its workforce into the future and ensure that everyone adapts and improves together (Go Construct, 2022).

2.3 Work experience and vacation work

Neill and Mulholland (2003) suggest that traditional educational programmes are failing to address the needs of both students and industry and contend that students should develop competencies and the aptitude for construction through undertaking work in a real economic setting.

Vacation work refers to work undertaken by students during vacations, and Mthunjwa (2022) cites the following as the benefits of vacation work: students can establish whether their career field of choice is the right one by undergoing real-time work experience, which may further solidify their choice of study, and the opportunity for new experiences and encounters. Industry 4.0 technologies being an example of the latter.

2.4 Adopting Industry 4.0

Although the construction industry is one of the slowest industries to adopt to Industry 4.0 concepts, globally, many firms have initiated the transition. According to Phuyal, Bista and Bista (2020), migrating to Industry 4.0 is a gradual process and takes time to upgrade operations from the existing system. Physical infrastructure, adoption of new technologies, familiarity therewith, and the availability of technical expertise are necessary for such upgrades.

The World Economic Forum (2018) contends that for the construction industry to remain relevant in a Construction 4.0 environment, firms should: attract new talent and develop capacity in terms of the required skills; integrate and

collaborate across the construction industry's value chain; adopt advanced technologies at scale, and maximise the use of data and digital models throughout processes.

2.5 Industry 4.0 skills

The workforce skills needed in the construction industry are evolving due to Industry 4.0. According to Emerald Publishing (2022), Construction 4.0 emerged as a concept to drive improvement of the overall quality of the workforce capacity involving professional, technical vocational, and education and training addressing skills, competency, and competence.

Autodesk and Chartered Institute of Building (2018) state that the current skills gap is a pressing issue that must be addressed, and that there is a need to evolve qualifications, courses, and apprenticeship programmes to include digital skills and introduce more digital training programmes on site.

2.5 Integrating Industry 4.0 into Construction Management curricula

Integrating Industry 4.0, or rather its technology into construction management curricula is not a new idea. According to the Construction Industry Training Board (CITB) (2018), Dudley College of Technology has built a Centre for Advanced Building Technologies. The curriculum focuses on using digital technologies delivering learning across disciplines such as building services engineering, civil engineering, construction, design and BIM, and environmental technologies.

Abbas, Din and Farooqui (2016) contend that the onus is on universities to introduce IT tools into construction management curricula, and that one such tool that appears promising is BIM.

3. Research

3.1 Research Method and Sample Stratum

The study entailed a self-administered online questionnaire survey. The sample strata for the research study were limited to Nelson Mandela University BSc (Honours) (Construction Management) Alumni from 2019 to 2021. The questionnaire consisted of twenty-seven questions; thirteen closed ended question, and eight of the close ended questions were Likert scale type questions, four were open-ended questions, four multiple choice questions and six were demographics related. The responses to the open-ended questions are not reported on. 19 Responses were included in the analysis of the data, which entailed the computation of frequencies, and a measure of central tendency in the form of a mean score (MS), which equates to a response rate of 45.2 %.

3.2 Results

Table 1 indicates the degree of familiarity which respondents have regarding Industry 4.0 concepts and technologies, and a MS ranging between 1.00 and 5.00. It is notable that both MSs are above the midpoint of 3.00, which indicates that respondents are moderately familiar to extremely familiar with Industry 4.0 concepts and technologies. Both MSs are > 3.40 to ≤ 4.20, which indicates that the respondents' self-rating of their familiarity of Industry 4.0 and its technologies is between familiar to more than familiar / more than familiar.

Table 1. Respondents' self-rating of their familiarity of Industry 4.0 and its technologies

Aspect	Response (%)							
	Unsure	Not at all familiar …Extremely familiar					MS	Rank
		1	2	3	4	5		
Industry 4.0 concepts	0.0	5.3	0.0	10.5	52.6	31.6	4.05	1
Industry 4.0 technologies	5.3	0.0	5.3	31.6	36.8	21.1	3.63	2

Respondents were required to indicate their level of exposure to Industry 4.0 technologies on a scale of not at all exposed to extremely exposed. The resultant MS of 2.63 is > 2.60 to ≤ 3.40, which indicates that respondents maintain their level of exposure to Industry 4.0 technologies is between less than exposed to exposed / exposed.

In terms of Industry 4.0 technologies respondents were exposed to in university, BIM (30.2%) predominates, followed jointly by drones and site automation (14.0%), and then jointly by the IoT and prefabrication and digital

fabrication (11.6%) (Table 2). It is notable that three further technologies were identified by less than 10% of respondents.

Table 2. Industry 4.0 technologies respondents were exposed to in university

Technology	Yes (%)
BIM	30.2
Drones	14.0
Site automation	14.0
IoT	11.6
Prefabrication and digital fabrication	11.6
Social and mobile computing	9.3
Augmented / Virtual reality	7.0
Other: Construction cost and planning software	2.3
Collision of the digital & physical world	0.0
Machine learning and artificial intelligence	0.0

Table 3 indicates the relevance of Industry 4.0 concepts and technologies to construction management undergraduate and postgraduate qualifications in terms of percentage responses to a scale of 1 (not at all relevant) to 5 (extremely relevant), and a MS ranging between 1.00 and 5.00. It is notable that both MSs are $> 4.20 \leq 5.00$, which indicates that the relevance of Industry 4.0 concepts and technologies to construction management undergraduate and postgraduate qualifications is between more than relevant to extremely relevant / extremely relevant.

Table 3. Respondents' rating of the relevance of Industry 4.0 concepts and technologies to construction management undergraduate and postgraduate qualifications

Qualification	Response (%)							
	Unsure	Not at all relevant …Extremely relevant					MS	Rank
		1	2	3	4	5		
Undergraduate	0.0	0.0	0.0	10.5	42.1	47.4	4.37	1
Postgraduate	0.0	5.0	0.0	5.0	45.0	45.0	4.25	2

57.9% of respondents participated in vacation work during their time of study, and 42.1% did not. The mean period of such work is 2.97 months.

Respondents were required to indicate the importance of vacation work for students on a scale of 1 (not at all important) to 5 (extremely important). The resultant MS of 4.79 is > 4.20 to ≤ 5.00, which indicates that respondents maintain vacation work is between more than important to extremely / extremely important.

In terms of the frequency at which respondents encountered Industry 4.0 technologies during vacation work on a scale of never to every time, the resultant MS of 2.00 is $> 1.80 \leq 2.60$, which indicates that respondents never to rarely / rarely encountered Industry 4.0 technologies during vacation work.

Respondents were required to indicate the frequency at which they engage in personal reading on a scale of never to constantly. The resultant MS of 3.16 is $> 2.60 \leq 3.40$, which indicates that respondents rarely to sometimes / sometimes engage in personal reading to remain abreast of recent news and technologies relevant to their field of study / career path.

Furthermore, in terms of a related issue, respondents were required to indicate the construction related magazines and newsletters they subscribe to (Table 4). Only three magazines and newsletters were subscribed to by more than 20.0% of respondents, and four by more that 10.0% of respondents. Construction Manager, BIM plus, and Construction news predominate. The Construction Manager is the Chartered Institute of Building's (CIOB's) online newsletter, and it should be noted that Construction Management students are encouraged to join the CIOB. The South African Council for the Project and Construction Management Professions (SACPCMP) is the statutory council responsible for accrediting Construction Management programmes, and they publish their magazine ShapeShifter quarterly.

Table 4. Construction-related magazines and newsletters respondents subscribe to

Technology	Yes (%)
Construction Manager	25.0
BIM plus	21.4
Construction news	21.4
Construction News Magazine	14.3
Global Construction Review	7.1
Construction Insight Magazine	3.6
Residential Contractor Magazine	3.6
ShapeShifter	3.6
Buildingtalk	0.0
The Construction Index	0.0

47.4% of respondents are registered with the SACPCMP, 42.1% are not registered. The remaining 10.5% of the respondents include those who have applied for registration and are awaiting feedback and registered with the South African Council for the Property Valuers Professionals.

52.6% of respondents are members of the CIOB, and 47.4% are not members. Zero respondents are members of the Association of Construction Project Managers (ACPM).

In terms of the readiness of respondents' workplaces for the adoption of Industry 4.0 on a scale of 1 (not at all ready) to 5 (extremely ready), the resultant MS of 2.62 is > 2.60 to ≤ 3.40, which indicates that their workplaces are between less than ready to ready / ready for the adoption of Industry 4.0.

Respondents were required to indicate the extent to which their workplaces have adopted Industry 4.0 on a scale of not at all, pre-adoption, adoption, and post-adoption. The resultant MS of 1.56 is $> 1.00 \leq 1.75$, which indicates the extent to which their workplaces have adopted Industry 4.0 is between not at all to pre-adoption.

Table 5 indicates the extent to which professionals need to acquire knowledge / skills to be successful in an Industry 4.0 workplace according to the respondents. It is notable that no knowledge / skill attracted more than 14.0% response, and that the general level of response is very low.

Table 5. Extent to which professionals need to acquire knowledge and skills to be successful in an Industry 4.0 workplace

Knowledge / Skill	Yes (%)
Problem solving	14.0
Computer programming, design, and knowledge of software tools	13.1
Data analytics	13.1
Digital competence	13.1
Information processing	12.2
Online communication	10.3
Decision making	9.4
Cyber security	7.5
Human machine communication	7.5

Table 6 indicates the Industry 4.0 technologies respondents have used in their workplace. It is notable that 8 / 19 (42.1%) responded 'none', 1 / 19 (5.3%) 'N/A', and 1 / 19 (5.3%) 'not sure'. 9 / 19 (47.4%) of the respondents have used Industry 4.0 technologies such as Additive Manufacturing, BIM, Drones, IoT, GPS land surveying tool, laser measuring devices, and prefabrication.

Table 6. Industry 4.0 technologies respondents have used in their workplace

R No.	Industry 4.0 technology
1	None
2	BIM
3	None
4	None
5	IoT
6	Not sure
7	Drone
8	GPS land surveying tool
9	Drones and laser measuring devices

10	None
11	N/A
12	None
13	Additive Manufacturing
14	Drones for mapping and surveying
15	None
16	None
17	Prefabrication and drones
18	IoT
19	None

15.8% of the respondents indicated that they had undergone Industry 4.0 related training in their workplace, and 84.2% had not. Respondent No. 5 cited 'BIM', No. 8 cited 'Using GPS Land surveying instruments', and No. 18 cited 'employee training and IoT privacy policy', and 'uniform cyber security standards and guidelines'.

Table 7 indicates the various Industry 4.0 skills and technologies respondents advocate that should be integrated into construction management curricula. 57. 9% opine that BIM should be integrated into construction management curricula, followed by drone technology (26.3%).

Other skills and technologies with a response of less than 20% include IoT, digitisation, VR, AR, site automation, machine learning, quality assurance technology, big data, additive manufacturing, autonomous vehicles, robotics, cloud computing, AutoCAD, Cyber security, AI, 3D Printing, along with data analytics, critical thinking and analysis, coding, online communication, computer programming and in-depth lessons on Microsoft Project, and in-depth lessons on quantity surveying software.

Table 7. Industry 4.0 skills and technologies which should be integrated into construction management curricula

R No.	Industry 4.0 technology / skill
1	BIM, IoT, site automation, drones, and 3D printing
2	BIM, IoT, and drone technology
3	Digitisation
4	BIM
5	BIM, VR, and drones
6	Site automation, and machine learning
7	Critical thinking and analysis
8	Quality assurance technology operated by internal management officer
9	BIM, IoT, and coding
10	Online communication, data analysis, IoT, and big data
11	Drones and computer programming
12	Drone technology and BIM
13	Additive Manufacturing
14	BIM
15	BIM
16	Drones and autonomous vehicles, AR, BIM, cloud computing, and robotics
17	BIM, AutoCAD, in depth lessons on Microsoft Project, and in-depth lessons on Quantity Surveying Software
18	Cyber security, AI, AR, and data analytics
19	BIM

Table 8 indicates the extent to which modules require the integration of Industry 4.0. Construction Management attracted the highest level of response (16.0%), followed by Project Management at 14.0%, Building Science (Environment and Services, Materials and Methods, and Structures) at 12.0%, Professional Practice for Construction Management, Production Analysis and Construction Surveying at 8%, and Basic Surveying and Computing Fundamentals with the lowest rating of 5 %.

Table 8. Extent to which modules require the integration of Industry 4.0

Technology	Yes (%)
Construction Management	16.0
Project Management	14.0

Building Science (Environment and Services)	12.0
Building Science (Structures)	12.0
Building Science (Materials and Methods)	12.0
Professional Practice for Construction Management	8.0
Production Analysis	8.0
Construction Surveying	8.0
Basic Surveying	5.0
Computing Fundamentals	5.0

4. Discussion

The respondents'self-rating of their familiarity of Industry 4.0 and its technologies is between familiar to more than familiar / more than familiar (MSs are > 3.40 to ≤ 4.20), despite maintaining their level of exposure to Industry 4.0 technologies is between less than exposed to exposed / exposed (MS is > 2.60 to ≤ 3.40). The latter is reinforced by the exposure of respondents to Industry 4.0 technologies in university, in which case BIM (30.2%) predominates, followed jointly by drones and site automation (14.0%), and then jointly by the IoT and prefabrication and digital fabrication (11.6%). It is notable that three further technologies were identified by less than 10% of respondents, and a further two by zero respondents. Effectively, the respondents indicated that their workplaces are between less than ready to ready / ready (MS is > 2.60 to ≤ 3.40) for the adoption of Industry 4.0. The latter finding is reinforced by the extent to which the respondents' workplaces have adopted Industry 4.0, which is between not at all to pre-adoption (MS is > 1.00 ≤ 1.75). Furthermore, 15.8% of respondents indicated that they had undergone Industry 4.0-related training in their workplace, 42.1% of the respondents indicated that they had not used any Industry 4.0 technologies in their workplace,

The respondents' rating of the relevance of Industry 4.0 concepts and technologies to construction management undergraduate and postgraduate qualifications, which is between more than relevant to extremely relevant / extremely relevant (MSs are > 4.20 ≤ 5.00) indicates awareness on the part of the respondents with respect to the role of Industry 4.0 in construction.

A notable finding arising from the study is that although respondents maintain vacation work is between more than important to extremely / extremely important (MS is > 4.20 to ≤ 5.00), only 57.9% responded that they participated in vacation work during their studies, the mean period being 2.97 months. It appears that the transition from students to graduates engendered a realisation on their part of the importance of vacation work. The vacation work-related findings are further reinforced by the finding that respondents rarely to sometimes / sometimes (MS is > 2.60 ≤ 3.40) engage in personal reading to remain abreast of recent news and technologies relevant to their field of study / career path. The latter finding is further reinforced by the findings that only three magazines and newsletters were subscribed to by > 20.0% ≤ 25.0% of respondents, and four by > 10.0% ≤ 25.0% of respondents. Vacation work and university studies are mutually reinforcing, as vacation work enables students to relate their university studies to their pending vocation, and vacation work assists their university studies in terms of understanding the theory and the development of skills in the university environment.

47.4% of respondents are registered with the SACPCMP, and 52.6% of respondents are members of the CIOB, which in general indicates a low level of commitment to professionalism.

In terms of integrating Industry 4.0 skills and technologies into construction management curricula, 57. 9% opine that BIM should be, followed by drone technology (26.3%). It is notable that the other skills and technologies were identified by less than 20% of respondents. Furthermore, in terms of the extent to which ten modules require the integration of Industry 4.0, Construction Management attracted the highest level of response (16.0%), followed by Project Management (14.0%), and each of the three Building Science modules Environment and Services, Structures, and Materials and Methods (12.0). The remaining five modules were identified by between 8.0% and 5.0%.

5. Conclusions

Graduates are aware and have been somewhat exposed to Industry 4.0, but they do not have much knowledge with respect to it, and how beneficial it could be to them as professionals, and their workplace.

Although the construction industry might be somewhat ready for Industry 4.0, it has not really made any drastic changes with regards to adopting Industry 4.0 technologies.

BIM is one of the construction Industry 4.0 technologies which graduates are more familiar with, and it is also being integrated into Construction Management curricula more than other technologies.

Universities need to integrate the range of Industry 4.0 technologies into their curricula, and the construction industry needs to make progress in terms of adopting Industry 4.0 concepts and technologies so that they can benefit from such adoption.

6. Recommendations

Innovative ways need to be evolved in terms of increasing the level of awareness regarding Industry 4.0 in both universities and the construction industry. The Construction Industry Development Board, statutory councils, and professional and employer associations have a major role to play, and should provide guidelines for the industry.

Construction Management curricula need to be restructured and integrated with the relevant construction Industry 4.0 skills and technologies.

Vacation work should be a requirement, or universities should introduce a work experience programme in partnership with the construction industry, which will enable students to apply what they learn in the lecture environment at work and experience the workplace environment.

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