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Exploring the Prospects of Industry 4.0 Technologies for Inclusive Construction Education

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Abstract: This study explores the social prospects of Industry 4.0 technologies in sustainable inclusive construction education. A quantitative research design was employed, and a structured questionnaire was administered to 85 registered professionals in the construction education and regulation. Principal Component Analysis (PCA) was used to identify the key components that account for the most variance in the dataset. The results showed that two components explain 65.15% of the total variance, with "The implementation of Industry 4.0 Technologies" being the most significant social prospect factor. This suggests that implementing Industry 4.0 technologies plays a crucial role in transforming social aspects of construction education sustainability. The study's findings emphasize the need for institutions to focus on digital transformation strategies, automation, and accessbility to learning resources to achieve social sustainability in inclusive construction education. The research contributes to the existing body of knowledge on Industry 4.0 and sustainable inclusive construction education, providing insights for practitioners, policymakers, and researchers.

Keywords: Inclusive construction, Inclusive education, Prospects, Industry 4.0.

Introduction

The fourth industrial revolution, commonly referred to as Industry 4.0, is transforming the manufacturing process by leveraging automation, artificial intelligence (AI), robotics, and the Internet of Things (IoT) to create "smart factories" (Kagermann et al., 2013). This new era of industrial production is characterized by interconnectedness, autonomy, artificial intelligence, and cyber-physical systems (Hermann et al., 2016). Interconnectedness enables the integration of physical and digital systems, facilitating real-time data exchange and analysis (Lee et al., 2015). Autonomy, on the other hand, involves the increased use of autonomous systems, such as robots and drones, to perform tasks (Bahrin et al., 2016). Artificial intelligence plays a crucial role in Industry 4.0, as it enables the use of AI and machine learning algorithms to analyze data, make decisions, and optimize processes (Duan et al., 2017).

Cyber-physical systems integrate physical and computational systems to create smart, connected products and systems (Monostori et al., 2016). Industry 4.0 technologies include IoT sensors and devices, AI and machine learning, robotics and automation, 3D printing and additive manufacturing, cloud computing and big data analytics, and cybersecurity (Marr, 2018). The adoption of Industry 4.0 has the prospect to bring about significant benefits, including increased efficiency and productivity, improved product quality and customization, enhanced inclusive construction education, reduced costs and waste,

and new business models and revenue streams (PWC, 2016). However, it also poses challenges, such as job displacement and skills gap, cybersecurity risks, data management and analytics complexity, and investment costs and ROI uncertainty (Deloitte, 2019). Industry 4.0 represents a significant shift in the way industries operate, and its adoption is expected to have far-reaching impacts on the global economy and society. As noted by the World Economic Forum (2018), "Industry 4.0 has the prospect to create new opportunities for growth, innovation, and employment, but it also requires a coordinated effort from governments, businesses, and individuals to address the challenges and ensure that the benefits are shared by all."

Literature Survey

The advent of Industry 4.0 has significant implications for the construction education and regulation, and by extension, construction education. As the construction education and regulation undergoes a transformation driven by automation, artificial intelligence, and the Internet of Things (IoT), it is essential that construction education adapts to prepare students for this new reality (Kagermann et al., 2013). Inclusive construction education must take into account the changing needs of the industry and ensure that students from diverse backgrounds have access to the skills and knowledge required to thrive in an Industry 4.0-driven construction sector.

One of the key areas of focus for inclusive construction education is digital literacy. As construction projects become increasingly digitized, it is essential that students have the digital skills to navigate this new landscape (PWC, 2016). Research has shown that digital literacy is a critical skill for construction educators, and that it can have a significant impact on productivity and efficiency (Bryson & Forth, 2017). Inclusive construction education must prioritize digital literacy, ensuring that students from all backgrounds have access to the digital tools and technologies that are transforming the industry. Another important consideration for inclusive construction education is diversity and inclusion. Industry 4.0 has the prospect to exacerbate existing inequalities in the construction education and regulation, particularly if certain groups are left behind in the transition to a more automated and digitized sector (Deloitte, 2019). Research has shown that diversity and inclusion are critical for innovation and productivity in the construction education and regulation, and that they can have a significant impact on project outcomes (Egbu, 2015). Inclusive construction education must prioritize diversity and inclusion, ensuring that students from underrepresented groups have access to the skills and knowledge required to succeed in the Industry 4.0-driven construction sector.

Accessibility is another key consideration for inclusive construction education. Industry 4.0 technologies, such as virtual and augmented reality, have the prospect to make construction education more accessible to students with disabilities (Burgstahler, 2015). Research has shown that accessible education can have a significant impact on student outcomes, and that it can help to reduce the achievement gap for students with disabilities (McKay, 2017). Inclusive construction education must prioritize accessibility, ensuring that all students have equal access to the learning resources and tools they need to succeed. Collaboration and communication are also critical skills for construction educators in the Industry 4.0 era. Industry 4.0 requires collaboration and communication between different stakeholders, including architects, engineers, contractors, and clients (Kotter, 2014). Research has shown that collaboration and communication can have a significant impact on project outcomes, and that they are critical for innovation and productivity in the construction education and regulation (Egbu, 2015). Inclusive construction education must prioritize collaboration and communication, ensuring that students have the skills and knowledge required to work effectively in multidisciplinary teams. Lifelong learning is a critical consideration for inclusive construction education. Industry 4.0 is a rapidly evolving field, and construction educators must be committed to lifelong learning to stay up-to-date with the latest technologies and trends (PWC, 2016). Research has shown that lifelong learning can have a significant impact on career outcomes, and that it is critical for innovation and productivity in the construction

education and regulation (Egbu, 2015). Inclusive construction education must prioritize lifelong learning, ensuring that students have the skills and knowledge required to adapt to changing industry needs. Inclusive construction education must take into account the changing needs of the industry and ensure that students from diverse backgrounds have access to the skills and knowledge required to thrive in an Industry 4.0-driven construction sector. By prioritizing digital literacy, diversity and inclusion, accessibility, collaboration and communication, and lifelong learning, inclusive construction education can help ensure that students are prepared for success in the Industry 4.0 era.

Research Design and Methodology

The research design serves as a roadmap, guiding the researcher in conducting a systematic investigation and addressing the research questions (Creswell & Creswell, 2017). The key components of the research design include a literature review, data collection, and data analysis (Kothari, 2004). The research population consists of individuals and institutions involved in the planning, teaching, and practitioners of construction education in Nigerian Education Sector. The sampling frame includes professor grades, lecturers, construction practitioners, practice regulators, engineering contractors, and stakeholders with a minimum of ten years of experience in the construction education and regulation.

A purposive sampling method was adopted, and a sample size of 85 registered professionals with more than 10 years of work experience was selected. A structured questionnaire was developed based on a comprehensive review of the literature, and it includes closed-ended questions designed to gather quantitative data on various aspects of sustainable inclusive construction education (Fink, 2019). The questionnaire was administered physically and electronically using an online survey platform. Prospect participants were contacted through professional networks, industry associations, and construction-related events to ensure a diverse and relevant sample. Each survey invitation included a cover letter that explained the purpose of the research, outlined confidentiality measures, and emphasized the voluntary nature of participation (Bryman, 2016). The collected data was cleaned and coded for analysis using statistical software SPSS. Descriptive statistics, including frequencies, percentages, and factor analysis, were utilized to summarize the characteristics of the sample and the responses to the survey questions (Pallant, 2016). The study's quality and reliability were evaluated using the Cronbach's alpha,

$$\alpha = (\frac{k}{(k\ -\ 1)})(1\ -\ (\sum\frac{(si^2)}{s^2}))$$

where; - k = number of items, - si^2 = variance of item i, - s^2 = variance of the total score. KMO,

$$KMO = \frac{(\sum(r^2))}{(\sum(r^2)\ +\ \sum(q^2))}$$

where; - r^2 = squared correlation coefficient between variables, - q^2 = squared partial correlation coefficient between variables, and Bartlett's test of sphericity,

$$\chi^2 = -\left(\frac{(n-1)-(2p+5)}{6}\right) ln(\det(R))$$

where; - n = sample size, - p = number of variables, - det(R) = determinant of the correlation matrix R. Principal Component Analysis (PCA):

$$Z = A * X$$

where; - Z = matrix of principal components, - A = matrix of eigenvectors, - X = matrix of original variables. The eigenvectors are obtained by solving the eigenvalue decomposition of the correlation matrix R:

$$R = A * \Lambda * A^{(-1)}$$

where; - Λ = diagonal matrix of eigenvalues, - A = matrix of eigenvectors was used to determine the prospects associated with adopting sustainable inclusive construction education and to gauge the overall impact of sustainable construction education practices in the construction sector. The data analysis methods used included frequency distribution and percentage, and factor analysis through

principal component analysis. The results were presented using tables and charts to facilitate the interpretation of questionnaire responses.

Discussion of Findings

The total variance explained by the extracted components in assessing the social prospects of Industry 4.0 technologies in sustainable inclusive construction education. The analysis was conducted using Principal Component Analysis (PCA), which identifies the key components that account for the most variance in the dataset. The "Initial Eigenvalues" column shows the eigenvalues associated with each component before extraction. The first component has an eigenvalue of 1.556, explaining 38.89% of the total variance. The second component has an eigenvalue of 1.050, contributing an additional 26.26% of the variance. Together, these two components account for a cumulative variance of 65.15%, meaning they explain 65.15% of the total variability in the data.

The third and fourth components have eigenvalues below 1 (0.842 and 0.552, respectively) and contribute less variance (21.06% and 13.79%). Since PCA typically retains only components with eigenvalues greater than 1 (based on the Kaiser criterion), only the first two components are extracted, as indicated in the "Extraction Sums of Squared Loadings" column. These extracted components retain the same variance explanation as in the initial eigenvalues, reinforcing that they effectively summarize the dataset. The factor analysis suggests that two key components adequately capture the majority (65.15%) of the variance in the social prospects of Industry 4.0 technologies, while the remaining components contribute relatively little information. This indicates that the underlying structure of the dataset can be effectively represented using these two components.

The scree plot visually represents the eigenvalues associated with each principal component for assessing the social prospects of Industry 4.0 technologies in sustainable inclusive construction education. The plot shows a clear decline in eigenvalues as the component number increases, indicating the relative importance of each component. The first two components have eigenvalues greater than 1, which aligns with the results. This suggests that these two components account for the majority of variance in the dataset and should be retained for further analysis. The third and fourth components have eigenvalues below 1 and contribute less variance, supporting their exclusion based on the Kaiser criterion. The "elbow" in the scree plot, where the eigenvalues begin to level off, occurs at the second component. This confirms that a two-component solution is optimal for summarizing the key patterns in the data. The component matrix presents the factor loadings, which indicate the correlation between each variable and the extracted components. Higher absolute values of loadings suggest a stronger association between the variable and the corresponding component. In this case, two components were extracted. The first component has strong positive loadings for "The implementation of Industry 4.0 Technologies" (0.809), "The digital literacy" (0.686), and "Industry 4.0 Readiness management and accessbility to learning resources system" (0.640). This suggests that these variables are closely related and collectively define the first component. The second component has a strong loading for "Diversithy and inclusion for students from underrepresented groups" (0.906), meaning this variable is distinct and primarily associated with the second component. Among these variables, "The implementation of Industry 4.0 Technologies" has the highest loading (0.809) on the first component, making it the most significant social prospect factor in Industry 4.0 adoption for sustainable inclusive construction education. This suggests that implementing these technologies plays a crucial role in transforming social aspects of construction education sustainability, likely through improved efficiency, communication, and collaboration across stakeholders.

The component plot visually represents how the four assessed social prospect factors of Industry 4.0 technologies are distributed across the two extracted components. The factor distribution across components shows that "The implementation of Industry 4.0 Technologies" and " The digital literacy" are closely positioned on Component 1, suggesting they are strongly related and primarily explained by this

component. "Industry 4.0 Readiness management and accessbility to learning resources system" also has a notable contribution to Component 1 but is slightly distinct. In contrast, “Diversithy and inclusion for students from underrepresented groups” are more associated with Component 2, indicating it has different underlying characteristics compared to the other three factors. Component 1 appears to explain most of the variance for three out of the four factors, meaning it captures the primary dimension of social prospects in Industry 4.0 adoption. Component 2 mainly explains "The digital literacy," indicating a separate influence or dimension in social prospect. Based on the factor loadings, "The implementation of Industry 4.0 Technologies" had the highest loading (0.809) on Component 1. This confirms that "The implementation of Industry 4.0 Technologies" is the most significant social prospect factor in sustainable inclusive construction education. The findings suggest that the implementation of Industry 4.0 technologies plays the most crucial role in enhancing social aspects of sustainable construction educations, while logistics transition represents a different, yet relevant, dimension. The results emphasize the need for institutions to focus on digital transformation strategies, automation, and accessbility to learning resources to achieve social sustainability in inclusive construction education.

Summary of Findings

The implementation of Industry 4.0 Technologies has the highest loading (0.809) on the first component, making it the most significant social prospect factor in Industry 4.0 adoption for sustainable inclusive construction education. This suggests that implementing these technologies plays a crucial role in transforming social aspects of construction education sustainability, likely through improved efficiency, communication, and collaboration across stakeholders.

Industry 4.0 technologies, such as energy conservation, pollution emission control, and sustainable practices, are key enablers for environmental sustainability for inclusive construction education. They contribute to the improvement of sustainability indicators and the reduction of pollution. Industry 4.0 technologies drive economic growth and environmental preservation by increasing construction efficiency, promoting circular economy principles, and addressing economic concerns of emerging countries. Technologies enhance materials, information, and cash flow efficiency. Technologies as Artificial Intelligence, Big Data, Blockchain, and Cloud Computing play a major role in improving inclusive construction education. These technologies are seen as highly effective in increasing transparency, efficiency, and sustainability within construction educations.

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