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Drivers of Digital Technology Adoption in Engineering Education

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***Abstract*—The integration of digital technology in engineering education is essential for improved learning outcomes and to adequately prepare engineering graduates for the demands of a rapidly transforming industry. This article examines the implementation of digital technology in Nigerian educational institutions. The study identifies drivers of digital technology in engineering education from previous literature. The mean rating of each of these drivers was computed and ranked based on importance. Further exploratory factor analysis revealed four major clusters: Institution Capacity Building, Academic Excellence and Support, Technology Enablement and Support, and Flexible Learning Solutions. These clusters represent the fundamental sectors that promote digital inclusion in the engineering educational system. The results provide a holistic overview of segments that could be addressed to transform engineering education through technology inclusion. By concentrating on the highlighted four crucial areas, institutions can provide a more impactful, holistic, and flexible learning environment for engineering students thus producing engineers that will adequately meet the changing demands of the industry.**

***Keywords*— Digital Technology; Engineering Education; Learning Solutions; Technology Enablement**

ICTIEE* Track*: Technology Enhanced Learning

ICTIEE Sub-Track: Transforming Education Through Technology: Best Practices and Case Studies

I. INTRODUCTION

Up until the middle of the 19th century, engineering education in Nigeria was undervalued compared to other academic subjects. However, shortly after gaining independence, Nigeria built a number of Technical Colleges, Polytechnics, and Faculty of Engineering in Universities, realizing that this sector is one of the main pillars of any nation (Oloyede et al., 2018). Owing to the significance and intricacy of engineering education, the duration of any engineering degree program in Nigeria is five years, with a year dedicated to general sciences studies (Gumus & Bubou, 2022). “A graduate of any engineering degree must practice for a minimum of four years in order to become a fully qualified engineer. This condition must also be met before the graduate can register as an engineer with the Council for the Regulation of Engineering in Nigeria (COREN)” (Engineers, 2019). By addressing the pressing needs of the early post-independence era, Nigerian engineering education fared admirably. The quality of teaching at the time was also praised, particularly considering that the majority of engineering professors used their industry knowledge in their work (Oloyede et al., 2018). However, the quality of engineering education in Nigeria has been increasingly concerning in recent years, particularly for the industries, since it appears that the standard is declining (Oloyede et al., 2018). Consequently, there is a gap between what graduates are capable of and the skills demanded by the labour markets (Ciarli et al., 2021). This prompts a request for enhancement of the current traditional course delivery approaches in order to satisfy the demands of the labour market (Ciarli et al., 2021). While the world has seen significant advancements in information technology, cutting edge ideas, and developmental initiatives over the years due to engineering innovations, Nigeria has not seen any significant changes in engineering education, lecture style, or attitude during the same period of time (Igbokwe et al., 2019).

A. Digital Education

Digital education is the creative use of digital tools and technologies in the classroom. Teachers can use digital technology to offer possibilities for learning that are engaging (Haleem et al., 2022). “All aspects of economic and social activities are impacted by and restructured by digital technologies” (Ciarli et al., 2021). When implemented in certain ways, they interfere with ongoing operations, but when implemented in other ways, they have a more gradual effect and enhance ongoing operations (Ciarli et al., 2021). These digital tools have caused a paradigm shift in the entire educational system (Parveen & Ramzan, 2024). Technological improvements in education makes the life of students easier. Students are able to use various software and tools to create

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projects and presentations, access online courses, read e-books, hence increasing interest in education and research (Raja & Nagasubramani, 2018). The impact of digital technology in teaching and learning has become very significant. The impact has spread across organizations, relationships, and various operations (Haleem et al., 2022).

B. Challenges of Integrating Digital Technology in Engineering Education

The usage of digital technologies in engineering education could pose some obstacles. Despite the significant benefits, there are also difficulties that are very likely to be faced (Haleem et al., 2022). It is pertinent that engineering lecturers and instructors are aware of these difficulties (Haleem et al., 2022). Budget constraints and restrictions are by far the biggest obstacle impeding educators' and administrators' attempts to deliver educational technology to pupils. “Those who support education technology must get beyond these obstacles in order to properly integrate tech into their classrooms” (The 7 Greatest Challenges Facing Education Technology Today, n.d.). When schools face financial distress, securing resources for integration and maintenance of sophisticated classroom technologies becomes a significant challenge. Every day, more and more cutting-edge educational technology is created. While the utilization of new technologies is an important skill educators need to learn, equally as important is the ability of these educators to transfer this knowledge to their students consequently (Johnson et al., 2016). A student's institutional experience is not likely to be enhanced by provision of learning environments with a new technology that neither the educator nor the student can easily use. It then becomes a headache for busy teachers to learn how to utilize this new technology owing to the cumbersome process of knowledge transfer (Strom, 2021).

“Studies have revealed that instructors' aversion to technology is not due to a hate of it. Instead, it is partially due to the fact that educators see picking up a new teaching instrument as a dangerous endeavour for which they lack the necessary training” (Batane & Ngwako, 2016). It is also partially due to the fact that their school officials fail to put up a united front by emphasizing the particular resources that can benefit their students (Johnson et al., 2016). Many teachers are unsure how to integrate technology into their curricula, even if giving them access to tablets and smart boards may increase their comfort level with it (Umugiraneza et al., 2018). Education technology can be a very useful tool, but in order for it to stay a viable option in the future, hardware and software must be dependable and consistent (Matthew et al., 2021).

C. Drivers Of Digital Technology Integration In Engineering Education

The advancement of digital technology in engineering education presents an abundance of chances for interpersonal engagement, cooperation, correspondence, and information exchange that will profoundly influence human existence (Timotheou et al., 2023). However, various problems are faced with the integration of these technologies. These problems need to be fixed if widespread adoption and acceptance are to be achieved (Qiao & Fu, 2023). Some of the drivers of digital technology in engineering education include:

1. Faculty Development and Training: The importance of thorough training and professional development for lecturers cannot be overemphasized. Training programs are necessary to help academic instructors develop proficiency in the application of these digital technologies to ensure seamless transfer of knowledge to students (Miranda et al., 2021).
2. Robust Technological Infrastructure: The dilapidated state of technological infrastructure also presents a major challenge hence a dire need for upgrade of these infrastructure. These may include ensuring updated software, reliable internet, and sophisticated engineering equipment required for successful technology integration (Gürdür Broo et al., 2022).
3. Collaborations with Industry: To stay updated with technological advancements and their practical implications, collaboration with industry is necessary to bridge the gap between theoretical nature of academia and the practical technological implementations among industry practitioners (Miranda et al., 2021).
4. Financial Resources and Funding: Imperatively, allocation of adequate financial resources and external funding will facilitate the integration of technology in engineering education. As these technologies most often have high cost implication, institutions should be able access grants, collaborations, and sponsorships to fund software and hardware purchases, capacity building initiatives, infrastructure renovations, and technical assistance (Gürdür Broo et al., 2022).
5. Curriculum Alignment: Aligning the engineering educational curriculum with the demands of technology in the engineering profession is also essential. This will mean a review of curriculum frameworks, course contents, and learning objectives to incorporate theoretical and practical knowledge of digital tools and technology with strategic learning objectives (Miranda et al., 2021).
6. Student Engagement and Support: Students must also be engaged and supported in this integration process being directly involved in the process and giving them required assistance. Using these digital technologies to improve student learning can easily be accomplished promoting continuous feedback from students, collaboration, active engagement, and provision of technical support (Bond et al., 2020).
7. The importance of research and evaluation cannot be left out in driving technology integration in engineering education. It is important to conduct studies to determine performance of these technologies and methodologies for improvement. Through informed decision making, systems thinking, and measuring growth opportunities offered by data-driven studies, the performance of these technologies can be maximized (Bond et al., 2020).

8. Partnerships with Educational Technology Providers: Technology providers in education can offer substantial support towards the supply of instructional technology which will democratize access to sophisticated equipment for engineering education. Effective collaboration with these suppliers can provide relevant knowledge, assistance, and direction for successful technology integration (Hadgraft & Kolmos, 2020).
9. Policy and Supportive Leadership: Technology integration in engineering education must be prioritized and encouraged, and this requires the establishment of appropriate policies and leadership. It is possible to promote an innovative culture and overcome reluctance to change by providing faculty members who adopt digital technologies with clear instructions, rewards, and recognition (Hadgraft & Kolmos, 2020).

This study seeks to systematically assess the challenges and drivers of integration of digital technologies in engineering education through extensive analysis of their perceived impact to understand crucial drivers of these technologies in Nigerian institutions. The study further explores these drivers to group them and ensure a streamlined and focused solution approach and strategy for educators and students.

II. Research Methodology

Convenience sampling was used to conduct the study using a quantitative research methodology (Amin et al., 2023). Due to the unique characteristics of the study, including its huge study population, potential financial ramifications, and time constraints, this sample strategy was chosen. The study's target respondents included instructors, industry practitioners, and students. Three hundred and fifty (350) questionnaires were sent to industry professionals working for government agencies, consulting firms, and contracting firms, as well as students and instructors at the University of Nigeria Nsukka. A total of thirty-two (302) questionnaires were returned for examination. There were two sections in the questionnaire. The first concentrated on the respondents' demographic data, paying special attention to their years of study, engineering specialization, and level of education. Responses regarding the respondents' opinions on the forces driving digital technology in engineering education were solicited in the second section. The following items were measured using a five-point Likert scale: 5-Strongly Agree, 4-Agree, 3-Neutral, 2-Disagree, 1-Strongly Disagree. The questionnaire's questions were created following a thorough and meticulous analysis of the available research.

A. Data analysis

The demographic characteristics of the respondents showed that 75.8% of the respondents were students while lecturers and industry practitioners consisted the remaining 24.2%. Nine (9) different engineering fields were covered in the study with majority of the responses coming from students, lecturers, and practitioners with background in civil engineering (26.5%), metallurgical and material engineering (13.6%), electronics engineering (13.2%), mechanical engineering (11.6%), electrical engineering (11.3%) and agric and bioresource engineering (8.3%).

The mean ratings and the relative importance index were computed and the variables ranked to ascertain the order of relevance of the drivers as perceived by the respondents (Tholibon et al., 2021). Table 1 reveals the perceived level of importance of the drivers of digital technology in engineering education. The most highly ranked driver is ‘Financial resources and funding’ with a mean rating of 4.47. Following ‘Financial resources and funding’ are ‘Learning analytics’, ‘Collaborations with industry’, and ‘Policy and supportive leadership’ with mean ratings of 4.38, 4.35, and 4.32 respectively. The least ranked drivers were ‘curriculum alignment’ and ‘student engagement and support’ with mean ratings of 2.96 and 3.15 respectively.

B. Factor analysis

In order to establish the variables of the same underlying dimensions, factor analysis was adopted (Shrestha, 2021). The Bartlett’s test of sphericity and the Kaiser-Meyer-Olkin (KMO) measure of sample adequacy are displayed in Table 2. These show that the data are sufficient to perform factor analysis. The results of the KMO test were 0.799, and Bartlett's test of sphericity yielded a significance level of 0.000, indicating that the data was suitable for factor analysis. This was further demonstrated by the dependability of the study instrument being assessed using Cronbach’s alpha, which returned a result of 0.854 indicating suitability. Table 3 displays the factor loadings derived from the factor analysis. This includes fifteen (15) variables loaded into four components, which were obtained by using varimax rotation and Principal Component Analysis (PCA) extraction. The first component consisted of six highly correlated variables, with a range value of 0.518 to 0.897. We refer to these associated variables as "Institution Capacity Building." With a range of 0.705 to 0.885, indicating that they measure the same construct, four variables—dubbed "Academic Excellence and Support"—accounted for the second component. "Technology Enablement and Support" was the label given to three variables that were loaded into the third component and had a range value of 0.623 to 0.905. The final part, dubbed "Flexible Learning Solutions," is made up of variables with values ranging from 0.820 to 0.861.

TABLE I
DRIVERS OF DIGITAL TECHNOLOGY IN ENGINEERING EDUCATION

S/N	Description	Mean	RII	Rank
DR-1	Learning analytics	4.38	0.877	2
DR-2	Robust Technological Infrastructure	4.23	0.846	6
DR-3	Collaborations with Industry:	4.35	0.871	3
DR-4	Financial Resources and Funding	4.47	0.894	1

DR-5	Curriculum Alignment	2.96	0.591	15
DR-6	Student Engagement and Support	3.15	0.629	14
DR-7	Research and Evaluation	3.40	0.681	13
DR-8	Partnerships with Educational Technology Providers:	3.88	0.777	10
DR-9	Policy and Supportive Leadership	4.32	0.864	4
DR-10	Blended learning model	4.30	0.861	5
DR-11	Sustainability initiative	4.22	0.844	7
DR-12	Grant and funding opportunities	4.05	0.811	8
DR-13	Faculty Development and Training	4.04	0.809	9
DR14	Cloud based solutions	3.72	0.744	11
DR-15	Open educational resources	3.57	0.714	12

TABLE II
KMO AND BARTLETT'S TEST

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.799
Bartlett's Test of Sphericity	Approx. Chi-Square	3018.433
	df	105
	Sig.	0.000

TABLE III
ROTATED COMPONENT MATRIX

Variables	Component			
	1	2	3	4
Policy and Supportive Leadership	0.897			
Learning Analytics	0.809			
Financial Resources and Funding	0.790			
Sustainability Initiative	0.637			
Blended Learning Model	0.563			
Collaborations with Industry	0.518			
Research and Evaluation		0.885		
Curriculum Alignment		0.833		
Grant and funding opportunities		0.798		
Student Engagement and Support		0.705		
Partnerships with Educational Technology Providers			0.905	
Faculty Development and Training			0.783	
Robust Technological Infrastructure			0.623	
Open educational resources				0.861
Cloud based solutions				0.820

III. RESULTS AND DISCUSSION

Table 4 shows the breakdown of the factor analysis (extraction and rotation). The extraction reduced the dimensionality of the data by identifying a smaller number of factors that represent the original variables while the rotation helped achieve a simple structure, where each variable has a high loading on one factor and low loadings on others. The initial eigenvalues shown represent the amount of variance explained by each component in the dataset before extraction with components greater than 1 considered significant based on Kaiser's selection criterion. Four (4) components meet this criterion, cumulatively accounting for 74.94% of the total variance. After extraction, the cumulative variance explained by the retained components remained the same as no further information is removed during extraction. After the rotation, the variance is redistributed among the components to achieve a clearer structure with components 1 – 4 explaining 23.90%, 18.17%, 17.07%, and 15.79% of the variance respectively. This analysis indicates that four underlying constructs significantly explain the variance in the data and certainly represent distinct themes in the dataset as outlined below.

A. Cluster 1 – Institution Capacity Building

The first cluster contains six extracted components, all of which include the latent trait "institution capacity building". This cluster reflects the essential components that collectively strengthen an institution's ability to effectively integrate digital technologies in engineering education (Haleem et al., 2022). Each variable, ranging from policy and supportive leadership to learning analytics, financial resources, sustainability initiatives, blended learning models, and industry collaborations, contributes to enhancing the institution's overall capacity. This cluster underscores how a well-supported, strategically guided institution, equipped with the necessary resources and industry partnerships, can successfully navigate the complexities of digital transformation in education (McCarthy et al., 2023).

B. Cluster factor 2 – Academic Excellence and Support

The second construct (Academic excellence and Support) had four variables included in it considering the correlation of the variables. This cluster covers the key drivers that foster a quality academic environment with the application of digital technologies in engineering education (Mondragon-Estrada et al., 2023). This cluster encompasses variables such as research and evaluation, that ensure that educational practices are continuously assessed and improved, and curriculum alignment, which ensures relevance of educational content with technological advancements. Grant and funding opportunities are crucial for supporting innovative research and educational initiatives, while student engagement and support focus on enhancing the learning experience and ensuring student success. Together, these drivers promote an academic environment that prioritizes excellence and provides the necessary support for both students and faculty to thrive in a digitally-enhanced educational landscape (Igbokwe et al., 2019).

C. Cluster factor 3 – Technology Enablement and Support

The third construct has five extracted factor loadings which are tagged ‘Technology Enablement and Support’. This cluster emphasizes the crucial elements required to effectively integrate and sustain digital technologies in engineering education (Wiangkham & Vongvit, 2024). This cluster highlights the importance of partnerships with educational technology providers, ensuring access to cutting-edge tools and resources. Faculty development and training are pivotal in equipping educators with the skills needed to effectively utilize these technologies, while a robust technological infrastructure forms the backbone that supports all digital initiatives. Together, these drivers create an environment where technology is not only accessible but also effectively integrated and supported, enabling a transformative educational experience (Wang et al., 2023).

D. Cluster factor 4 – Flexible Learning Solutions

The fourth component was tagged "Flexible Learning Solutions," and had four extracted variables. This cluster explains the importance of adaptability and accessibility in modern engineering education (Krasniewski & Woznicki, 1998). By coagulating solutions related to scalability, this cluster includes cloud-based solutions, which offer scalable and accessible platforms for learning anytime and anywhere, and open educational resources, which provide cost-effective, customizable learning materials. These drivers are essential to enable a more flexible and inclusive educational environment, where students and educators can leverage a wide array of resources and tools to tailor the learning experience to individual needs and preferences (Blended Learning And Traditional Learning: A Comparison, n.d.). The shift towards more dynamic and learner-centered educational models is also emphasized by this cluster.

TABLE IV
TOTAL VARIANCE EXPLAINED

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.201	34.674	34.674	5.201	34.674	34.674	3.585	23.899	23.899
2	2.599	17.328	52.002	2.599	17.328	52.002	2.726	18.172	42.070
3	2.228	14.855	66.858	2.228	14.855	66.858	2.561	17.074	59.144
4	1.212	8.078	74.936	1.212	8.078	74.936	2.369	15.791	74.936
5	0.883	5.888	80.823						
6	0.504	3.361	84.184						
7	0.474	3.160	87.344						
8	0.368	2.454	89.798						
9	0.328	2.189	91.987						
10	0.256	1.708	93.695						
11	0.238	1.586	95.282						
12	0.212	1.414	96.695						
13	0.204	1.358	98.053						
14	0.172	1.146	99.199						
15	0.120	0.801	100.000						

CONCLUSION

The complex dynamics of incorporating digital technology into engineering education in Nigeria have been brought to light by this study, which also reveals the obstacles and forces that influence this process. Four major clusters, Institution Capacity Building, Academic Excellence and Support, Technology Enablement and Support, and Flexible Learning Solutions, were found through factor analysis. A distinct aspect of the digital transformation in education is reflected in each cluster, which highlights the significance of well-planned resource allocation, ongoing professional development, a strong technology foundation, and flexible learning settings. By addressing these issues comprehensively, it will be possible to close the gap between present educational methods and the changing needs of the labour market, leading to the development of a more inventive and resilient engineering education system in Nigeria. While embracing these forces, educational institutions also need to be aware of the difficulties in integrating technology in a way that improves instruction and gets students ready for success in the digital age.

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