

## ORIGINAL RESEARCH ARTICLE

## A K-means Clustering Analysis to Assess Educators' and Students' Perceptions of Digital Technology in Higher Education

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### ABSTRACT

Digital technology has transformed the way teaching and learning are approached, shifting from a teacher-centered model to a student-centered one. Educators and students are the key stakeholders driving the integration of digital technology into educational processes. Many studies have examined educators' and students' perceptions of digital technology use through descriptive analyses. However, descriptive analysis cannot uncover complex non-linear relationships between the main explanatory variables. It also depends on domain experts to identify important features for investigating the phenomenon. Therefore, a detailed examination of faculty and student perceptions of digital technology in education is necessary, and machine learning offers powerful tools, such as advanced algorithms, to better detect patterns in data. This study gathers data from educators and students at Nigerian higher education institutions through questionnaires. The data is analyzed using the K-means clustering algorithm to identify trends in perceptions of digital technology use in teaching and learning. The results show three groups among educators: laggards, adorers, and adopters, representing low, moderate, and high levels of integration and perception, respectively. Student perceptions of digital technology integration follow a similar pattern but with greater variability. Findings suggest the need for sufficient digital technology resources in higher education and for strategies to support educators and students with low perceived benefit and low integration of digital technologies in academic activities, especially by integrating professional development training for educators into pedagogy.

### ARTICLE HISTORY

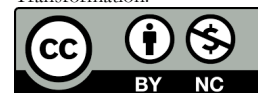
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### KEYWORDS

Digital Technology  
Integration, K-Means  
Clustering, Digital Technology  
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Transformation.



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### INTRODUCTION

The use of digital technologies and the revolutionary power of artificial intelligence in improving teaching, learning, research, and decision-making in education are growing (Hwang et al., 2020; Akram et al., 2022). Research demonstrates that integrating digital technology into teaching and learning is essential because of its significant benefits, such as enabling students to gain relevant experience and develop competitive skills (Lawrence & Tar, 2018; Mather et al., 2022). There is evidence of positive attitudes toward using digital technology in pedagogy among primary and secondary school teachers, as shown in studies by Chiu (2022), Ndebele and Mbodila (2022), Hartman et al. (2019), and Mahdum et al. (2019). Additionally, opinions vary regarding the impact of integrating digital technology into teaching and learning (Qasem & Viswanathappa, 2016), which may be linked to factors such as educators' self-efficacy and the availability of technological tools to support the process. Despite the importance of digital technology in education, its adoption faces several barriers, including a lack of training, the

absence of pedagogical frameworks for digital technology integration, limited access to technological tools, and unreliable power supply (Karsh, 2018; Salem & Mohammadzadeh, 2018; Paul & Lal, 2018; Ohei & Brink, 2019), especially in developing countries. The obstacles to using digital technology in teaching and learning have been identified by Mercader and Gairín (2020), Ohei and Brink (2019), and Salem and Mohammadzadeh (2018). These include technophobia, lack of confidence, insufficient pedagogical concepts related to digital tools, poor planning, and high workload.

Furthermore, the successful integration of digital technology into teaching and learning depends on the availability of technological tools (Mwila, 2018) and the extent of technology use by educators and students. Empirical evidence shows that digital technology positively impacts educational outcomes, though challenges remain in effectively integrating it for both educators and students. However, there is limited in-depth

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analysis to identify trends in educators' and students' perceptions of digital technology use using machine learning methods. K-means clustering is a machine learning method that is widely used to analyze perceptions and behaviors regarding digital technology in higher education, revealing distinct patterns among both educators and students. K-means clustering applications in higher education include:

1. Digital Readiness and Socio-Emotional Perceptions: Cluster analysis has identified groups of students with varying levels of digital readiness, influenced by technology access, prior experience, and digital skills. These clusters show significant differences in socio-emotional perceptions, such as stress and loneliness, underscoring the importance of targeted support during transitions to digital education (Händel et al., 2020).
2. Digital Culture and Technology Acceptance: Clustering based on the Technology Acceptance Model (TAM) parameters indicates that, while perceived usefulness and intention to use digital systems are high, actual system use and perceived ease of use remain low. This underscores the importance of socialization and guidance in improving digital culture in higher education (Maylawati et al., 2020).
3. Student Engagement and Perception: K-means clustering has been used to classify students into low- and high-engagement groups based on behavioral, emotional, and cognitive aspects in online learning environments (Kim et al., 2023).
4. Digital Competencies of Educators: K-means clustering has also been applied to assess professors' digital competencies, identifying four distinct clusters corresponding to different competency levels. (Chahuán-Jiménez et al., 2025).

Thus, failure to examine patterns in the perceptions and use of digital technology in academic activities could lead to a poor understanding of how they naturally cluster and relate to each other. This gap may slow the progress of digital transformation in higher education. Therefore, this study uses K-means clustering to explore trends in how educators and students perceive digital technology integration in higher education institutions. The objectives are as follows:

1. To analyze educators' and students' perceptions of digital technology use in teaching and learning across Nigerian higher education institutions.
2. To uncover patterns in the perspectives of educators and students on digital technology use in teaching and learning across Nigerian higher education institutions.
3. To evaluate the usefulness of K-means clustering in pattern recognition, focusing on faculty and student perceptions of digital technology integration in higher education institutions.

Researchers have developed a number of theories that explain the processes through which innovation and/or technology are accepted and used, diffused within society, or introduced into society. These theories include the Technology Acceptance Model (TAM) by Davis (1989), the Technology Organization Environment (TOE) by Tornatzky & Fleischer (1990), the Innovation Diffusion Theory (IDT) by Rogers (2003), and the Unified Theory and Use of Technology (UTAUT) by Venkatesh et al. (2003). This study aligns with the UTAUT model and its extension to guide the exploration of the phenomenon in focus, as it integrates both the TAM and IDT models to explain the process of technology integration in academic activities by individuals.

## MATERIALS AND METHODS

This section describes the data collection process and the analysis used to identify patterns in Educators' and students' perceptions of digital technology integration in higher education institutions.

### Data Collection and Preparation

A questionnaire was developed using items adapted from the study by Mahdum et al. (2019) to assess educators' motivation and perceptions regarding the use of digital technology. The questionnaire includes three sections: respondents' demographic information, a closed-ended section with a 5-point Likert scale, and an open-ended section with three questions. It was developed using Google Forms and distributed electronically via email and WhatsApp to educators in Nigerian higher education institutions. The close-ended responses helped determine the demographic distribution of the respondents and the pattern of digital technology integration. Both quantitative and qualitative data were collected from the responses. The quantitative data underwent descriptive analysis. A total of 1,333 responses were received from educators, and 1,412 responses from students. The few missing values were filled with the most frequent responses.

### Data Preprocessing

To preprocess the collected data, the responses were separated into quantitative and qualitative forms. As for the quantitative data, a few missing values in the gender variable of the demographic responses were replaced with the most common value. The data were then transformed to numerical values as specified in the questionnaire; for example, a response classified as "Strongly Agree" was coded as 1, "Agree" as 2, "Neutral" as 3, "Disagree" as 4, and "Strongly Disagree" as 5. This transformation is required for quantitative analysis and machine learning modelling, specifically for clustering analysis. Then, outliers, which are observations that are abnormally away from other observations in a random population (Liu, et al., 2022), were replaced using an imputation method, that is, the median value of the features was used to replace the outlier, which is not influence by the outlier compared to mean value of the features (Bonthu, 2021).

**Table 1: Result of Reliability Test for students**

Constructs	Cronbach's Alpha
Perceived Usefulness	0.778
Ease of Use	0.810
Self-efficacy	0.216
Technology Integration	0.765

**Table 2: Result of Validity Test for students**

Constructs	Construct Validity
Perceived Usefulness	0.68
Ease of Use	0.78
Self-efficacy	0.55
Technology Integration	0.82

**Table 3: Result of Validity Test for Educators**

Constructs	Cronbach's Alpha
Perceived Usefulness	0.822
Ease of Use	0.728
Self-efficacy	0.713
Workload	0.403
Institutional Culture	0.842
Educational Value	0.839
Learning Environment	0.736
Technology Integration	0.700

**Table 4: Result of Reliability Test for Educators**

Constructs	Convergent Validity
Perceived Usefulness	0.788
Ease of Use	0.729
Self-efficacy	0.478
Workload	0.600
Institutional Culture	0.806
Educational Value	0.765
Learning Environment	0.694
Technology Integration	0.774

A test of reliability and validity was conducted using Cronbach's alpha and convergent validity. The Cronbach's alpha coefficient for the total items in students' responses is 0.65, whereas that of the constructs in students' responses ranges from 0.216 to 0.810, as shown in Table 1. The validity score for each item ranges from 0.55 to 0.82, as shown in Table 2. For the educators'

responses, the Cronbach's alpha coefficient for the total items is 0.75, whereas that of the constructs ranges from 0.478 to 0.806, as displayed in Table 3. The validity score for each item in the educators' responses ranges from 0.70 to 0.842, as shown in Table 4.

The coding or conversion of responses to numerical values was achieved with Microsoft Excel, which has built-in functions that are easy to use. Similarly, for ease of reference, questions were also coded. For instance, the question "The use of DT makes learning process more effective," which falls under the perceived usefulness construct, was coded as PU1. Moreover, the average of all constructs within each category was taken, thereby yielding a single feature representing a particular group of constructs. This approach was adopted to all questions (for both educators' and students' responses).

Furthermore, features were standardized into a uniform scale prior to use by machine learning algorithms. Standardization involves scaling data to fit a normal distribution (Nair, 2022), i.e., converting all features to a uniform scale, which impacts modelling and reduces the potential for outliers. Features were standardized using the scikit-learn MinMaxScaler, and the standardized features were used as input to machine learning algorithms.

**Data Analysis**

A descriptive analysis was conducted using respondents' demographic data. A clustering method was used to find trends in the open-ended responses. An unsupervised machine learning method called clustering organizes data points according to common traits, patterns, or features (Chen, 2022). The K-means clustering technique was used in this investigation. One of the most popular and successful algorithms in data mining and research is K-means, implemented in the scikit-learn Python library (Ahmed et al., 2020). The approach maximizes the distance between different clusters while minimizing the within-cluster sum of squares, or the distance between data points inside the same cluster. The pseudocode for the K-means clustering algorithm is shown in Listing 1.

```

Name: k-means clustering algorithm
Input: Number of clusters, sample data.
Output: Clusters.
Begin
    1. Decide the number of clusters, also known as k
    2. Randomly select k data points as the initial centroids.
    3. Assign data points to nearest centroids
    4. Update the centroids by computing the new centroids mean
    5. Repeat 3 to 4 until:
        5.1. No change in centroids
        5.2. Maximum iterations reached
Stop
    
```

**Listing 1: K-means Clustering Algorithm**

The elbow approach, which identifies the point at which adding more clusters results in a negligible drop in information gain, was used to determine the optimal

number of clusters (Sammouda & El-Zaart, 2021). A silhouette score was also used to determine distinct, non-overlapping clusters (Saraswat et al., 2023). Several

parameters were used to configure the K-means model: the number of clusters, `n_clusters`, was set to 3. The `init` parameter was set to `'k-means++'`, which ensures better centroid initialization and faster convergence. The `n_init` parameter was set to `'auto'`, which permits several initializations to increase resilience. The `random_state` parameter was set to 42 to ensure reproducibility.

**RESULTS AND DISCUSSION**

This section presents and discusses the results of the demographic and clustering analysis conducted.

**Demographic Analysis**

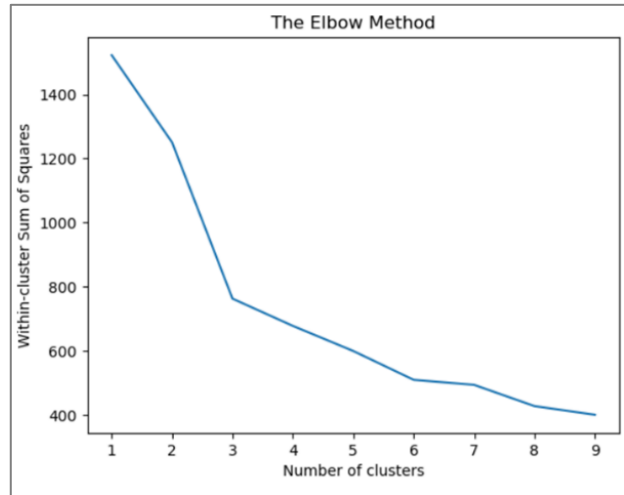
The demographic information of the respondents is presented in Table 5. The data show that 67% of the educators are males (894 respondents), whereas 33% are females (439 respondents). The age distribution indicates four categories: 5% were aged 18 to 28 years, 50% were aged 29 to 39 years, 29% were aged 40 to 50 years, and 16% were aged 51 years or older. The distribution of educators by highest qualification shows that 54% (717 respondents) held a master's degree, while 32% (422 respondents) held a doctoral degree. The educators with a bachelor's degree as their highest qualification constitute 14% (194 respondents). As for the students, the data show that 62% are males (875 respondents), whereas 38% are female (537 respondents). The data also indicates four age groups among students: 54% of the population (70 respondents) were aged 16 to 25, whereas 30% of the population (658 respondents) were aged 25 to 35. The 36- to 45-year-old respondents accounted for 13% of the population (388 respondents). Finally, 3% of the population (217 respondents) are 46 years of age or older.

**Table 5: Demographic Information of the Respondents**

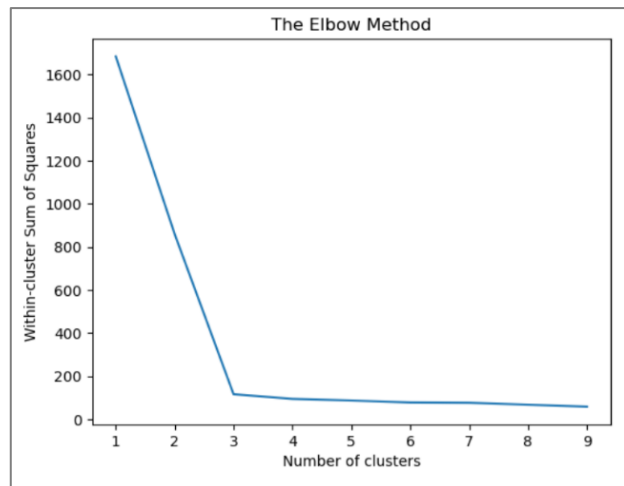
	Item	Category	Distribution
Educators	Gender	Female	33%
		Male	67%
	Age	18-28	5%
		29-39	50%
		40-50	29%
Qualification	51 & more	16%	
	BSc	14%	
	MSc	54%	
Students	Gender	PhD	32%
		Female	62%
	Age	Male	38%
		16-25	54%
26-35		30%	
		36-45	13%
		46 & more	3%

**Cluster Analysis**

The results of the K-means clustering analysis show patterns in educators' and students' perceptions of digital technology integration in teaching and learning. The optimal number of clusters was determined using the elbow method, which indicates the point at which the inertia drops, as shown in Figure 1 and Figure 2 for educators and students, respectively.



**Figure 1: An elbow method showing Optimal Number of clusters for Educators**



**Figure 2: An elbow method showing the Optimal Number of clusters for Students**

Figure 3 illustrates the results of the K-means clustering analysis for educators. The results indicate three distinct clusters. The first cluster, referred to as laggards, has 503 respondents. The cluster represents a category of educators who have a very low level of digital technology integration in teaching and learning and a very low perception of its positive impact on the teaching process. The second cluster, referred to as Adorers, has 423 respondents. This cluster shows educators who have a low level of digital technology integration but a high perception of its positive impact on academic activities. The third cluster, referred to as adopters, has 407 respondents. This cluster shows educators who have a high level of technology integration and a moderate perception of its benefits in academic activities.

A silhouette score of 0.91 was obtained, indicating distinct, non-overlapping clusters, as illustrated in Figure 4. Figure 5 illustrates the results of the K-means clustering analysis for students, which also indicate three distinct clusters. The laggards, with 446 respondents, have a very low level of digital technology integration in their learning process and a low perception of its benefit. The adorers, with 424 respondents, have a low level of digital technology integration but have a high perception of its

benefits in the learning process. The adopters, with 542 respondents, are students with high digital technology integration and a moderate level of perception of its

benefits. Similarly, a silhouette score of 0.97 was obtained, further demonstrating the distinctness of the clusters, as shown in Figure 6.

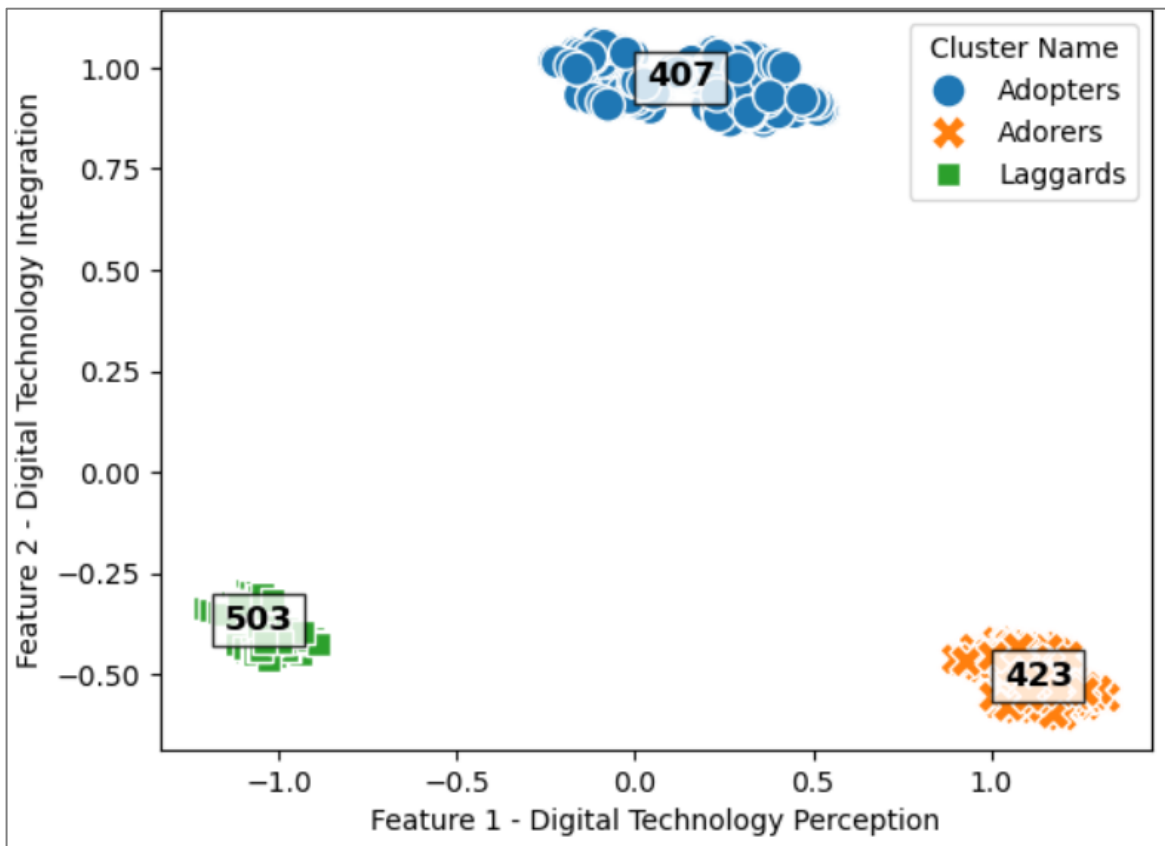


Figure 3: Pattern of digital technology integration in learning by educators

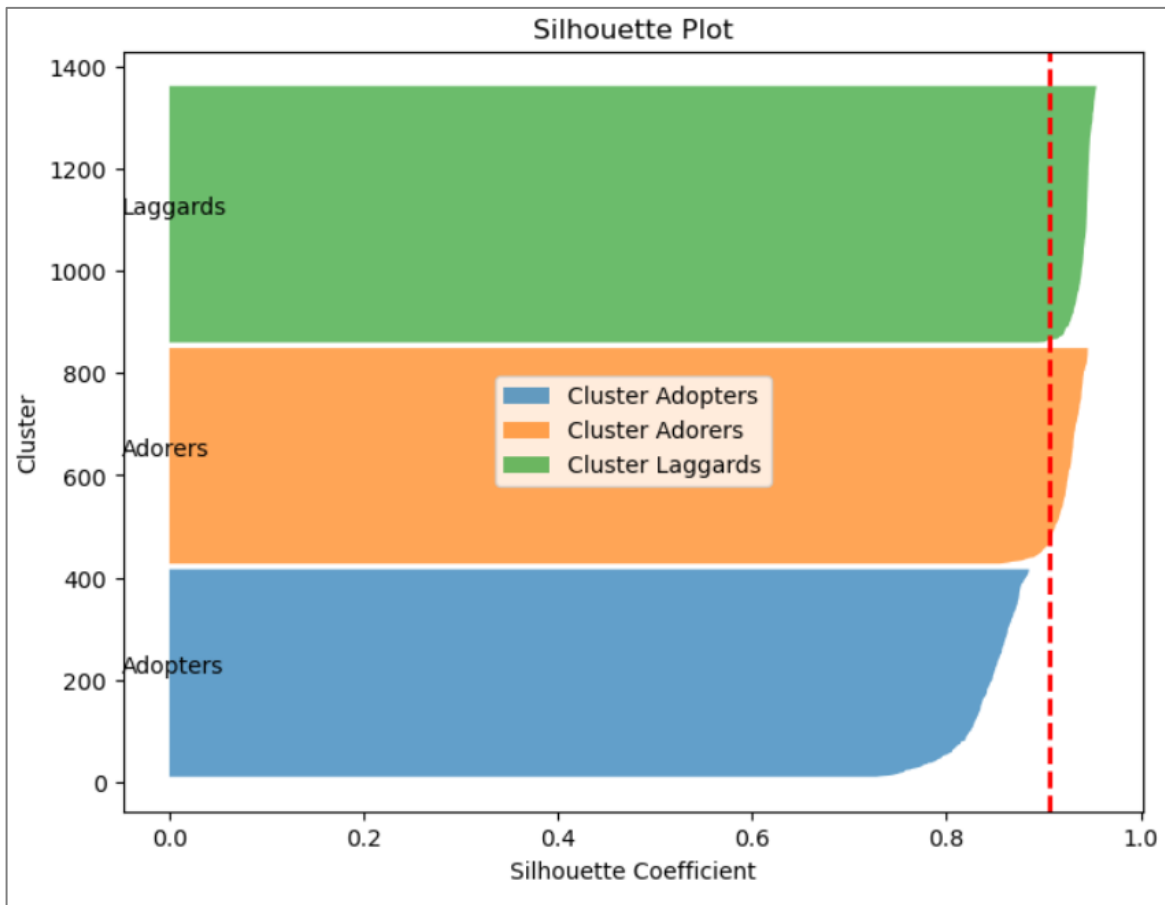


Figure 4: Silhouette plot for educators' clusters

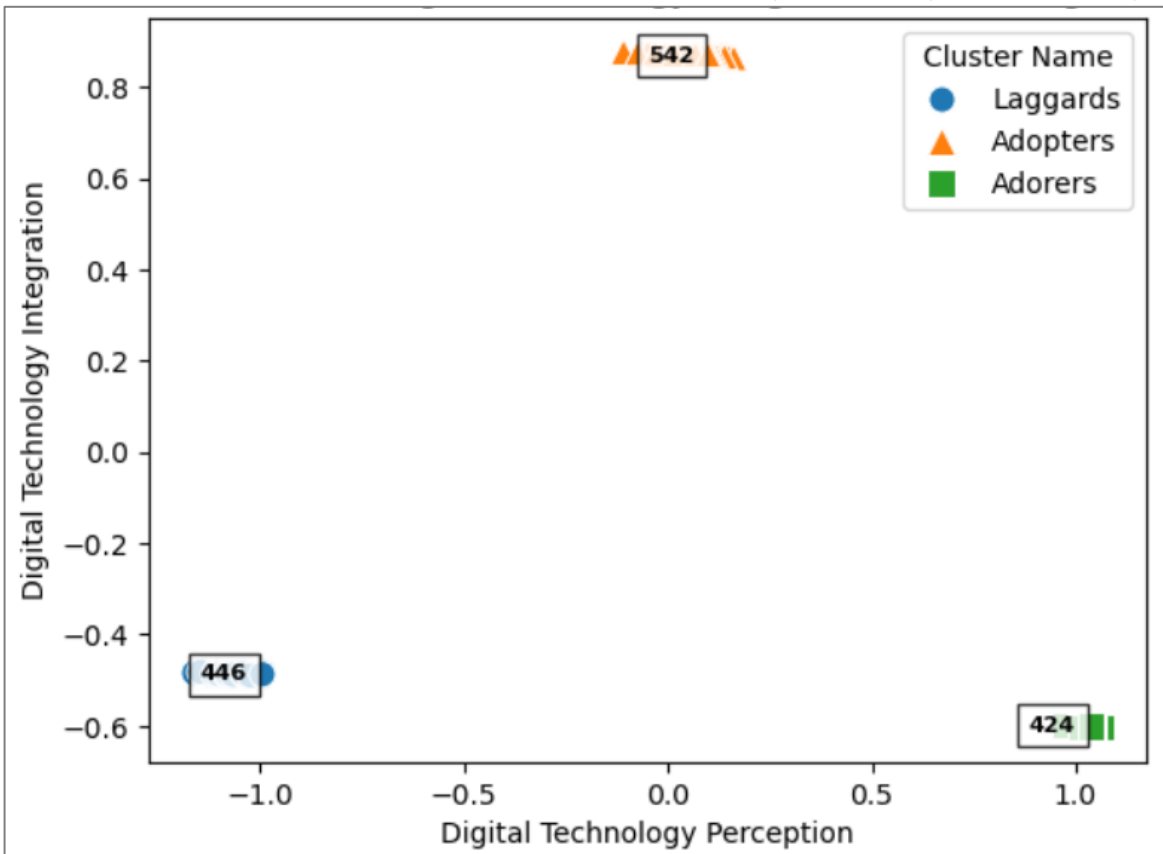


Figure 5: Pattern of digital technology integration in learning by student

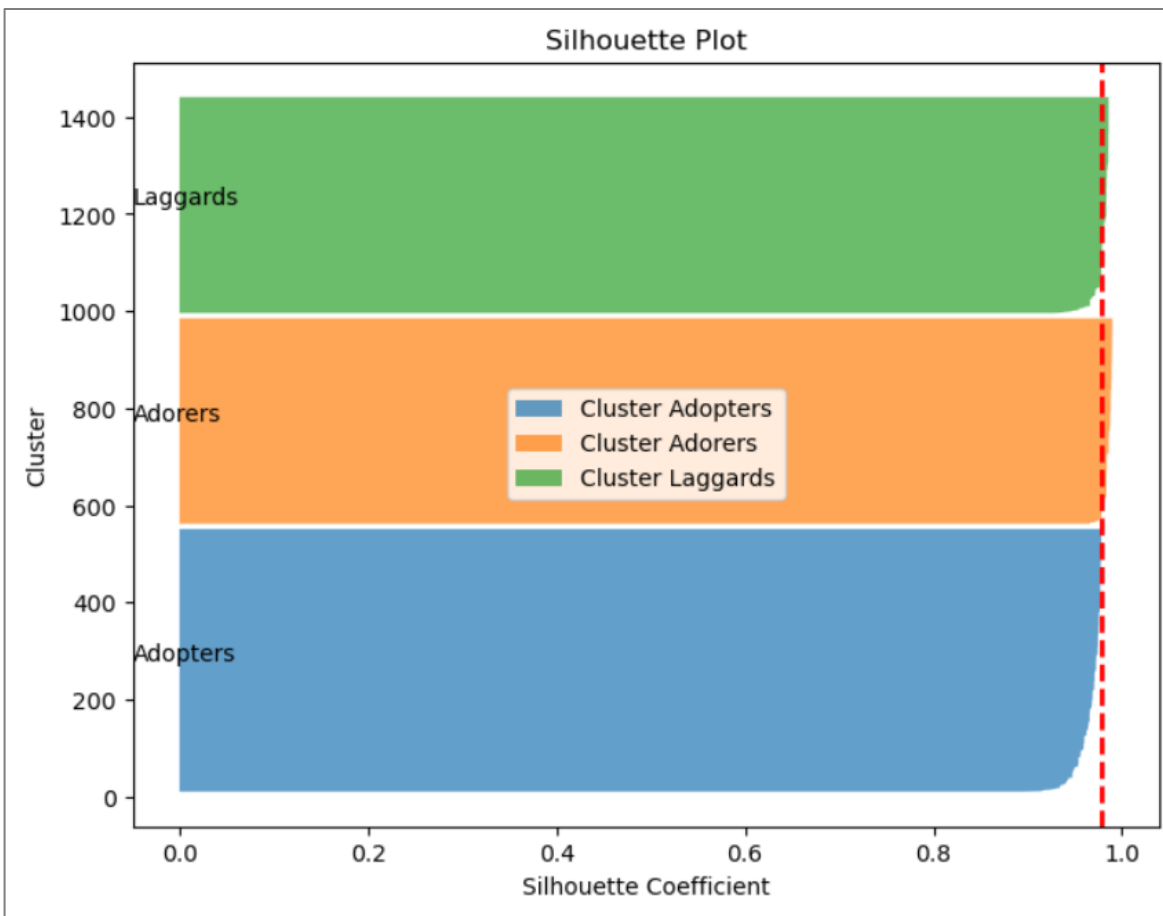


Figure 6: Silhouette plot for students' clusters

The clustering analysis revealed that 38% of the educators have low perception of the benefit of digital technology integration in academic activities. However, 62% (adorers and adopters) of educators understand the benefits of

digital technology for academic activities in higher education. This distribution reflects the UTAUT construct of performance expectancy, where the individual's perception that technology will improve academic tasks directly influences the likelihood of adoption. The presence of a sizable low-perception group suggests that performance expectancy remains a critical factor in technology adoption among educators in HEIs in Nigeria. This is similar to the findings of Chahuán-Jiménez et al. (2025), who assessed digital competencies among educators in higher education and found that educators fall within intermediate to higher levels. Furthermore, the perception and level of digital technology integration among students show a pattern similar to that of educators, but the majority of students are adopters. Kim et al. (2023) assessed students' engagement on an asynchronous online platform using K-means clustering, which classified students into low and high engagement groups based on behavioral, emotional, and cognitive aspects in online learning environments. García-Morales et al. (2021) suggested that limited access to digital tools and services, as well as a lack of digital skills, can hinder the integration of digital technology into pedagogy, consistent with differences in effort expectancy and performance expectancy described in the UTAUT model.

These findings suggest the need for sufficient digital technology resources in higher education and for strategies to support educators and students with low perceived benefits and limited integration of digital technologies into academic activities, further emphasizing the importance of facilitating conditions for technology adoption. In addition, professional development will advance educators' digital skills, leading to increased digital technology integration by adopters and encouraging laggards to understand the benefits of digital technology and integrate it into academic activities. These challenges correspond to the UTAUT assertion that favorable and organizational conditions are necessary for sustained technology use.

Generally, educators and students have a positive perspective on the benefits of digital technology, reflecting strong performance expectations, which suggest the need for a framework that will motivate educators and students to use it in teaching and learning. Thus, the findings inform targeted interventions by developing a digital transformation framework enhance engagement, digital readiness, and effective technology adoption in higher education institutions (Kim et al., 2023; Händel et al., 2020; Chahuán-Jiménez et al., 2025; Maylawati et al., 2020).

## CONCLUSION

The advancements in digital technology for teaching, learning, and research have shifted the learning paradigm from teacher-centered to student-centered. By eliminating time and location barriers to educational resource access, the incorporation of technology into teaching and learning will enhance educational quality and foster collaboration between educators and students. This study used K-means

clustering to investigate patterns of digital technology integration in teaching and learning by educators and students at Nigerian higher education institutions. The K-means clustering results provide valuable insights into students' and educators' perceptions of digital technology integration in higher education. The study's findings highlight three clusters among educators and students: laggards, adorers, and adopters. The laggards are educators and students with low level of digital technology integration and very low perception of its positive impact in academic activities. The adorers are those with a low level of digital technology integration but a high perception of its positive impact, whereas the adopters are those with a high level of digital technology integration and a moderate perception of its benefits in academic activities. The findings also highlighted that the majority of educators and students have a positive view of the integration of digital technology into teaching and learning.

Future research should investigate the use of a large-scale dataset to better understand the patterns of technology integration among educators and students in higher education institutions, as machine learning algorithms require large volumes of data to perform effectively. The functions of various clustering algorithms can be investigated to better understand how well they perform in assessing educators' and students' perceptions and use of digital technology in academic activities. Lastly, as AI in education advances, it is possible to investigate how stakeholders view its use and acceptability in teaching and learning.

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**APPENDIX**

**A Framework for Technology Integration in Academic activities based on Machine Learning Techniques.**

**Section A: Demographic information**

For questions under this section, please tick (√) one choice that is applicable to you.

1. What is your gender?  Male  Female  Neutral
2. Which age group are you?  18 -28 years  29-39 years  40-50 years  51-above
3. What is your marital status?  Married  Single  Divorced
4. How long have you been Lecturing?  0-5year  6-10year  11-15years  16 - above
5. What is your highest level of Qualification?  Bachelor's  Masters  Doctorates
6. What is your Rank?  Graduate Assistant  Assistant Lecturer  Lecturer II  Lecturer I  Senior Lecturer  Professor
7. Which College/Faculty are you?  Sciences  Management Science  Social Science  Medicine  Pharmacy  Art & Humanities  Education

**SECTION B**

Please (Tick √) in spaces provided to indicate your best choice against each statement using the ranking provided below.

**Rank: SA=Strongly Agree (1), A=Agree (2), N=Neutral (3), D=Disagree (4), SD=Strongly Disagree (5).**

Code	Question Items	SA	A	N	D	SD
	<b>Perceive Usefulness</b>					
PU1	The use of DT makes learning process more effective					
PU2	DT has no benefit in instructional delivery					
PU3	DT can improve teaching performance					
PU4	DT aids the creation of various learning activities					
PU5	Students comprehend better when DT is used in teaching					
PU6	DT tools facilitate the explanation of concepts					
	<b>Ease of Use</b>					
EU1	DT provides ease in learning activities					
EU2	DT provides ease of controlling and monitoring student activities					

EU3	DT makes assessment easier					
EU4	DT provides ease of meeting the needs of learning resources					
EU5	Technical challenges often arise when using DT					
EU6	DT enhances effective communication with students					
	<b>Self-Efficacy</b>					
SE1	Ability and knowledge of DT determine its integration into academic activities.					
SE2	Educators' confidence of DT usage can lead to better learning					
SE3	Ability to choose DT tool for teaching influence learning outcome					
SE4	Ability to solve problems when using DT tools influence its usage					
SE5	Continuous usage of DT tools in learning activities demonstrates educator's capacity and skills					
SE6	An educator's knowledge of DT does not influence its usage					
	<b>Workload Capacity</b>					
WL1	Using DT tools simplify the whole teaching processes					
WL2	The use of DT tools is best suited for large size of class					
WL3	Students comprehend quickly when DT tools are used					
WL4	It is simple to do research/project with the aid DT tools					
WL5	I can supervise many students with the support of DT tools					
WL6	My services to community are mediated by the use of DT tools					
	<b>Institutional Culture</b>					
IC1	There should be penalty for not using DT tools in teaching					
IC2	Exam questions are safe to be shared via email					
IC3	Trainings on new DT Innovation should always be organized					
IC4	Internet connectivity availability across the campus eases learning & research.					
IC5	The available DT tools align with all the course content needs.					
IC6	Educator is best suited for sourcing DT tools for teaching					
	<b>Educational Value</b>					
EV1	The use of DT in teaching can facilitate students centred learning					
EV2	The use of DT in teaching can prepare students for their future career					
EV3	DT improves student understanding of educational activities					
EV4	The use of DT improves my teaching quality					
EV5	The use of DT keeps me update on its application in teaching					
EV6	Students' performance depends on effective use of DT					
	<b>Teaching Impact</b>					
TI1	The use of DT in academic activities makes students work more actively and problem based.					
TI2	ICT usage improves student confidence and skills					
TI3	Learning is made more meaningful when ICT is incorporated					
TI4	DT improves quality of learning					
TI5	The use of ICT has improved my pedagogical skills					
TI6	ICT simplifies preparation and conducts of instructional delivery					
	<b>Learning Environment features</b>					
LEF1	Availability of DT tools encourages technology integration					
LEF2	Learning environment must be compliant for digital technology integration in academic activities to be successful.					
LEF3	The nature of learning environment determines the level of DT use for academic activities.					
LEF4	Laboratories should always be separated from classes					
LEF5	Technological tools should be made available during lecture period only					
LEF6	Students should always have access to laboratories with or without educators					
	<b>Professional Development</b>					
PD1	DT training impact academic activities outcomes					
PD2	Educator's choice of training development impact integration process					
PD3	Pedagogical training of ICT has no impact on integration process					
PD4	ICT Training related to academic discipline improves integration process					
PD5	Continuous ICT training ensures continuous integration process					
PD6	Self-development of ICT skills is educator's responsibility					
	<b>Technology Integration</b>					

TI1	Student comprehend faster when DT tools are used to support the learning process					
TI2	I develop new skills while using ICT tools in teaching process					
TI3	Using ICT tools have simplify my teaching process					
TI4	I should always use LMS for management of class activities					
TI5	My communication with students has always been effective using DT tools					
TI6	Technology integration in teaching, research and learning should be the norm of modern teaching.					

Adapted from [Mahdum et. al., \(2019\)](#)