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PAPER

A Comprehensive Analysis of Faculty Adoption of Cloud Computing E-Learning in Ghanaian Technical Universities

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ABSTRACT

Cloud-based e-learning is a technology used to enhance teaching and learning in universities. However, its adoption in technical universities is low, and research into the factors influencing teacher adoption is limited. To address this situation, a study was conducted at Ghanaian technical universities to examine the determinants of teachers' adoption of cloud-based e-learning. The study involved 1258 respondents, the majority of whom were male (853, or 67.8%), aged between 30 and 40 (47%), and 79.1% had a master's degree. The results showed that individuals with a master's degree had a higher level of knowledge of cloud-based e-learning compared to those with a bachelor's, doctorate, or another master's degree in technology. The study identified seven factors influencing the use of cloud-based e-learning, including pedagogical innovation, e-infrastructure readiness, cloud-based e-learning security, university location, the usefulness of cloud-based e-learning, and provider support. Interestingly, the cost of cloud-based e-learning had no significant impact.

KEYWORDS

cloud computing, e-learning, Ghanaian technical universities, multiple regression

1 INTRODUCTION

The field of education is undergoing a major transformation, with cloud computing becoming increasingly popular in educational institutions worldwide. It has become increasingly popular in educational institutions worldwide [1], including technical universities in Ghana. As a result, educational institutions around the world are taking advantage of their inherent ability to transcend geographical boundaries and time restrictions [2], [3]. According to [4], "instructors around the world have been at the forefront of implementing hybrid learning spaces for knowledge transmission." Through the utilization of virtualized resources [5] and

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its capacity to offer seamless accessibility, cloud-based e-learning has effectively surpassed the limitations imposed by traditional physical classrooms [6]. "*University teaching has had to undergo major transformations, moving from a face-to-face environment to an online learning space*" [7]. In the context of Ghanaian technical universities, the emergence of cloud-based e-learning has the inherent ability to bring about a paradigm shift in the delivery and acquisition of education. The implementation of cloud-based e-learning in Ghana's technical universities offers several advantages, including greater reliability, scalability, adaptability, storage of e-learning materials, collaboration between staff and learners, and accessibility of educational resources worldwide. In a developing country like Ghana, it appears that the majority of higher education institutions still lack in terms of performance and utilization of technology in the classroom [6]. The lack of resources and infrastructure can be seen as a major obstacle to the implementation of educational technologies in these institutions. Several studies have been conducted in higher education institutions in Ghana on the factors influencing user integration of e-learning through cloud computing [6], [8–10].

However, all this research has focused on universities other than technical universities, commonly referred to as "traditional universities" in Ghana. The significant gap in research on the utilization of e-learning through cloud computing by technical universities deserves attention. In this context, the present study examines the factors influencing teachers' utilization of e-learning through cloud computing in Ghanaian technical universities. The present study is necessary in Ghanaian technical universities because most of their teaching and learning activities are practice-oriented. We visited all ten technical universities in Ghana and explained the purpose of the research to the faculties. We didn't want to limit ourselves to a sample; instead, we aimed to involve all faculty members and justify our mission by visiting all the technical universities. We sought to achieve the following three research objectives:

1. Investigate teachers' perceptions of integrating cloud computing and e-learning into their teaching practices.
2. Identify factors influencing teachers' decisions to adopt cloud computing in e-learning.
3. Identify the primary factors influencing teachers' adoption of cloud computing e-learning in technical universities in Ghana.

This study utilized empirical data from a questionnaire survey conducted at ten technical universities in Ghana to investigate the factors that teachers consider when utilizing cloud computing for e-learning. The study is divided into four sections: introduction, methodology, data review and interpretation, and results and analysis. The results of this study have implications for both theory and practice. In terms of theory, this study contributes to the literature on the adoption of cloud-based e-learning and offers a solid framework for teachers in Ghanaian technical universities. In practical terms, this study offers an overview of the development and utilization of cloud-based e-learning in Ghanaian technical universities, highlighting essential factors for stakeholders to take into account.

The remainder of this paper is organized as follows: Section 2 begins with a review of the relevant literature. Section 3 discusses the research design and data collection process. The results are presented in Section 4, and the discussion follows in Section 5. Section 6 concludes the paper with a discussion of the study's limitations and future research directions.

2 RELATED WORK

2.1 Cloud computing e-learning in Ghana

E-learning is a term that lacks a precise definition and is typically defined from the author's perspective, as it continuously evolves with technological advancements. Different researchers have defined e-learning based on specific contexts. We define e-learning as the use of information and communication technologies (ICT) to enhance the teaching and learning process. ICT is evolving rapidly, driving innovations in education such as "smart education," that is, intelligent students, advanced pedagogy, and innovative learning environments [11]. This evolution has also led to the creation and rapid launch of numerous innovative e-learning services and applications [12]. As a result, individuals and institutions are making significant investments to adapt [13], [14].

Over time, e-learning has evolved into Internet-based e-learning (cloud learning) due to the widespread adoption of the World Wide Web (WWW) [15–17], in particular cloud services. Cloud computing has become a contemporary framework that offers streamlined network access to computing resources at a reduced cost [14], [18–20]. Cloud-based e-learning has grown in popularity in recent years because it offers numerous benefits to learners and educators, including scalability, accessibility, cost reduction, and personalization [14], [19], [21], [22].

Cloud-based solutions are designed for exceptional reliability and accessibility. As a result, e-learning platforms and electronic resources can be accessed 24 hours a day, seven days a week, without any downtime or interruptions. The use of electronic technologies for delivering educational content has become significantly important in the Ghanaian context [8], [9], [23–25]. According to a study by [26], most higher education institutions in Ghana have implemented e-learning practices by utilizing learning management systems (LMS) to enhance teaching and learning. Ghanaian universities, such as the Kwame Nkrumah University of Science and Technology (KNUST), the University of Ghana (UG), the University of Cape Coast (UCC) and the University of Education Winneba (UEW), have implemented programs delivered through e-learning [27]. Unfortunately, this study was conducted at non-technical universities. However, when comparing Ghana with other developed countries, it is clear that many schools in these countries have sufficient infrastructure and practices for e-learning programs, so their readiness to transition to online teaching and learning is not far-fetched [28]. Cloud-based solutions enable learners to easily access e-learning platforms and electronic materials from any location with Internet access. However, cloud-based e-learning also poses certain challenges and barriers to adoption, especially within higher education institutions. Several factors influence whether or not teachers adopt cloud computing e-learning at a university [6], [29–32]. The security and ease of use of cloud-based e-learning, the competitive pressure on teachers, and the lack of adequate infrastructure remain major obstacles to the successful implementation of technological advances. The most common but significant problems in e-learning are the lack of reliable servers capable of hosting integrated and comprehensive e-learning solutions, the absence of virtual laboratory facilities, inadequate preparation of the e-learning environment and its fundamental instruments, and electronic courses (e-courses) that are not yet fully developed or ready for implementation. The problem of inadequate Internet speed and limited bandwidth capacity is a source of concern [33–35]. Little research has been conducted on e-learning in Ghana, especially in higher education institutions [23], [24], [36–38]. Previous studies have mainly focused on "traditional universities"

rather than technical universities. This study aims to fill the gap by focusing specifically on Ghana's technical universities.

2.2 Recent developments in cloud computing e-learning

Researchers and educators have shown considerable interest in the latest advances in cloud-based e-learning. Cloud-based e-learning has been recognized as a versatile and scalable method of delivering educational programs [39]. Research has revealed a growing use of cloud-based e-learning systems in educational institutions, including colleges, universities, and schools [14]. The integration of cloud computing technology into e-learning infrastructure has been recognized as an upcoming trend, emphasizing the use of ICT to enhance the quality of teaching and learning [40]. In addition, the use of cloud computing has facilitated the emergence of cloud-based e-learning systems, which utilize this technology to enhance online learning [41]. Studies have also focused on identifying the key features that contribute to the success of cloud-based e-learning. These include the ability of cloud services to handle issues, the level of technology available to schools, and the readiness of organizations [42]. In addition, the acceptance of cloud-based e-learning is influenced by elements such as perceived usefulness and necessity, highlighting the importance of understanding users' motivations and attitudes towards cloud-based e-learning systems [19]. The issue of security and access control in cloud-based e-learning systems has been addressed by developing secure e-learning systems that integrate group key mechanisms and access control functions. These systems utilize cloud computing to offer secure and flexible access to e-learning [43]. Furthermore, the empirical study conducted by [44] examined the effects of using cloud computing, revealing its ability to enhance the provision of e-learning services in educational institutions. The research also focused on the architecture and design of cloud-based e-learning systems. Proposals have been made for efficient cloud architectures for lifelong online education as well as for the development of systems to manage multi-tenant learning processes in cloud computing environments [45]. In addition, the integration of cloud computing technology has led to the development of intelligent learning services that offer tailored and individualized learning experiences, utilizing context awareness and cloud-based resources [45].

2.3 Factors affecting the use of cloud computing in e-learning

Several studies have examined in detail the factors influencing the use of cloud computing in e-learning environments. Numerous critical success factors (CSFs) have been identified in the literature for the effective deployment of cloud-based e-learning [46], [47]. [48] identified several key factors that impact the adoption of security measures in organizations, including aspects such as security, confidentiality, integrity, availability, trust issues, and vendor influence. In addition, [49] identified perceived usefulness, self-efficacy, and trust as significant factors that have a positive impact on the application of cloud computing technology in higher education institutions. In addition, the technology-organization-environment (TOE) framework has been used to classify the factors influencing the use of cloud computing in the technological, organizational, and environmental domains [50]. The slow adoption of cloud computing can be attributed to challenges such as limited awareness of cloud computing and apprehensions about job displacement within the IT workforce [51].

Conversely, security and privacy concerns had a negative impact on the willingness to adopt cloud computing in the Saudi banking sector [52]. The study of cloud computing implementation in Nigeria revealed that perceived usefulness, perceived ease of use, and attitude toward cloud computing are important factors determining its adoption [53]. In addition, obstacles encountered in the use of cloud computing in university administration in Nigeria include security issues, electrical problems, and file vulnerabilities [54]. Compatibility and readiness have been recognized as key factors in improving the effectiveness of cloud computing implementation within public organizations [55]. Nevertheless, the utilization of cloud computing by public organizations is impeded by information security concerns, despite the significant demand for cloud computing [56].

In addition, a theoretical framework for the approval of cloud-based e-learning in Saudi Arabia highlighted the importance of competitive pressure, business partner pressure, relative advantage, top management support, and organizational size in attitudes towards cloud adoption [57]. Ultimately, cloud integration in e-learning environments is influenced by various aspects, such as security cancerns, organizational support, perceived usefulness, and readiness. A comprehensive understanding of these elements is essential for the successful adoption of cloud-based e-learning systems.

We sought to address the following research questions:

- How do teachers perceive the use of cloud computing in e-learning for their teaching and learning processes?
- What factors influence teachers' decisions to adopt cloud computing in e-learning?
- What are the main determinants of teachers' adoption of cloud computing e-learning in technical universities?

3 MATERIALS AND METHODS

3.1 Research methodology

The study utilized a quantitative research approach, specifically a questionnaire survey, to collect data on the implementation of cloud-based e-learning by teachers at ten technical universities in Ghana. Quantitative research methods, such as questionnaire surveys, offer numerous advantages, including scalability, efficiency, and empirical associations. They enhance understanding and help identify effective practices in large samples at a low cost and within a short timeframe [58–60]. The questionnaires were adapted from previous studies [61–66] and designed based on the results of the literature review. The survey instrument consisted of 33 items measuring the desire to adopt cloud computing e-learning using a five-point Likert-type scale where 1 = "strongly disagree"; 2 = "disagree"; 3 = "neutral"; 4 = "agree"; and 5 = "strongly agree." A pilot survey was conducted at a private university, and the survey instrument was reviewed for content validity by an expert panel.

The study involved 1,395 lecturers from 10 universities, covering 1,778 active members of the Technical Universities Association of Ghana (TUTAG). Out of the 1395 questionnaires distributed, 1258 were returned, indicating a return rate of 90.2%. The issue of missing data was addressed by employing Little's multivariate test for missing completely at random (MCAR) and the expectation maximization (EM) algorithm methods. The research analysis was conducted using IBM SPSS (version 27) [67] and Jamovi (version 2.4) [68] software. IBM SPSS Statistics is a

widely used statistical software package that offers an intuitive interface, a wide range of statistical processes, and the ability to analyze diverse data sources across multiple disciplines. However, it is expensive. On the other hand, Jamovi is a free statistical program with an aesthetically pleasing and user-friendly interface. The software performs calculations in real-time, displays results with visually appealing graphs, and provides well-organized APA tables in the output window.

A three-step analysis was performed, as shown in Figure 1. We first examined the descriptive statistics of the constructs. Mean scores and standard deviations for each of the 33 items measuring variables influencing cloud computing e-learning adoption, as provided by respondents, were calculated using Jamovi statistical software. This was followed by an inspection of the means and standard deviations of the constructs. Descriptive statistics summarize and describe the main characteristics of a data set, helping to understand the central tendency, variability, and distribution. They make it possible to visually represent the shape and distribution of data.

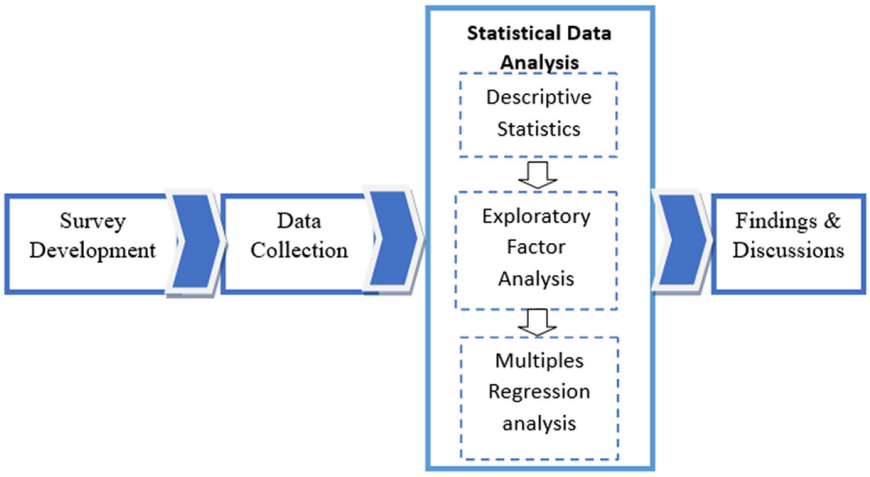

Fig. 1. Research methodology

Secondly, we utilized principal component analysis (PCA), a dimension reduction method, to organize the subscale items into constructs. According to [69], PCA is best used when the analysis aims to group highly correlated observed or measured indicators into a smaller number of factors or constructs. This was followed by a reliability analysis to ensure that each construct holds together well. It assesses the extent to which a group of observed variables, or items, may be combined into a unified scale.

The third analysis conducted involved multiple regression analysis using IBM SPSS Statistics. The purpose of this analysis was to examine the variance explained (R2) by the independent variables (factors) and identify and compare the relative strengths of the factors influencing the adoption of cloud-based e-learning by technical university lecturers. According to [70] and [71], multiple regression analysis can identify significant predictors associated with a dependent variable, accommodate multiple independent variables, and provide a more comprehensive understanding of the underlying relationships, leading to more accurate estimations and predictions.

3.2 Demographics

Of the 1,258 respondents, 853 (67.8%) were male and 405 (32.2%) were female. The majority of participants were between 30 and 40 years old (47%), followed by

those aged 41–50 (34.2%), under 30 years old (6%), 51–60 years old (10.3%), and others. 60 years old (2.5%). Their educational levels reveal that most participants held a master's degree (79.1%), followed by a doctorate or DTech (16.4%), and a bachelor's degree (4.5%). The number of professors from each technical university is presented in Figure 2. The chart displays the distribution of the 1,258 professors who participated in the study across various technical universities in Ghana. The average number of professors in each technical university is 125.8, and the average percentage of professors in each technical university is 10%.

It shows that Kumasi Technical University, with 141 professors, representing 11.2% of the total, had the highest number of respondents among the universities in the study. The least popular technical university is Tamale Technical University, with 108 students, accounting for 8.6% of the total.

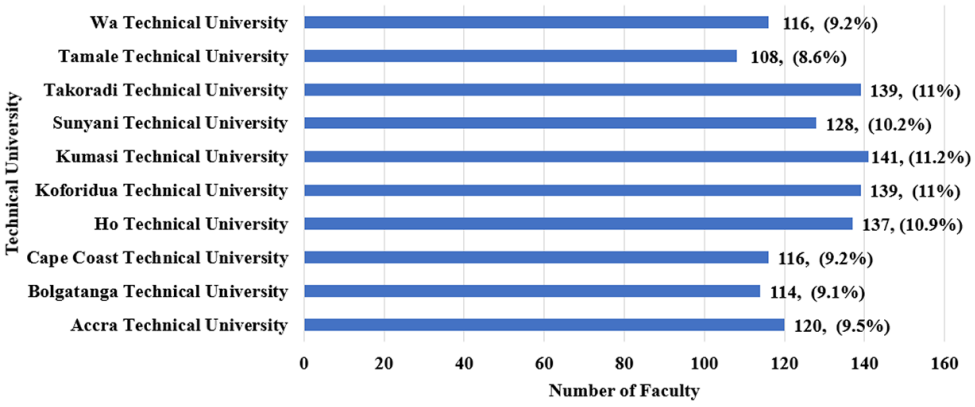

Fig. 2. Number of lecturers from each technical university

3.3 Respondent's knowledge level about cloud computing e-learning

Respondents were asked to indicate if they have a sufficient understanding of cloud computing and e-learning. The result is illustrated in Figure 3. From Figure 3, it is evident that their concept of cloud computing e-learning revealed that a majority of the respondents had a high knowledge of cloud computing (51.4%), while 48.6% reported low knowledge, as shown in Figure 3.

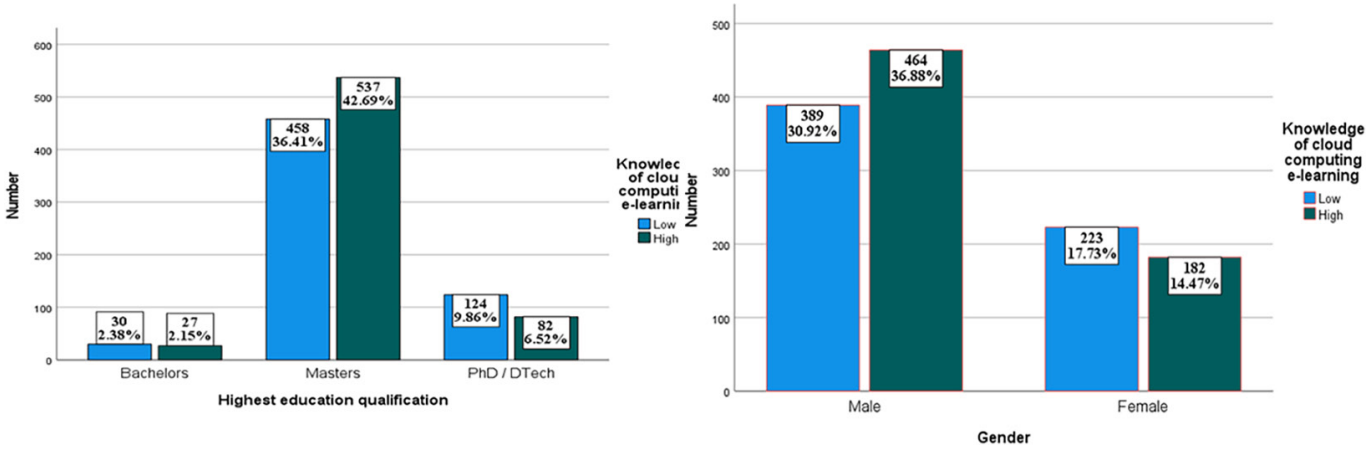

Fig. 3. Distribution of respondents' knowledge level of cloud computing e-learning in terms of education level and gender

The study examined lecturers' knowledge of cloud computing e-learning, focusing on their education level and knowledge level. The results suggest that there are more master's degree holders with a higher level of knowledge, 537 (42.69%), than those with a lower level, 458 (36.41%), of cloud computing e-learning. The gender ratio of lecturers with low and high knowledge was also examined. The results showed more male lecturers than female lecturers in both groups, with the difference being more pronounced in the high-knowledge group. The low-knowledge group had a higher percentage of female lecturers than the high-knowledge group.

4 MAIN RESULTS

4.1 Foreword

We investigated the utilization of cloud computing e-learning among faculty members at Ghanaian technical universities using a five-point Likert scale. Table 1 shows that members generally agreed with most subscale items, as indicated by high mean values exceeding 3.5 (90.91%), except for three items with means of 3.30, 3.39, and 3.33. The average rating for the availability of infrastructure to access cloud computing and e-learning is 4.20, indicating a high level of agreement. The data also revealed varying degrees of consistency in lecturers' responses, with the minimum standard deviation value of 0.72 indicating uniformity. The highest standard deviation value of 1.24 indicates low consistency, possibly due to socio-cultural factors in the university's geographical setting. The study also revealed differences and similarities among individual items within each subscale. Items related to cloud computing e-learning usefulness and simplicity showed high mean values, while items concerning security and cost exhibited low mean values and low standard deviation values.

The study reveals that teachers generally have positive perceptions of the usefulness and simplicity of cloud computing in e-learning, as indicated by high mean values and low standard deviation values. However, they have a less favorable view of safety and cost. Most teachers chose "agree" or "strongly agree" for most concepts, indicating a positive perception of the factors that influence their adoption of cloud computing e-learning.

Table 1. Descriptive statistics of cloud computing e-learning subscale items

No	Subscale Items	Mean	SD
1	It enhances access to instructional information for lecturers, researchers, and learners.	**3.73**	**1.03**
2	By using cloud computing and e-learning, I can complete my teaching tasks more quickly.	**3.87**	**1.02**
3	Cloud computing allows my students to access teaching and learning materials from anywhere and at any time	**3.93**	**0.88**
4	I can use simulation software and supporting hardware to teach practical skills in a virtual lab.	**3.92**	**0.75**
5	Cloud computing e-learning improves teaching and learning delivery quality.	**4.03**	**0.79**
6	Cloud computing e-learning is a source of security concern for both teachers and students	**3.55**	**1.04**
7	The maintenance and support costs for cloud computing e-learning applications are high.	**3.81**	**0.94**

(Continued)

Table 1. Descriptive statistics of cloud computing e-learning subscale items *(Continued)*

No	Subscale Items	Mean	SD
8	Cloud computing service providers offer incentives to attract customers.	**4.13**	**0.75**
9	Cloud Computing service vendors offer free training sessions for Cloud Computing e-learning users	**4.03**	**0.80**
10	Cloud Computing service vendors provide technical support for effective use of Cloud Computing e-learning	**4.07**	**0.72**
11	E-learning data saved in the cloud will be very safe since cloud computing technologies are more secure than traditional computing.	**3.94**	**0.82**
12	I am very satisfied with the security environment of a Cloud e-learning system.	**3.63**	**1.07**
13	I can access and use Cloud computing e-learning technology anywhere and at anytime	**4.07**	**0.85**
14	I can easily manage and track students' performance online	**3.91**	**0.92**
15	Cloud computing e-learning technology platforms and contents can be tailored to my preferences.	**3.30**	**1.14**
16	I have the necessary tools/computer to use cloud computing e-learning	**3.79**	**0.99**
17	I use cloud computing e-learning technology because of the socio-culture of the location of my university	**3.39**	**1.24**
18	The use of cloud computing e-learning technology is economical because of the location of my university	**3.71**	**1.17**
19	Internet connection is readily available to access Cloud Computing.	**3.57**	**1.05**
20	Internet connectivity is reliable for access to cloud computing e-learning.	**3.73**	**1.02**
21	Cloud computing e-learning enables smart interactions with my students.	**3.77**	**0.85**
22	It improves the process of teaching and learning. (making instruction easier).	**3.86**	**1.00**
23	It is expensive to use Cloud Computing e-learning for my daily teaching and learning activities	**3.82**	**0.98**
24	It makes it easier for educational solutions to be delivered quickly.	**3.90**	**0.99**
25	The competent professionals at my university are equipped with the necessary knowledge to implement cloud computing e-learning.	**3.87**	**0.89**
26	The cost of live practical training can be very expensive using a cloud	**3.58**	**1.00**
27	The introduction of a cloud-based e-learning system is compatible with our current information technology infrastructure.	**3.75**	**0.99**
28	A cloud-based e-learning system protects data from unauthorised access, modification, or use.	**3.70**	**1.03**
29	The use of Cloud computing e-learning offers new opportunities for educational service delivery.	**3.75**	**0.97**
30	I use cloud computing e-learning technology for my lectures because of the location of my university	**3.42**	**1.13**
31	The use of Cloud computing e-learning technology offers new opportunities for me because of the location of my university	**3.33**	**1.14**
32	There is the required infrastructure to access Cloud Computing e-learning.	**4.20**	**0.72**
33	Unauthorised access to data may be exploited by perpetrators with malicious intent (both inside and outside the cloud).	**3.63**	**1.07**

4.2 Dimension reduction of factors influencing the adoption of e-learning in cloud computing

As noted previously in the methodology section, we employed exploratory factor analysis (EFA) to investigate the factors influencing faculty members' decisions to adopt cloud computing for e-learning. This was done to address our research question.

Before proceeding with factor extraction, the Kaiser-Meyer-Olkin (KMO) test, which assesses sampling adequacy, and Bartlett's test of sphericity were conducted. These tests are essential for determining the suitability of the data for factor analysis. The KMO test assesses sample adequacy by quantifying the ratio of variance between variables, while the Bartlett test examines the presence of correlations between variables. According to [72] and [73], for factor analysis to be considered appropriate, the KMO index must be equal to or greater than 0.50, and Bartlett's test of sphericity must yield a significant result ($p < 0.05$). The results are presented in Table 2. The obtained KMO value of 0.826 and the significant result of Bartlett's test of sphericity with a p-value less than 0.001 suggest that the dataset was sufficiently sampled, indicating that it is advisable to conduct a factor analysis on the appropriate data [74].

Table 2. KMO and Bartlett's test results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.826
Bartlett's Test of Sphericity	Approx. Chi-Square	10707.411
	df	465
	Sig.	0.000

Exploratory factor analysis was used to examine the underlying structure of the subscale items using PCA and variance rotation. The results presented in Table 3 (rotated component matrix) show that seven components remained with eigenvalues greater than 1, indicating a seven-factor solution. The determination of the number of components was supported by a scree plot, as shown in see Figure 4. The factor loading for each item was generally higher than the minimum values acceptable in an exploratory analysis (>0.4), which is a critical threshold that determines significant variables contributing to the underlying factors. The minimum factor loading in factor analysis has been the subject of controversy, with some advocating a minimum of 0.6 [75] and others suggesting 0.4 [76], [77]. The large sample size of the study resulted in loadings equal to or greater than 0.4, and two items with loadings less than 0.4 were removed. The results of the study provide valuable information on the factors contributing to the underlying aspects of the subscale items.

The PCA analysis reveals that the seven main components—educational innovation (EI), e-infrastructure readiness (ER), cloud computing e-learning security (CCeS), location of the university (UL), utility of cloud computing e-learning (CCe), cost of CCe, and vendor support (VS)—represent 53.93% of the total variance, with the first factor explaining 18.13%. This high percentage of total variance indicates a strong relationship between the variables in this study.

4.3 Reliability testing

The reliability test was conducted to assess the internal consistency of the subscale items and the accuracy of the PCA results using Cronbach's alpha coefficient test. Internal consistency is crucial for the reliability of a scale because it ensures that

the items measure the same construct. Reliability varies depending on the sample, so it is essential to check the reliability of each scale. Subscale scores for each extracted factor were converted to composite scores by calculating the average score for each composite factor based on the items loading on each factor. This provides a consolidated representation of the underlying constructs within the data. The generally acceptable minimum value for Cronbach's alpha is above 0.7, but short scales may have values below 0.7, while others report values above 0.9 [75]. According to [7], a score above 0.90 does not necessarily indicate high internal consistency but rather redundancy or duplication of items. The Cronbach Alpha test results in Table 4 are above the recommended value of 0.7, indicating that the questionnaire is suitable for data collection and study purposes.

Table 3. Rotated component matrix of factors influencing cloud computing e-learning

Construct	Items	Factors						
		1	2	3	4	5	6	7
Education Innovation (EI)	EI1	0.625						
	EI3	0.759						
	EI4	0.666						
	EI5	0.579						
	EI6	0.633						
	EI7	0.634						
E-infrastructure Readiness (ER)	ER1		0.663					
	ER2		0.721					
	ER3		0.685					
	ER5		0.611					
	ER6		0.537					
University Location (UL)	UL1			0.838				
	UL2			0.706				
	UL3			0.755				
	UL4			0.750				
Cloud Computing e-learning security (CCeS)	CeS1				0.503			
	CeS2				0.749			
	CeS3				0.719			
	CeS4				0.602			
	CeS5				0.646			
Cloud computing e-learning usefulness (CCeU)	CeU1					0.649		
	CeU2					0.679		
	CeU3					0.551		
	CeU4					0.415		
	CeU5					0.647		
Cost of cloud computing e-learning (CCe)	CCe1						0.797	
	CCe3						0.684	
	CCe2						0.720	

(Continued)

Table 3. Rotated component matrix of factors influencing cloud computing e-learning *(Continued)*

Construct	Items	Factors						
		1	2	3	4	5	6	7
Vendor support (VS)	VS1							0.723
	VS2							0.783
	VS3							0.774
Total Variance Explained								
Eigenvalue		5.62	3.03	1.95	1.78	1.74	1.34	1.26
Variance of each factor explained		18.13	9.77	6.30	5.75	5.61	4.33	4.05
Cumulative % Variance Explained		18.13	27.89	34.19	39.94	45.55	49.88	53.93
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization								

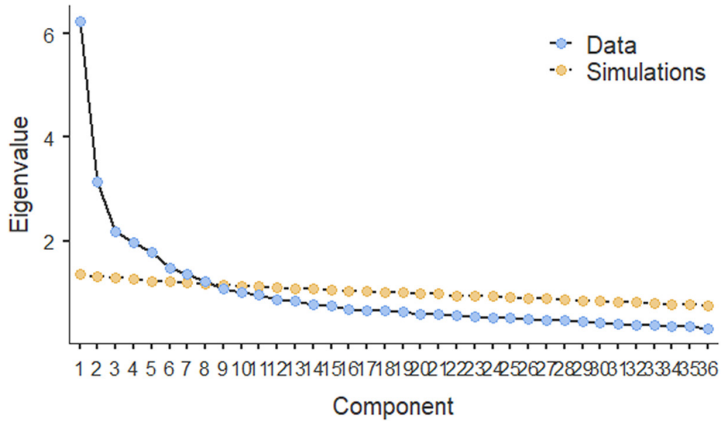

Fig. 4. Screen diagram of CSFs for adoption

Table 4. Results of Cronbach alpha values

Model	Item Reliability Test	
	No. of Items	Cronbach's Alpha
Cloud computing e-learning Adoption (DV)	5	0.704
Cloud computing e-learning usefulness (CCeU)	5	0.701
Cost of cloud computing e-learning (CCe)	3	0.709
E-Infrastructure readiness (ER)	5	0.745
Cloud computing e-learning security (CCeS)	5	0.706
University location (UL)	4	0.791
Vendor support (VS)	3	0.701
Education Innovation (EI)	6	0.749
Overall	36	0.849

Notes: a. Dependent Variable (DV): Cloud computing e-learning Adoption, b. Predictors: Cloud computing e-learning usefulness, Cost of cloud computing e-learning, E-Infrastructure readiness, Cloud computing e-learning security, University location, Vendor Support, and Education Innovation.

4.4 Predictors of cloud computing e-learning adoption

We conducted multiple regression analysis to investigate the correlation between the retrieved factors and identify the primary elements that influence the adoption of cloud computing in e-learning. This was undertaken to address our third research question. Multiple regression analysis is a reliable statistical method for evaluating the relationships between variables and making predictions. It is particularly useful when there is a need to consider the impact of multiple variables simultaneously (Çelik et al., 2018). To ensure the reliability of the regression analysis, an investigation was conducted to examine any potential concerns related to multicollinearity that could impact the accuracy of the results.

4.5 Investigating multicollinearity

According to [78], multicollinearity in models increases standard errors, modifies analysis outcomes, renders significant variables statistically insignificant, and augments variance in regression coefficients, making them unstable and presenting difficulties in coefficient interpretation. The variance inflation factor (VIF) and tolerance analysis are essential for detecting multicollinearity in multiple regression models. A VIF and tolerance analysis presented in Table 5 show that the VIF values for all factors range from 1.099 to 1.473, which is less than 10. The tolerance values range between 0.679 and 0.910, indicating that the variables are not highly collinear [74], and therefore regression analysis will not be affected.

Table 5. Tolerance and VIF for independence variables

Items	Tolerance	VIF
CCeU	0.751	1.332
CCe	0.779	1.283
ER	0.679	1.473
CCeS	0.784	1.276
UL	0.879	1.138
EI	0.866	1.155
VS	0.910	1.099

4.6 Multiple regression analysis

We used multiple regression analysis to examine the relationship between independent variables and the dependent variable. Multiple regression analysis was utilized in this study because it can identify significant predictors associated with a dependent variable [70], accommodate multiple independent variables [71], and provide a more comprehensive understanding of the underlying relationships, leading to more accurate estimations and predictions. Based on the data and the results in Table 6, six factors have a statistically significant influence and account for 24.1% of the total variance in the adoption of cloud computing e-learning by lecturers. This was determined using an F-test, with a coefficient of determination (R2) of 0.241 and an F value of 56.577 at $p < 0.001$. As can be seen in Table 6, the significant factors are

cloud computing e-learning (CCeU), ER, CCeS, UL, VS, and EI. However, VS influences the model negatively since it has a negative beta value of –0.130. Also, the beta coefficient of CCe is –0.007, with $p > 0.005$, indicating a weak negative relationship that is not statistically significant to the model.

Table 6. Multiple regression results between the dependent and independent variables

Model	Unstandardized Coefficients		t	Sig.	95.0% Confidence Interval for B	
	β	Std. Error			Lower Bound	Upper Bound
(Constant)	1.087	0.192	5.652	0.000	0.709	1.464
Cloud computing e-learning usefulness (CCeU)	0.072	0.030	2.396	0.017	0.013	0.130
Cost of cloud computing e-learning (CCe)	–0.007	0.027	–0.279	0.780	–0.060	0.045
E-Infrastructure readiness (ER)	0.350	0.032	10.936	0.000	0.287	0.413
Cloud computing e-learning security (CCeS)	0.132	0.030	4.374	0.000	0.073	0.192
University location (UL)	0.099	0.021	4.655	0.000	0.057	0.141
Education Innovation (EI)	0.162	0.035	4.619	0.000	0.093	0.231
Vendor support (VS)	–0.130	0.032	–4.029	0.000	–0.194	–0.067

Notes: *F = 56.577, $p < 0.05$, $R^2 = 0.241$, Adjusted R Square = 0.236.

Furthermore, we identified the factors that significantly influence the adoption of cloud computing in e-learning by lecturers and ranked them based on the magnitude of their beta values, as shown in Table 6. The beta value in the coefficient table represents the individual contribution of each predictor to the model. A larger beta value indicates a stronger influence on the dependent variable, and vice versa. The result indicates that e-infrastructure readiness (ER) has a beta value of 0.350, suggesting it has the highest relative influence among the seven factors in cloud computing e-learning adoption. This is shown in Figure 5 to visualize their relative contribution. It is followed by education innovation (EI) with a value of 0.162 and CCeS with a value of 0.132. Vendor support is the least contributing factor in the analysis of e-learning adoption in cloud computing.

In Figure 5, the height of each bar indicates the level of influence of each factor on the model. Vendor support has a negative influence on the model, so it is not depicted in Figure 5.

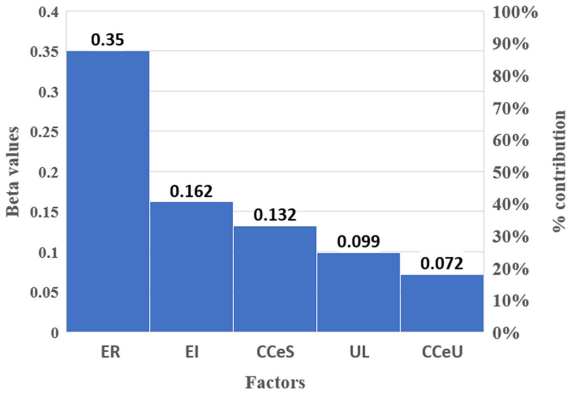

Fig. 5. Relative contribution of positive significant factors in the model

5 DISCUSSION

To address the first research question, we examined the utilization of cloud computing e-learning among lecturers in technical universities in Ghana, employing a five-point Likert scale. The data show that teachers generally agree with most items in the subscale, with mean values above 3.5 for all but two items. The average rating for the availability of infrastructure to access cloud computing and e-learning is 4.20, indicating a high level of agreement. The data also reveal different degrees of variation or consistency in teachers' responses, with the minimum standard deviation value of 0.72 indicating uniformity and the highest standard deviation value of 1.24 indicating low consistency, possibly due to sociocultural factors associated with the geographical context of the university. The study found that educators generally have positive perceptions of the usefulness and simplicity of cloud-based e-learning, but they have less favorable views of security and cost.

To address the second research question, an EFA was conducted to examine the item structure of the subscale using PCA and varimax rotation. The results showed seven components with eigenvalues greater than 1, indicating a reasonable assumption of a seven-factor solution. The PCA revealed that the seven main components—educational innovation, electronic infrastructure readiness, security of e-learning in cloud computing, usefulness of e-learning in cloud computing, cost of online learning in cloud computing, the location of the university (TU), and the support of the provider—explained 53.93% of the total variance. This indicates a strong relationship between the research variables.

This study utilized multiple regression analysis to analyze the relationship between independent variables and the dependent variable. This analysis was conducted to address the third research question. The results showed that six factors significantly influence the adoption of cloud computing in e-learning by lecturers, accounting for 24.1% of the total variance. According to [79], this value is very significant.

These factors include EI, e-infrastructure readiness (ER), CCeS, university location (UL), cloud computing e-learning usefulness (CCeU), and vendor support (VS). VS had a negative beta value, whereas CCe exhibited a weak negative relationship. This finding confirms several studies, including [19], [80–83]. These studies highlight the importance of infrastructure readiness, security, CCeU, and vendor support.

According to our results, the cost of cloud computing e-learning ($\beta = -0.007$, p-value = 0.780) had no significant impact on lecturers' intentions to adopt cloud computing e-learning. This suggests that lecturers at technical institutions do not perceive it as a crucial factor when deciding to implement cloud computing for e-learning. Lecturers may not view the cost of cloud computing for e-learning as a decisive component in their teaching and learning process, as they heavily depend on their university's internet and e-infrastructure. This conclusion contradicts the prevailing research consensus that has consistently demonstrated cost reduction or savings as a significant factor influencing the adoption of technology [15], [19], [46], [82], [84], [85].

The factors that strongly influence the adoption of cloud computing in e-learning by lecturers were ordered based on their beta values. ER was found to be the strongest predictor of lecturers' adoption of cloud computing e-learning. A study by [86] indicated that understanding the readiness of faculty members to use e-learning platforms is essential for e-infrastructure readiness, highlighting its significance in the successful adoption of e-learning platforms.

6 CONCLUSIONS

This study aimed to investigate the factors that influence teachers' adoption of cloud computing e-learning in Ghanaian technical universities. This study addresses the existing knowledge gap in the literature on cloud computing and e-learning in Ghana. We sought to address the following research questions:

- How do teachers perceive the use of e-learning and cloud computing in their teaching and learning processes?
- What factors influence teachers' decisions to adopt online learning through cloud computing?
- What are the primary factors influencing teachers' adoption of online learning in technical universities?

This study surveyed 1,395 teachers from ten Ghanaian technical universities, of which 1,258 responses were received, resulting in a response rate of 90.2%. The missing data was processed using MCAR and EM algorithms.

We first examined the descriptive statistics of the building by inspecting the averages and standard deviations. The main results have shown that readers exhibit varying degrees of coherence, possibly influenced by socio-cultural factors. They generally perceive cloud computing and e-learning as useful but less secure.

Through a factor analysis, seven main factors that affect readers' decisions to use cloud computing in e-learning at technical universities were identified. These factors include educational innovation, e-infrastructure readiness, university rental, security, usefulness, cost, and vendor support. A multiple linear regression analysis was used to examine the impact of these seven factors on the adoption of cloud computing e-learning by users. The results showed that there are six factors—education innovation, e-infrastructure readiness, cloud computing e-learning security, cloud computing e-learning usefulness, university rental, and vendor support—that are statistically significant and account for 24.1% of the total variance in the adoption of cloud computing e-learning by readers. According to [79], it is also very significant.

This study found that e-infrastructure readiness is the most critical influencing factor in teachers' adoption of cloud-based e-learning, followed by the security of cloud e-learning, university location, and educational innovation. The factors with the lowest relative importance are the usefulness of e-learning in cloud computing and provider support. The only factor that did not have a significant impact on teachers' intentions to adopt cloud computing e-learning was the cost, which contradicts many research findings.

This work presents some limitations and suggests directions for future research. Due to its narrow focus on lecturers at technical universities in Ghana, the study's scope and context are limited. Therefore, the generalizability and applicability of the results may be limited to other contexts and settings. Future research could broaden the scope and context of the study by incorporating various types of universities, both private and public, from different regions or countries. Additionally, involving other stakeholders, such as students, staff, and managers, could provide a more comprehensive understanding. The fact that the study only used a survey method and a cross-sectional design also limits its scope. Therefore, the causality and temporality of the relationships between the factors and the adoption of cloud computing e-learning by teachers cannot be established. Future research could employ various methods and designs, including experiments, interviews, case studies, and longitudinal studies, to comprehend the dynamic perspective of cloud e-learning adoption.

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