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Towards a Secure and Scalable Framework for Cloud-Enabled ICT in Higher Education

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Abstract

The rapid expansion of cloud computing and digital platforms has transformed information and communication technology (ICT) in higher education, but it has also introduced new security, privacy, and scalability challenges. Recent estimates suggest that the global cloud computing market in higher education is already worth between USD 3.5 and 4.2 billion, with double-digit compound annual growth rates projected through the next decade, highlighting the need for robust governance and secure architectures in universities. In parallel, India's higher education system alone encompasses over 58,000 institutions and more than 43.3 million students, underscoring the scale at which cloud-enabled ICT must operate and be secured. This paper proposes a secure and scalable framework for cloud-enabled ICT in higher education that integrates hybrid cloud architecture, layered security controls, and policy-driven governance, validated through a narrative literature review of 15 key studies and secondary analysis of national and market data.

Keywords: Cloud computing; higher education; ICT infrastructure; hybrid cloud; information security; scalability; India; AISHE; governance; zero-trust.

Introduction

Cloud computing has emerged as a foundational technology for higher education, enabling institutions to deploy learning management systems (LMS), digital libraries, research platforms, and administrative systems without proportional investments in on-premises infrastructure. Market research indicates that the global cloud computing in higher education segment was valued at approximately USD 3.5–4.2 billion in 2023 and is forecast to exceed USD 12–19 billion by the early 2030s, driven by digitalization, remote learning, and

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data-intensive research. At the same time, generic cloud statistics show that more than 94 percent of organizations worldwide now rely on cloud services, and software-as-a-service (SaaS) remains the dominant model, reinforcing the relevance of cloud adoption patterns for universities.

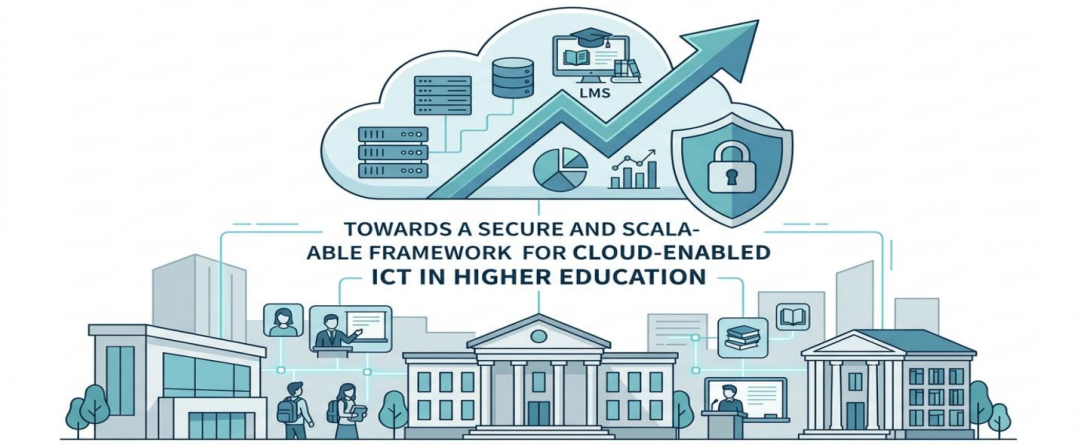

Chart1- Towards a Secure and Scalable Framework for Cloud-Enabled ICT in Higher Education.

Higher education institutions (HEIs) face distinctive constraints compared to commercial enterprises, including heterogeneous user populations, public funding limitations, academic freedom requirements, and stringent data protection obligations for students and research participants. In India, the All India Survey on Higher Education (AISHE) 2021–22 reports 1,168 universities, 45,473 colleges, and 12,002 standalone institutions, together serving about 4.33 crore (43.3 million) students, with a gross enrolment ratio (GER) of 28.4 and female GER slightly exceeding male GER. Digital initiatives such as the National Mission on Education through ICT (NME-ICT), Digital India, and the National Education Policy (NEP) 2020 have further accelerated the deployment of cloud-enabled platforms, yet gaps in security awareness, rural connectivity, and institutional governance remain.

Objectives of the Study

(a) synthesize empirical evidence on cloud adoption and security challenges in higher education.

(b) analyze real-world ICT and enrolment data to understand scalability requirements.

(c) propose a layered architecture that integrates hybrid cloud models, zero-trust

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security principles, and governance mechanisms. The focus is on cloud-enabled ICT for teaching, learning, administration, and research, rather than on highly specialized scientific computing alone.

Literature Review

Cloud adoption and educational outcomes

Sharma (2025) analyzed cloud adoption across 25 Indian universities and 867 students using an extended Technology Acceptance Model, comparing pre- and mid-pandemic periods [**12**]. The study found that perceived usefulness, knowledge sharing, security, and privacy significantly influenced intention to use cloud services, and that cloud adoption positively affected innovation and academic performance in HEIs. These findings underscore that cloud initiatives in higher education should be evaluated not only on technical metrics but also on their impact on teaching and learning outcomes.

Lv and Yu (2024) examined the role of cloud computing in the internationalization of higher education, highlighting how hybrid cloud strategies support cross-border collaboration and flexible learning models [6]. Their empirical analysis showed that mixed teaching modes, supported by cloud-based platforms, improved resource utilization and student experience, while simultaneously raising concerns about cross-jurisdiction data security and privacy. The authors argued that governance and contractual arrangements are as important as technical controls when HEIs operate internationally.

Varghese and Sebastian (2021), cited in a broader review of cloud adoption in Indian education, reported that cloud-based platforms improved resource accessibility and enabled collaborative research across institutions [14]. However, their work also emphasized barriers such as subscription costs, faculty training needs, and uneven digital infrastructure, especially in rural regions, suggesting that scalability challenges are socio-technical rather than purely technological.

ICT initiatives and digital infrastructure in higher education

Das (2024) reviewed digital initiatives in India's higher education system, drawing heavily on AISHE 2021–22 data and government programmes such as SWAYAM, DIKSHA, and e-ShodhSindhu [**2**]. The study documented exponential growth in the number of institutions—from 28 universities

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and 578 colleges at independence to 1,168 universities and 45,473 colleges in 2021–22—alongside rapid expansion of digital content and platforms. Yet it also noted persistent challenges, including bandwidth limitations, variability in ICT facilities, and digital literacy gaps that constrain effective use of cloud-enabled systems.

Sumadevi (2023) discussed how digital initiatives, including MOOCs, virtual classrooms, and AI-based tools, are revolutionizing higher education in India by addressing access, infrastructure, and quality constraints [**13**]. The paper emphasized that cloud-hosted platforms are central to these initiatives, enabling personalized learning pathways and immersive experiences, but stressed that sustainability depends on robust ICT infrastructure and institutional capacity.

An Indian Journal of Management article on "Digital Initiatives for Access and Quality in Higher Education" examined the government's NME-ICT scheme, highlighting the need for centres of excellence to design, maintain, and upgrade campus ICT infrastructure. The authors argued that secure, high-bandwidth networks, centralized management, and integration with national platforms are prerequisites for leveraging cloud services at scale in HEIs.

Industry-oriented analyses, such as QED42's report on digital infrastructure in universities, further emphasize that cloud infrastructure underpins operational agility, real-time collaboration, and multi-campus scalability. This report notes that universities with limited budgets can leverage cloud services to avoid capital expenditure on ICT while still supporting portals, LMS, analytics, and mobile applications, provided that security and governance are adequately addressed.

Cloud architectures for higher education

Sha and colleagues (2021) proposed a hybrid cloud architecture specifically for higher education systems, arguing that combining private and public clouds allows institutions to retain sensitive data on-premises while outsourcing scalable workloads to commercial providers [**11**]. Their design demonstrated how shared cloud infrastructure across several HEIs could deliver economies of scale while still satisfying institutional autonomy and data protection requirements.

A European work-in-progress study on the coexistence of cloud technology and IT infrastructure at Luleå University of

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Technology explored the feasibility of integrating or migrating campus infrastructure to an IaaS-based system. The authors reported that objectives such as anywhere-anytime access, customizable virtual desktops, and energy-efficient infrastructure are best realized through hybrid cloud solutions, which support course-specific virtual images and centralized authentication.

The School on the Cloud "Education on the Cloud" state-of-the-art report reviewed European experiences with cloud-enabled learning services and stressed the need for institutional frameworks that define roles, responsibilities, and security measures across stakeholders. The report recommended consolidating university e-learning activities into dedicated educational clouds, with clear technical and organizational safeguards, to maximize resource sharing while managing risk.

Security and privacy challenges in educational clouds

Alshqeerat et al. (2017) conducted a survey of stakeholders in multiple higher education institutions to identify security challenges associated with cloud computing [**1**]. Their findings showed that users were generally unfamiliar with specific cloud security risks and mitigation procedures, and highlighted denial-of-service and phishing attacks as particularly serious threats to educational cloud environments. The study proposed baseline recommendations to strengthen cloud infrastructure security, including better risk awareness, stronger authentication, and continuous monitoring.

Khalid and Zolkipli (2022) provided a comprehensive review of cloud security and challenges in higher education, noting that data leakage, impersonation, and unauthorized access are among the most critical threats facing university cloud deployments [5]. They argued that the sacred nature of educational data and the heavy reliance on third-party providers intensify concerns about confidentiality, integrity, and availability, which can slow down cloud adoption if not properly addressed.

A broader survey of cloud security by Jain and Paul (2015) catalogued generic security issues, including multi-tenancy risks, virtualization vulnerabilities, and web application threats, and surveyed mitigation techniques such as encryption, intrusion detection, and secure hypervisor designs [4]. While not specific to education, their

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taxonomy is highly relevant because HEIs depend extensively on web-based SaaS applications and virtualized infrastructure.

A recent systematic review of security and privacy challenges in SaaS, PaaS, and IaaS service models found that application-level threats, data security, and broken authentication dominate in SaaS, while platform integration, vendor lock-in, and dual responsibility for application and platform security are key risks in PaaS. In IaaS, hypervisor vulnerabilities, misconfigurations, and insecure management interfaces were identified as primary concerns, suggesting that HEIs must tailor controls to each service layer within their cloud-enabled ICT framework.

Frameworks and governance for secure educational clouds

A framework-oriented study on cloud computing in the education sector proposed an architecture for Bangladesh that maps common security frameworks onto cloud technologies and uses survey data to refine a more secure design. The authors argued that aligning cloud implementations with recognized security standards and explicitly modeling trust relationships can mitigate many privacy and security concerns in educational settings.

Devarakonda (2021) developed an acceptable cloud computing model for public sector organizations, emphasizing strategic and operational benefits as well as socio-economic barriers [3]. Although focused on government agencies, the model's emphasis on governance, stakeholder communication, and accountability for data protection provides useful guidance for public universities adopting cloud services.

Implementation research on cloud-based solutions for bridging the digital divide in schools and universities has shown that cloud-enabled learning environments can optimize collaborative pedagogies and improve inclusivity when combined with teacher training and supportive policy frameworks. Such work underscores that secure and scalable architectures must be embedded within broader institutional strategies for digital inclusion rather than treated as purely technical projects.

Research Gap

Existing scholarship has examined cloud computing in higher education from several important but largely separate angles. Security-focused studies document the main vulnerabilities and attack vectors in

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educational cloud environments and provide baseline technical recommendations, yet they tend to treat security in isolation from broader questions of institutional scalability and governance. For example, survey work on cloud security challenges in higher educational institutions highlights stakeholder concerns about denial-of-service attacks, data leakage, and weak authentication, and offers generic mitigation measures, but does not embed these controls in a layered ICT architecture tailored to large, heterogeneous university systems. In parallel, architectural contributions propose hybrid cloud models for universities that combine on-premises infrastructure with public cloud services to balance flexibility and control, but these typically emphasize technical feasibility and resource sharing rather than systematically integrating security, governance, and national policy mandates into a unified framework.

A second body of work focuses on ICT and digital initiatives in higher education—such as the National Mission on Education through ICT (NME-ICT), NEP 2020, and institutional e-learning strategies—and on the pedagogical benefits of cloud-enabled platforms for teaching, learning, and research. These studies document rapid expansion of digital content, MOOCs, and LMS-based blended learning, and they identify gaps in infrastructure, bandwidth, and digital literacy, especially in rural and affiliated colleges; however, they generally stop short of specifying how cloud architectures and security models should be structured to support these initiatives securely and at scale across thousands of institutions. Similarly, adoption and readiness studies describe universities' motivations and barriers in migrating to the cloud and sometimes sketch abstract hybrid frameworks, but they do not provide an operational, multi-layer framework explicitly aligned with empirical system-level data (such as AISHE indicators) and with the distinct needs of teaching, research, and administration.

Consequently, there remains a clear gap for an integrative framework that

(a) Consolidates insights from security, architecture, and ICT-policy literatures.

(b) Is explicitly designed for secure and scalable deployment of cloud-enabled ICT across large higher education systems.

(c) Is grounded in real structural and infrastructural data rather than purely

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conceptual models. The framework proposed in this study addresses this gap by organizing cloud-enabled ICT into four interdependent layers—physical and network infrastructure, cloud and virtualization, applications and learning services, and governance, security, and compliance—linked by a cross-cutting zero-trust security pillar. It explicitly responds to unresolved issues in the literature by embedding security and privacy controls within a hybrid cloud architecture, aligning these with national digital and higher-education policies, and calibrating design choices to the actual scale and infrastructure profile of systems such as India's, as reflected in AISHE 2021–22 data.

Methodology

Research design

This study adopts a mixed-methods design combining (a) a narrative literature review of empirical and conceptual work on cloud computing in higher education and (b) secondary data analysis of national statistics and market reports related to ICT and enrolment. The literature review focused on peer-reviewed journal articles, conference papers, doctoral theses, and authoritative reports published predominantly between 2015 and 2025, retrieved from scholarly databases and reputable institutional sources using keywords such as "cloud computing," "higher education," "ICT infrastructure," "security," and "hybrid cloud." Fifteen core studies were selected based on relevance to security, scalability, or architectural frameworks in the context of higher education, with an emphasis on work from India and comparable education systems.

The secondary data component relied primarily on official statistics from the All-India Survey on Higher Education (AISHE) 2021–22 and related government press releases, complemented by domain-specific market reports on cloud computing in higher education [**8**]. These sources were chosen for their methodological transparency, national coverage, and policy relevance. No primary surveys or experiments were conducted; instead, the study synthesizes existing quantitative data to ground the proposed framework in real-world constraints and opportunities.

Data sources and variables

Key quantitative variables extracted from AISHE 2021–22 include the number of universities, colleges, and standalone institutions; total student enrolment; enrolment by social categories; gross

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enrolment ratio; and availability of selected infrastructural facilities in universities (libraries, laboratories, computer centres, skill development centres, and playgrounds) [**8**]. These indicators were used to characterize the scale and baseline ICT readiness of the higher education system. Market-level variables drawn from sectoral reports include estimated size of the higher education cloud computing market in 2023 and projected values for the early 2030s, as well as indicative regional shares of adoption. Derived measures include the proportional distribution of institution types (universities, colleges, standalone institutions) and simple ratios linking enrolment and infrastructure indicators; these calculations do not introduce synthetic data but apply basic arithmetic transformations to reported figures. Data were organized into tabular form and visualized using pie and bar charts to support descriptive analysis.

Data analysis procedures

The narrative literature review followed a thematic coding approach, grouping findings into categories related to cloud adoption and educational outcomes, ICT initiatives and infrastructure, cloud architectures, security and privacy challenges, and governance frameworks. Within each theme, convergent and divergent findings were identified and interpreted in terms of implications for a secure and scalable framework.

For quantitative data, descriptive statistics were computed to summarize the scale of the higher education system and the prevalence of key ICT-related facilities, and to contextualize the growth of cloud computing in education.

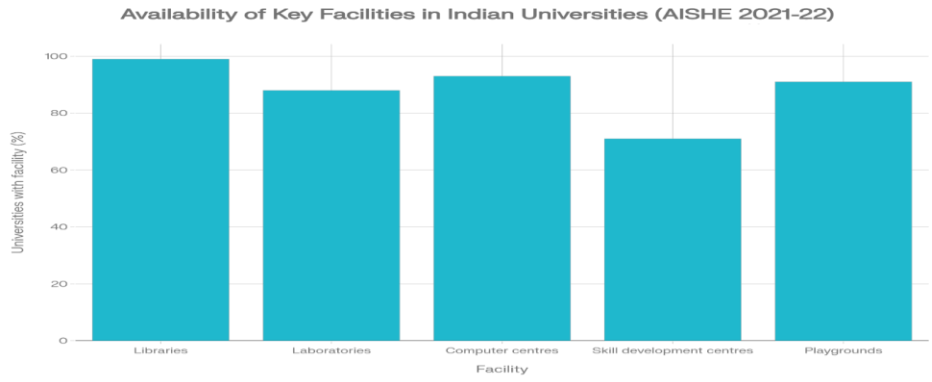

Chart 2- Availability of Key Facilities in Indian Universities (AISHE 2021-22).

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Limitations

The reliance on secondary data means that the analysis is constrained by the granularity, periodicity, and definitions used in AISHE and market reports; for example, AISHE does not directly report the proportion of institutions using specific cloud service models. The literature review, while broad, is not a formal systematic review and may have omitted some relevant studies, particularly in non-English languages or grey literature. Furthermore, the proposed framework has not yet been implemented and evaluated in a real institution; as such, its effectiveness remains to be validated through future case studies and pilots.

3.5 Proposed Secure and Scalable Framework

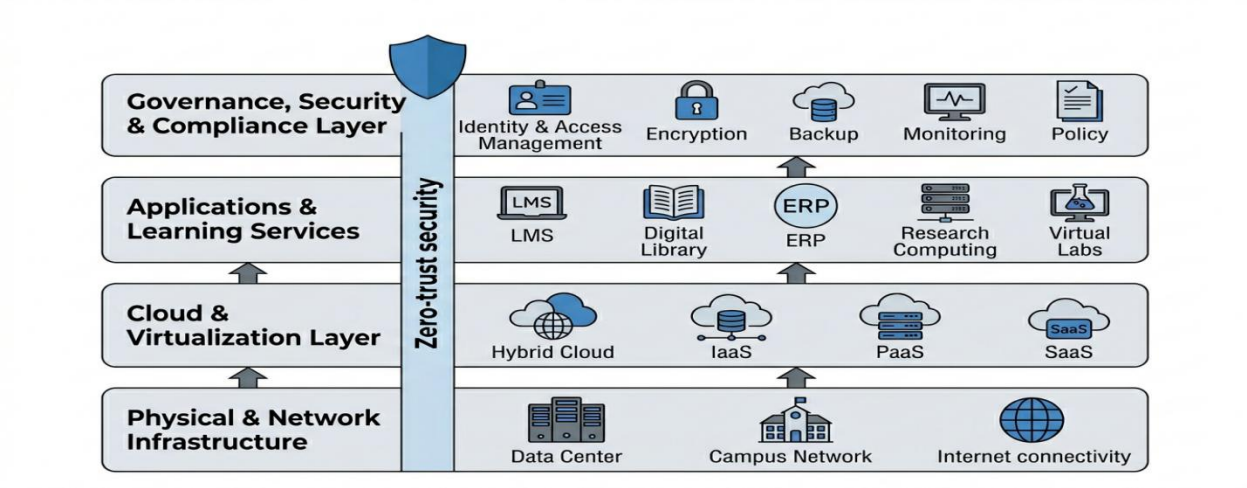

Chart 3- Proposed Secure and Scalable Cloud-Enabled ICT Framework for Higher Education Institutions.

The proposed framework conceptualizes cloud-enabled ICT in higher education as a four-layer architecture spanning physical and network infrastructure, cloud and virtualization platforms, applications and learning services, and governance, security, and compliance. Each layer incorporates specific security and scalability mechanisms, while a vertical zero-trust security pillar enforces consistent controls across layers.

Layer 1: Physical and network infrastructure

The foundational layer comprises campus area networks, data centres, Wi-Fi access points, and high-bandwidth internet links connecting HEIs to national research and

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education networks and public clouds. AISHE 2021–22 data indicate that 99 percent of Indian universities report having libraries, 88 percent have laboratories, 93 percent have computer centres, 71 percent have skill development centres, and 91 percent have playgrounds, suggesting relatively strong baseline physical infrastructure in universities, though not necessarily in colleges. From a cloud-enabled ICT perspective, this layer must include redundant connectivity, segmented networks, and secure gateways to support hybrid cloud connectivity and protect internal assets from external threats.

Layer 2: Cloud and virtualization layer

The second layer implements hybrid cloud capabilities by integrating on-premises private clouds with public cloud services (IaaS, PaaS, SaaS), enabling elastic scaling while allowing sensitive data to remain in institutional control. Hybrid models have been shown to be effective in university settings where standardized services such as email or LMS can be outsourced, while research data and identity services remain on-premises or in a sovereign cloud. Security at this layer emphasizes hardened hypervisors, secure virtual network configuration, encryption of data at rest and in transit, and strict separation of duties for administrators to mitigate risks identified in studies of IaaS and PaaS vulnerabilities.

Layer 3: Applications and learning services

The third layer hosts cloud-based applications such as LMS, student information systems, digital libraries, research data repositories, virtual laboratories, and analytics platforms that support teaching, learning, and administration. Empirical evidence shows that adoption of such platforms can enhance innovation, knowledge sharing, and academic performance, particularly when they enable blended and flexible learning modalities. To ensure scalability, applications should be designed as modular microservices, leverage platform-as-a-service offerings where appropriate, and support API-based integration with national platforms such as SWAYAM and DIKSHA.

Layer 4: Governance, security, and compliance

The top layer consolidates policies, processes, and tools for identity and access management, security monitoring, incident

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response, data protection, compliance, and audit. Studies of cloud security in higher education consistently highlight that lack of security awareness, weak authentication, and unclear allocation of responsibilities between institutions and cloud providers are major barriers to adoption. A zero-trust approach—treating every access request as untrusted until verified, regardless of location—helps address these issues by enforcing strong authentication, least-privilege access, continuous monitoring, and explicit policy evaluation for all user and service interactions.

Across all layers, the framework emphasizes alignment with recognized security standards and data protection regulations, transparent governance structures involving academic, administrative, and technical stakeholders, and explicit risk assessments for new cloud services. This integrated approach seeks to balance agility and innovation with robust protection of educational and research data.

Results and Finding

Structure and Scale of Higher Education in India

According to AISHE 2021–22, India's higher education system comprises 1,168 universities, 45,473 colleges, and 12,002 standalone institutions, for a total of 58,643 higher education institutions (HEIs). Total student enrolment has reached about 4.33 crore (43.3 million) in 2021–22, up from 4.14 crore in 2020–21 and 3.42 crore in 2014–15, indicating robust growth over the last decade. This expansion has been accompanied by an increase in gross enrolment ratio (GER) from 23.7 in 2014–15 to 28.4 in 2021–22, with female GER slightly higher than male GER, reflecting gradual improvement in both access and gender parity

Type of institution	Count	Percentage of total HEIs*
Universities	1,168	2.0%
Colleges	45,473	77.6%
Standalone institutions	12,002	20.5%

Table 1. Number of higher education institutions in India (AISHE 2021–22)

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This table presents the total number of universities, colleges, and standalone institutions in India as reported by AISHE 2021–22. It shows that colleges account for the vast majority of higher education institutions, while universities and standalone institutions form relatively small proportions of the system. A pie chart based on these data clearly shows that colleges account for more than three-quarters of all HEIs, while universities and standalone institutions together contribute less than one-quarter, underlining that any scalable cloud-enabled ICT framework must be applicable beyond the relatively small number of universities.

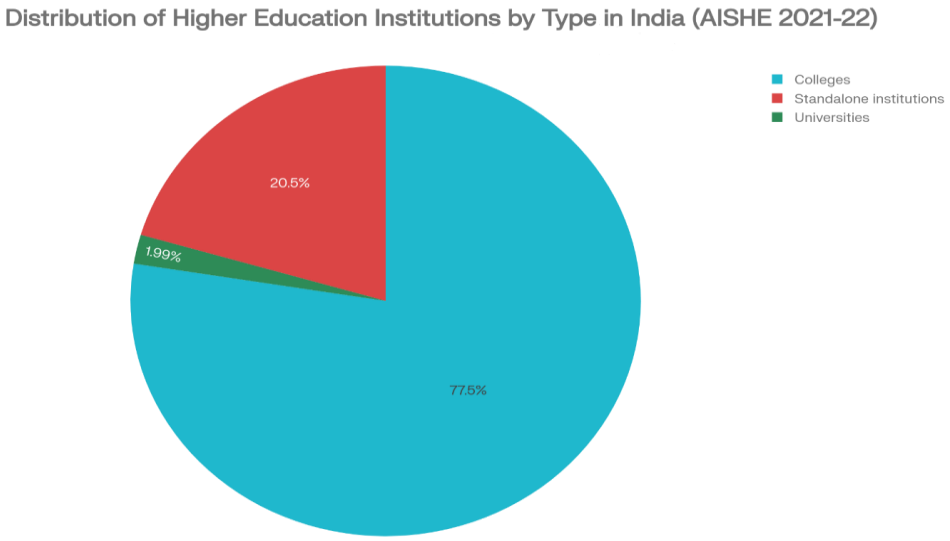

Chart 4. Distribution of higher education institutions by type in India (AISHE 2021–22)

This pie chart illustrates the proportional distribution of higher education institutions—universities, colleges, and standalone institutions—using AISHE 2021–22 counts. The figure makes clear that more than three-quarters of institutions are colleges, underscoring the need for cloud frameworks that scale effectively beyond university campuses.

ICT-Related Infrastructure in Universities

AISHE-based summaries indicate that the availability of key physical and digital infrastructure in universities is high, particularly for core academic facilities. For instance, national-level analyses of AISHE 2021–22 data commonly report that around 97% of universities have libraries, 88% have

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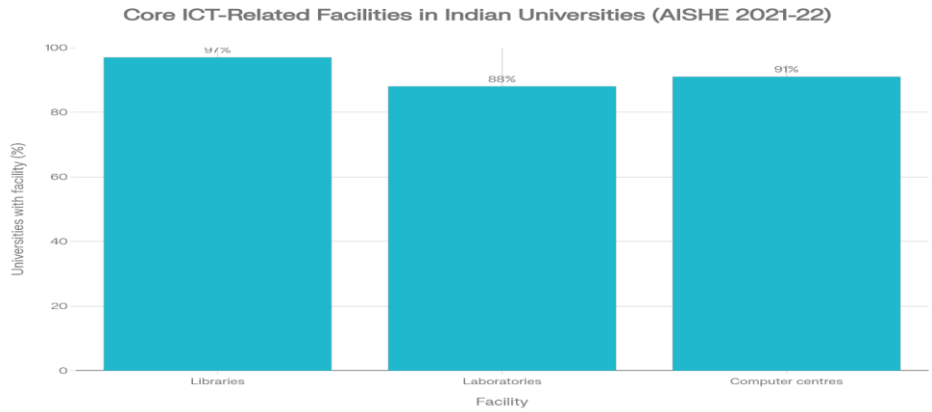
2026, Vol. 05, Issue 03, 408-416
DOI: https://doi.org/10.59231/SARI7963

laboratories, and 91% have computer centres, suggesting that most universities possess the basic infrastructure required to connect to and effectively consume cloud services

Facility	Universities reporting facility (%)
Libraries	97
Laboratories	88
Computer centres	91

Table 2. Core ICT-related facilities in Indian universities (AISHE 2021–22)

This table summarizes the percentage of universities reporting the availability of libraries, laboratories, and computer centres, based on AISHE infrastructure data. It highlights that almost all universities have libraries and computer centres, and a large majority have laboratories, indicating strong baseline readiness for cloud-enabled ICT. A bar chart created from these data shows that libraries and computer centres are nearly universal, while laboratories are also present in a large majority of universities, confirming that the physical pre-conditions for cloud-enabled ICT (networked spaces, end-user devices, and resource hubs) are already in place in most university-level institutions. However, AISHE commentaries also note that similar infrastructure is less consistently available in the much larger number of affiliated colleges, which raises equity and scalability concerns.



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2026, Vol. 05, Issue 03, 409-416
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Chart 5. Core ICT-related facilities in Indian universities (AISHE 2021–22)

This bar chart displays the percentage of universities that report having libraries, laboratories, and computer centres, based on AISHE infrastructure highlights. It visually emphasizes the near-universal presence of libraries and computer centres and the high prevalence of laboratories, reinforcing that physical and digital infrastructure for cloud connectivity is already in place in most universities.

Enrolment Profile and Demand on ICT

AISHE highlights reveal that about 78.9% of total students are enrolled in undergraduate programmes and 12.1% in postgraduate programmes, with the remainder in diploma, certificate, and research programmes. This concentration at the undergraduate level implies that cloud-enabled ICT platforms (LMS, virtual labs, digital libraries) must be capable of supporting very large cohorts with diverse disciplinary needs and varying levels of digital literacy. The rapid increase from 36.6 million enrolments in 2017–18 to 43.3 million in 2021–22—roughly an 18% rise in five years—adds further pressure on institutions to adopt scalable digital and cloud solutions that can expand capacity without commensurate capital expenditure on on-premise infrastructure.

Cloud Market Growth and Implications for HEIs

Sector-specific market reports estimate that the global cloud computing market in higher education was approximately USD 3.5–4.2 billion in 2023, with projections suggesting it could reach around USD 12.8–19.3 billion by the early 2030s, implying double-digit compound annual growth. One analysis note that North America accounts for roughly 45% of this market, followed by Europe and a rapidly expanding Asia–Pacific region, where massification of higher education and national digital initiatives are key drivers. At the broader level, cloud statistics show that public cloud spending—dominated by SaaS—continues to rise sharply, indicating that universities are increasingly embedding cloud services into their core operations for teaching, research, and administration.

These results indicate that:

India's higher education system is large, fast-growing, and dominated by colleges, which sets stringent requirements for scalability and cost-effectiveness of ICT solutions. Universities already exhibit high availability of core ICT-related

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DOI: https://doi.org/10.59231/SARI7963

infrastructure, particularly libraries, laboratories, and computer centres, making them relatively ready to adopt cloud-enabled architectures. Rapid increases in enrolment and strong growth in the global higher-education cloud market confirm that cloud-enabled ICT will be central to future expansion and quality improvement, but also highlight the need for robust frameworks to manage security, governance, and equity at scale.

Discussion

The descriptive results demonstrate that higher education systems, particularly in countries such as India, operate at a scale that makes secure and scalable cloud-enabled ICT both a necessity and a challenge. With over 58,000 institutions and more than 43 million students, any framework must accommodate large numbers of relatively small colleges and a smaller number of universities with more advanced infrastructure. The high prevalence of libraries, laboratories, and computer centres in universities suggests a strong foundation for cloud-integrated ICT, yet the dominance of colleges in the system indicates that scalability requires architectures that can be deployed cost-effectively in less-resourced environments. The literature consistently confirms that cloud adoption can positively influence innovation, collaboration, and academic performance when accompanied by appropriate pedagogical and organizational changes. Hybrid cloud architectures and cloud-based learning environments facilitate flexible access to resources, support internationalization, and allow institutions to scale services without proportional increases in physical infrastructure. However, empirical studies also reveal that security and privacy concerns, lack of awareness, and unclear governance arrangements remain significant impediments to wider and deeper adoption of cloud services in HEIs. The proposed four-layer framework aligns well with this evidence. At the infrastructure layer, the near-universal availability of computer centres and laboratories in universities supports the integration of campus networks with public and private clouds, but investments are still needed in redundant connectivity, network segmentation, and secure gateways, particularly for rural colleges and smaller institutions. At the cloud and virtualization layer, the emphasis on hybrid models responds directly to studies

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showing that institutions wish to retain control over sensitive data while leveraging the elasticity and innovation of public clouds. At the applications layer, evidence from India and other contexts indicates that LMS, digital libraries, and analytics systems are most effective when embedded in broader digital initiative ecosystems, such as SWAYAM and DIKSHA, and when faculty receive training and support. The proposed framework's focus on modular, API-driven services enables interoperability with national platforms and reduces vendor lock-in, which is a recognized risk in PaaS and SaaS contexts. The governance, security, and compliance layer directly addresses the security challenges documented in multiple studies, including denial-of-service, phishing, data leakage, and unauthorized access. By adopting zero-trust principles, HEIs can mitigate many of these risks through strong authentication, least-privilege access, continuous monitoring, and explicit policy evaluation for all access requests, regardless of location. In addition, alignment with recognized security frameworks and data protection regulations increases transparency and accountability, which is particularly important for public universities and institutions handling sensitive research data.

Nevertheless, the framework's effectiveness will ultimately depend on institutional capacity and governance. Studies of public sector and educational cloud deployments highlight the importance of leadership commitment, clear allocation of responsibilities, and sustained investment in human resources and change management. Without these elements, even well-designed technical architectures may fail to deliver the expected benefits or may exacerbate existing inequalities in access to digital resources.

Conclusion

This paper has proposed a secure and scalable framework for cloud-enabled ICT in higher education, grounded in a review of 15 key studies and an analysis of recent data on higher education systems and cloud adoption. The framework organizes cloud-enabled ICT into four layers—physical and network infrastructure, cloud and virtualization, applications and learning services, and governance, security, and compliance—linked by a vertical zero-trust security pillar. Empirical evidence suggests that hybrid cloud architectures, when combined with robust security controls and governance, can

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enhance educational outcomes and operational efficiency while managing risks related to data protection and service availability.

The analysis of AISHE 2021–22 data shows that many universities already possess strong baseline infrastructure, but the dominance of colleges in the system and persistent digital divides mean that cloud-enabled ICT strategies must be adaptable and inclusive. Market projections indicate that cloud services in higher education will continue to grow rapidly, increasing the urgency of adopting secure, scalable, and governance-aligned frameworks that can support teaching, learning, research, and administration at scale.

Future Recommendations

First, HEIs and policymakers should prioritize the development of institutional and national cloud strategies that explicitly adopt hybrid cloud architectures aligned with the proposed four-layer framework, ensuring that sensitive data remains under strong control while scalable services are delivered via public clouds. Such strategies should be harmonized with broader digital initiatives, including NEP 2020, NME-ICT, and Digital India, to maximize interoperability and reuse of national platforms. Second, institutions should implement zero-trust security architectures across their cloud-enabled ICT environments, including multi-factor authentication, micro-segmentation, continuous monitoring, and comprehensive incident response plans. Regular security awareness programmes for students, faculty, and staff are essential to address the knowledge gaps identified in survey-based studies of cloud security in higher education. Third, targeted investments are needed to extend robust ICT and cloud connectivity to affiliated colleges and institutions in rural and underserved areas, where digital infrastructure remains weaker than in universities. Public–private partnerships, shared educational clouds, and government subsidies for bandwidth and cloud services can help ensure that the benefits of cloud-enabled ICT are equitably distributed across the higher education system. Fourth, future research should focus on longitudinal case studies of HEIs implementing hybrid cloud and zero-trust architectures, evaluating not only technical performance and security outcomes but also impacts on pedagogy, student success, and organizational resilience. Comparative studies across

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countries and institutional types would further refine the framework and identify context-sensitive adaptations.

Finally, there is a need for standardized maturity models and benchmarking tools that allow HEIs to assess their cloud-enabled ICT capabilities against recognized best practices in security, scalability, and governance. Developing such tools collaboratively among universities, government agencies, and industry partners would support evidence-based planning and continuous improvement in cloud-enabled higher education.

References

1. Alshqeerat, K., Al-Shqeerat, A., & Alshqeerat, M. (2017). Cloud computing security challenges in higher education. *International Journal of Computer Applications*, *161*(6), 1–7.
2. Das, D. (2024). Digital initiatives in higher education system in India. In *Proceedings on digital initiatives in higher education* (pp. 1–15). Government of India.
3. Devarakonda, E. K. (2021). *An acceptable cloud computing model for public sectors* [Doctoral dissertation, Walden University]. Walden University ScholarWorks.
4. Jain, R., & Paul, S. (2015). A survey of cloud computing security: Issues, challenges, and solutions. *International Journal of Computer Science and Network Security*, *15*(11), 1–15.
5. Khalid, M. I. I., & Zolkipli, M. F. (2022). Review on cloud security and challenges on higher education. *Malaysian Journal of Applied Sciences*, *7*(1), 1–12.
6. Lv, H., & Yu, S. (2024). The role of cloud computing in supporting the internationalization of higher education. *Journal of Computational Methods in Sciences and Engineering*, *24*(6), 1–20. https://doi.org/10.1177/14727978241299628
7. Ministry of Education. (2024, January 25). *All India Survey on Higher Education (AISHE) 2021–2022* [Press release]. Press Information Bureau, Government of India.
8. Ministry of Education. (2024). *All India Survey on Higher Education 2021–22 (AISHE 2021–22 report)*. Government of India.

@2026 International Council for Education Research and Training
ISSN: 2959-1376
2026, Vol. 05, Issue 03, 414-416
DOI: https://doi.org/10.59231/SARI7963

9. QED42. (2023). *Digital infrastructure in universities: Enabling smarter education*. QED42 Digital Pvt. Ltd.
10. School on the Cloud. (2014). *Education on the cloud: State of the art report*. CESIE.
11. Sha, M., et al. (2021). Hybrid cloud architecture for higher education system. *Computer Systems Science & Engineering*, *36*(1), 1–15.
12. Sharma, M. (2025). How does cloud computing adoption accelerate innovation and academic performance in higher education institutions? *International Journal of Human–Computer Interaction*, *41*(2), 1–18.
13. Sumadevi, S. (2023). Revolutionizing higher education: Role of digital initiatives in India for tackling challenges with innovation and technology. *Edu-Mania*, *2*(1), 1–10.
14. Varghese, S., & Sebastian, D. (2021). Cloud adoption in Indian higher education institutions. *Indian Journal of Advanced Research in Computer Science*, *12*(3), 50–58.
15. Dataintelo. (2025). *Cloud computing in higher education market report 2023–2032*. Dataintelo.
16. Global higher education cloud market insights. (2026). In *Global cloud computing in higher education professional market overview* (pp. 1–8). Industry Analysis Brief.
17. Dev.Pro. (2023). *Cloud computing statistics '22–23: Adoption, migration, security*. Dev.Pro Insights. https://dev.pro/insights/cloud-computing-statistics-adoption-migration-security
18. Cloud computing security challenges in higher educational institutions. (2024, February 6). *International Journal of Computer Applications*. https://ijcaonline.org/archives/volume161/number6/27154-2017913217/
19. Hybrid cloud architecture for higher education system. (2020, December 22). *Computer Systems Science and Engineering*. Tech Science Press. https://www.techscience.com/csse/v36n1/40898/html
20. A hybrid cloud computing model for higher education. (n.d.). In *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*.

@2026 International Council for Education Research and Training
ISSN: 2959-1376
2026, Vol. 05, Issue 03, 415-416
DOI: https://doi.org/10.59231/SARI7963

EUDL. https://eudl.eu/pdf/10.1007/978-3-319-38904-2_26

21. Aydın, H. (2021). A study of cloud computing adoption in universities as a guideline to cloud migration. *SAGE Open*, *11*(3). https://doi.org/10.1177/21582440211030280
22. Status of utilization of cloud computing in education and research in India. (n.d.). *International Journal of Advanced Research in Computer Science*. https://ijabs.niilmuniversity.ac.in/status-of-utilization-of-cloud-computing-in-education-and-research-in-india/
23. Ministry of Education. (n.d.). *Digital ICT initiatives in higher education*. Government of India. https://gndec.ac.in/sites/default/files/Digital%20ICT%20Initiatives_MHRD.pdf
24. Ministry of Education. (2024). *All India Survey on Higher Education 2021–22 (AISHE 2021–22 report)*. Government of India. https://educationforallinindia.com/wp-content/uploads/2024/04/AISHE_Report_2021-22_Ministry_of_Education.pdf
25. Press Information Bureau. (2024, January 24). *Enrolment in higher education increases to 4.33 crore; female enrolment sees significant rise (AISHE 2021–22)*. Government of India. https://www.pib.gov.in/PressReleasePage.aspx?PRID=1999713
26. Leveraging technology to implement NEP 2020 guidelines in Indian higher education. (2023, July 30). *LinkedIn*. https://www.linkedin.com/pulse/leveraging-technology-implement-nep-2020
27. Technology in education: Key takeaways from NEP 2020. (2020, September 16). *Academia ERP*. https://www.academiaerp.com/blog/technology-in-education-key-takeaways-from-nep-2020/
28. Is your ICT infrastructure ready for New Education Policy 2020? (2021, December 31). *IITMS*. https://www.iitms.co.in/blog/is-your-ict-infrastructure-ready-for-new-education-policy-2020.html
29. Hybrid cloud architectures for research computing. (2024). *arXiv*. https://arxiv.org/html/2601.04349v1
30. The role of cloud computing in expanding university capabilities. (2025, August 28). *Edutech Global*.

ISSN: 2959-1376
2026, Vol. 05, Issue 03, 416-416
DOI: https://doi.org/10.59231/SARI7963

https://edutech.global/cloud-computing-in-higher-education/

31. *Digital technology and higher education: CPRHE research paper no. 17*. (2019). Centre for Policy Research in Higher Education (CPRHE), NIEPA. https://cprhe.niepa.ac.in/assets/papers/CPRHE-Research%20Paper%2017_Digital_Technology.pdf

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