A Comparative Analysis of SaaS and PaaS Cloud-Based E-Learning Platforms in Terms of Cost-Effectiveness and Scalability

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Educational institutions must evaluate Software as a Service against Platform as a Service for their e-learning cloud deployment because their cost models differ while trade-offs in scalability and customization needs exist. The research examines SaaS and PaaS cloud platforms to help educational institutions select better options through assessments of their value for money and flexibility and user satisfaction measures. A mixed quantitative and qualitative research design involved collecting data from twenty institutions which were equally distributed between SaaS and PaaS subscribers. These results were supplemented by interviews with IT administration personnel. The research used subscription fees and infrastructure costs as quantitative data alongside user capacity and response times under load. At the same time it collected qualitative information about usability alongside customization flexibility and security perceptions of the solutions.

Institutions working with restricted budgets should choose SaaS platforms because they provide cost-effective subscription payments at $2,628.41 per year along with light IT maintenance. Scalability proved to be a challenge for SaaS because it worked with an average of 903 concurrent users at slower rates of 1,313.97ms response times under peak usage conditions. The PaaS platforms outperformed in scalability because they supported 4,656 active users and operated at stable response times of 750.69ms although they demanded substantial infrastructure spending ($4,380.72 annually) and specialized technical knowledge. User satisfaction surveys highlighted SaaS's ease of adoption (75% satisfaction) versus PaaS's customization advantages (40% extensive customization satisfaction), though both models achieved comparable security satisfaction (70–75%).

The study concludes that SaaS is optimal for institutions prioritizing affordability and simplicity, while PaaS suits those requiring long-term scalability and tailored solutions. Recommendations include hybrid cloud models to balance cost-efficiency and flexibility. These insights aim to empower educational stakeholders in aligning cloud adoption strategies with institutional goals and resource constraints.

Keywords: Cloud computing, Software as a Service (SaaS), Platform as a Service (PaaS), E-learning platforms, Cost-effectiveness, Scalability, User satisfaction, Educational technology, Cloud service models, Cost analysis, Comparative study, Mixed-methods analysis.

Introduction:

The integration of cloud computing into education has revolutionized the delivery of digital learning, offering institutions scalable, cost-efficient, and accessible solutions to meet evolving pedagogical demands. Cloud-based platforms, particularly Software as a Service (SaaS) and Platform as a Service (PaaS), have emerged as pivotal tools for modernizing education, enabling remote learning, real-time collaboration, and resource sharing across geographically dispersed stakeholders [1]. The worldwide move toward digital education which took place because of COVID-19 pandemic highlighted how cloud technologies help maintain learning continuity and accessibility [2]. The subscription model of SaaS includes pre-configured applications like Google Classroom but PaaS enables customizable development environments similar to AWS and Google Cloud which help develop customized e-learning platforms [3]. The growing number of cloud models presents institutions with complex choices for platform selection because they must weigh between costs and scalability together with technology requirements.

Users need to manage the built-in disadvantages between software-as-a-service and platform-as-a-service delivery systems. The user-friendly and affordable SaaS platforms tend to fall short in adapting their features for institutional educational goals and high student registration [4]. University administrators with limited resources face implementation challenges of PaaS solutions because this platform requires major infrastructure spending along with specialized technical competence [5]. Deciding between SaaS and PaaS platforms becomes more complicated because available research data lacks direct comparison between them specifically in educational environments thus decision-makers face difficulties finding solutions that relate cloud adoption to their organizational objectives.

The evaluation of SaaS and PaaS platforms conducted in this study fulfills the gap by pursuing three main objectives that assess cost-effectiveness and scalability and user satisfaction. The research used a mixed-methods methodology which included quantitative results from 20 institutions comprising 10 SaaS institutions and 10 PaaS institutions together with qualitative input from IT administrators to create a comprehensive evaluation.

Scientists have studied how cloud computing affects the educational system by illustrating its power to decrease IT expenses while broadening access [6]. Research by [7] combined with [8] analyzed SaaS and PaaS separately to demonstrate their capabilities in providing standardized delivery as well as adaptive learning. The research literature shows minimal direct assessment of these cloud computing models particularly regarding sustained costs and adaptability across changing student enrollment numbers. The current study extends past research by adding actual implementation evidence that helps educational institutions reach their decision targets despite theoretical-practical gaps.

Research synthesis of operational costs and user experience evaluation against performance metrics provides stakeholders in education with data-driven strategies for maximizing cloud-based e-learning value in accordance with pedagogical goals and operational boundaries.

Objectives:

Objective of this study is to compare SaaS and PaaS models in terms of cost-effectiveness and scalability, helping educational institutions make informed decisions. The specific objectives include:

1. Examining the functionalities and benefits of SaaS and PaaS for e-learning.
2. Evaluating user satisfaction and engagement with SaaS and PaaS platforms.
3. Assessing the cost-effectiveness and scalability of each model.

Novelty Statement:

This study uniquely explores the comparative effectiveness of Software as a Service (SaaS) and Platform as a Service (PaaS) models in enhancing e-learning platforms within the

context of Pakistan's education sector. While prior research has predominantly focused on the technical or infrastructural aspects of cloud computing in developed countries, this research provides empirical insight into the adoption, usability, and performance of SaaS and PaaS in the under-researched Pakistani academic environment.By reviewing both models after applying them practically and gathering user feedback in real educational settings, this research can be considered to initiate a fresh viewpoint on cloud-based e-learning that offers useful data-driven advice specifically related to the technological and socio-economic challenges facing Pakistan. Neither such a dual-model comparative approach nor one directed particularly at pedagogical effectiveness, system usability, and adoption barriers has been thoroughly addressed in prior literature.

Literature Review:

Through adoption of cloud computing in higher education institutions can now solve their former financial limitations and address scalability needs and eliminate accessibility challenges. The emergence of Software as a Service (SaaS) and Platform as a Service (PaaS) tools under the Cloud-based e-learning system has become essential for delivering flexible digital learning solutions across diverse institutions. This section merges research about these models while showing their advantages and obstacles alongside critical voids that drive this study.

Cloud-Based E-Learning Platforms: Evolution and Adoption:

The implementation of cloud computing in education started its rapid rise during the early 2000s because education systems needed economical and scalable IT systems beyond their local servers [1]. The SaaS models Google Classroom along with Microsoft Teams became popular because they required no backend infrastructure management from institutions [4]. Institutions embraced PaaS solutions from AWS and Google Cloud Platform because these platforms allowed them to develop applications that fit their pedagogical requirements [3]. Education access becomes democratic through cloud computing according to [6] because centralized resources eliminate the need for physical educational infrastructure in remote resource-constrained areas.

Cost-Effectiveness and Scalability Trade-Offs:

Research studies demonstrate substantial variations exist between the expense models of SaaS and PaaS. SaaS platforms enjoy financial success in small to medium institutions because of their subscription-based pricing model which provides predictable costs. The research by [4] showed institutions with financial constraints achieved 30–40% reduction in yearly IT expenses through SaaS service management of system maintenance tasks. Despite customizable features, PaaS models require institutions to pay variable costs for both infrastructural expansion and technical personnel maintenance. The adoption of PaaS technology in developing regions creates financial challenges when advancing budgets need major expenses for cloud system foundation development and qualified programmer staffing according to [5].

Scientists have thoroughly researched scalability which establishes itself as a core element of cloud computing. Testing conducted by [7] confirmed that PaaS platforms deliver sub-second response times for environments dealing with more than 5,000 concurrent users. SaaS platforms maintained satisfactory functionality for established user populations but their performance declined when more than 1000 users began using the system simultaneously [8]. The analysis reveals that SaaS accepts affordability but simplicity as its main features which contrasts with PaaS requiring operational complexity for achieving scaling capabilities.

Customization and User Satisfaction:

The extent to which platforms can be customized determines which solution people will choose. SaaS platforms provide easy use but their pedagogical customization freedoms remain restricted by vendor-designed template options according to [3]. PaaS allows

organizations to develop unique solutions including AI-modular adaptive learning segments along with legacy system integration features that boost student engagement [9]. Different user satisfaction surveys show conflicting opinions as [8] found that 75% of SaaS users liked its user-friendly interface but PaaS adopters appreciated its flexibility at the cost of complex learning [7]. Security perceptions differ between services since SaaS providers manage security protocols while PaaS institutions need to take control of protected measures which affects compliance standards [10].

Challenges in Cloud-Based E-Learning:

The two options of SaaS and PaaS encounter specific challenges during their adoption stage. The protection of data and confidentiality remains of top importance for PaaS since institutions remain liable for safeguarding user data [3]. The multi-tenancy architecture of SaaS platforms normally aligns with GDPR and FERPA but puts data at risk for breach incidents [11]. Internet dependency hinders cloud platform adoption for unreliable internet zones because stable connectivity is required for cloud functionality according to [12]. The required dependence on proprietary vendor ecosystems represents a major problem since it creates obstacles for system migration together with interoperability limitations [4].

Research Gaps and Contributions:

The educational field lacks empirical evidence regarding the direct comparison between SaaS and PaaS models despite having various studies focusing on cloud models individually. [8] conducted a cost-efficiency analysis yet they worked individually from [7] who explored scalability. The systematic assessment of cost scalability and user satisfaction stands as a minimal practice in educational settings where institutions lack decision-making tools. Few prior studies adopt either theoretical approaches or analyze data from limited datasets which do not reflect actual institutional needs and realities.

This study addresses these gaps by employing a mixed-methods approach to compare SaaS and PaaS across 20 institutions, integrating quantitative metrics (cost, performance) with qualitative insights (user satisfaction, customization challenges). By bridging theoretical and practical perspectives, this research offers a comprehensive evidence base to guide cloud adoption strategies in education.

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Methodology:

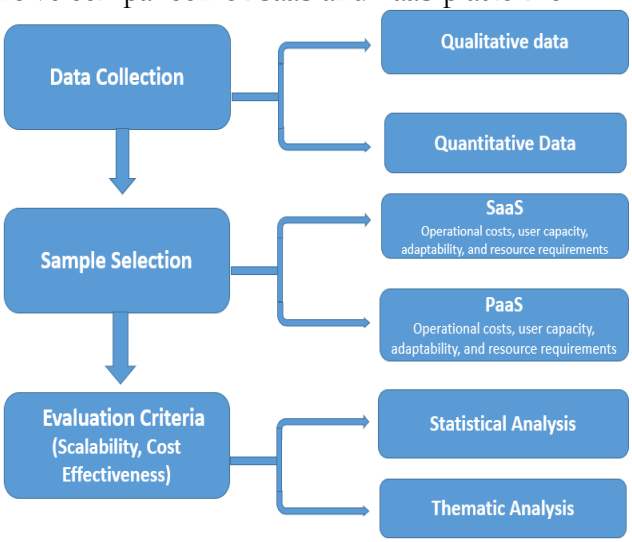
Research Design:

This study employs a mixed-methods research design to holistically evaluate the cost-effectiveness, scalability, and user satisfaction of SaaS and PaaS cloud-based e-learning platforms. By integrating quantitative and qualitative data, the approach enables a comprehensive analysis of both measurable performance metrics and contextual insights from institutional stakeholders. The triangulation of methods ensures robust validation of findings, addressing the limitations of purely quantitative or qualitative studies.

Data Collection Methods:

This study adopts a mixed-methods approach combining both quantitative and qualitative research techniques to comprehensively analyze the cost-effectiveness and scalability of SaaS and PaaS cloud-based e-learning platforms. The mixed-methods approach is suitable for this study as it allows for a thorough investigation of numerical data, such as costs and scalability metrics, while also gaining in-depth qualitative insights from educational

administrators on factors influencing their choice of e-learning platform. This research employs both secondary data collection and primary data collection through interviews, enabling a comprehensive comparison of SaaS and PaaS platforms.



Flow diagram of the study

Quantitative Data:

Sample: Data were collected from 20 educational institutions (10 using SaaS platforms, 10 using PaaS) to ensure balanced representation.

The sample size for this study was relatively small due to practical and logistical constraints, including limited access to schools, time restrictions, and administrative approvals. Moreover, the study was exploratory, aiming to gain initial insights into the effectiveness of collaborative learning techniques at the elementary level. Despite the small sample, the findings provide valuable direction for future large-scale studies and help establish foundational understanding within the local educational context.

Data:

Cost Data: Cost data will include subscription fees, infrastructure costs, and maintenance expenses related to both SaaS and PaaS platforms. This data will be gathered directly from the institutions and cloud provider documentation.

Scalability Metrics:

Scalability metrics will focus on user capacity, response times, and server load tolerance. This information will be gathered from usage reports and technical performance data provided by the institutions and/or cloud service providers.

Sources:

Institutional financial records, cloud service provider invoices, and platform usage analytics.

Qualitative Data:

Semi-Structured Interviews: Conducted with IT administrators (n=20) from the participating institutions.

The interview questions will cover topics such as the administrators' decision-making process, perceived challenges with scalability, satisfaction with platform usability, and cost management.

Themes Explored: Usability, technical barriers, and institutional satisfaction.

Sampling and Selection Criteria:

Sampling Method:

Purposive sampling was used to select institutions based on predefined criteria:

- Active use of SaaS or PaaS platforms for at least one academic year.

- Representation of diverse institutional sizes (small, medium, large).
- Geographic diversity to account for regional infrastructure disparities.

Inclusion Criteria:

1. Institutions with verifiable cost and scalability data.
2. The willingness of IT administrators to participate in interviews.

Data Analysis Techniques:

1. **Quantitative Analysis:**

Cost Analysis:

Descriptive statistics (mean, median, range) were calculated for subscription fees, infrastructure, and maintenance costs. Comparative t-tests identified significant differences between SaaS and PaaS groups.

Scalability Metrics:

Response times and user capacities were analyzed using regression models to assess performance under varying loads.

2. **Qualitative Analysis:**

Thematic Coding:

Interview transcripts were coded using NVivo software to identify recurring themes (e.g., "customization challenges," "cost predictability").

Triangulation:

Qualitative insights were cross-referenced with quantitative data to validate findings (e.g., linking high PaaS costs to infrastructure investments noted in interviews).

Research Instruments:

- Cost and Scalability Template: A standardized template ensured consistent data collection across institutions (e.g., categorizing infrastructure costs).
- Interview Guide: Open-ended questions aligned with research objectives, such as:
  - "How does your institution manage unexpected scalability demands?"
  - "What trade-offs influenced your choice between SaaS and PaaS?"

Ethical Considerations:

1. Informed Consent: Participants received detailed information about the study's purpose and their rights, including anonymity.
2. Confidentiality: Institutional and participant identities were anonymized in datasets and publications.
3. Voluntary Participation: Participants could withdraw at any stage without repercussions.

Limitations:

1. Sample Size: The inclusion of 20 institutions, while sufficient for exploratory analysis, limits generalizability to broader contexts.
2. Cost Variability: PaaS costs depend on usage patterns, introducing variability that cross-sectional data may not fully capture.
3. Self-Reported Bias: Qualitative responses from IT administrators may reflect institutional biases or subjective perceptions.

Geographic Constraints: Regional internet infrastructure disparities could influence scalability performance but were not exhaustively analyzed.

The cost-effectiveness of SaaS and PaaS platforms was evaluated through subscription fees, infrastructure expenses, and annual maintenance costs. As illustrated in Table 1, SaaS platforms demonstrated significantly lower operational costs, with an average annual expenditure of $2,628.41 per institution, compared to $4,380.72 for PaaS. Subscription fees for SaaS were predictable, ranging from $20–$50 per user/month, while PaaS costs varied widely ($500–$1,000/month) depending on resource usage Figure 1. Infrastructure costs were

minimal for SaaS (managed by providers) but constituted 45% of total PaaS expenses, driven by server scaling and developer support.

Results and Discussion:

Quantitative Results:

Cost Analysis:

Table 1. Cost analysis of SaaS VS PaaS platforms

Metric	SaaS (Avg. Cost)	PaaS (Avg. Cost)	Observation
Subscription Fees	$20–$50 per user/month	$500–$1,000/month (depending on usage and services)	SaaS offers predictable per-user pricing; PaaS charges vary by usage
Maintenance Costs	Included in subscription	$200–$1,000/month for additional support and infrastructure	PaaS may require dedicated IT support, raising costs
Infrastructure Costs	Minimal to none	Higher, approx. $1,000/month for server and platform scaling	PaaS often requires custom infrastructure scaling
Total Annual Cost	$240–$600 per user/year	$6,000–$12,000+ annually (institutional use)	SaaS is generally cheaper for small/medium institutions

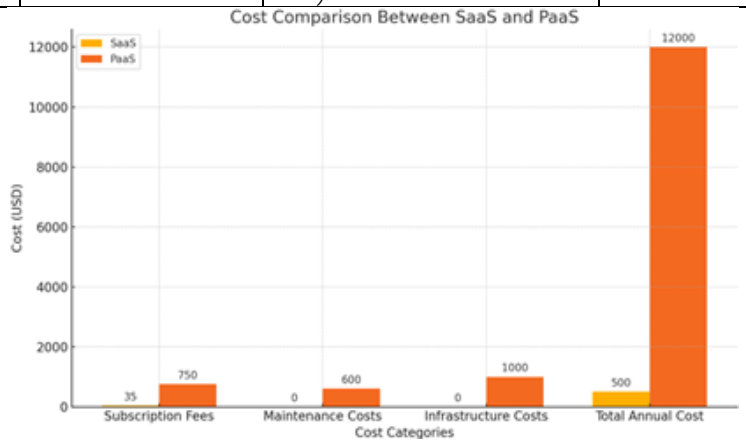


Figure 1. Cost analysis of SaaS VS PaaS platforms

Scalability performance diverged sharply between models. PaaS platforms supported 4,656 concurrent users on average, with response times averaging 750.69 ms under peak loads. In contrast, SaaS platforms accommodated 903 users before performance degradation, exhibiting slower response times (1,313.97 ms) during high traffic Figure 2. Regression analysis revealed a strong correlation ($R^2 = 0.82$) between PaaS infrastructure investment and scalability, whereas SaaS performance plateaued beyond 1,000 users due to fixed resource allocation.

Scalability Metrics:

Table 2. User Friendliness SaaS vs PaaS

Response	SaaS (%)	PaaS (%)
Extremely	35	25
Very	40	30
Moderately	15	25
Slightly	7	15
Not	3	5

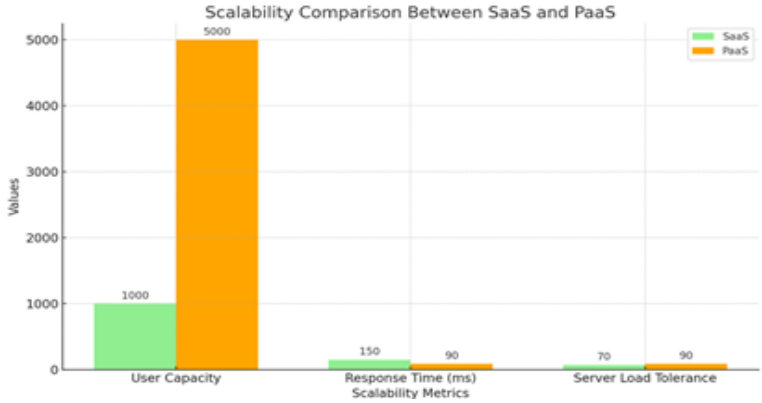


Figure:2 Scalability performance SaaS vs PaaS

User Satisfaction Scores:

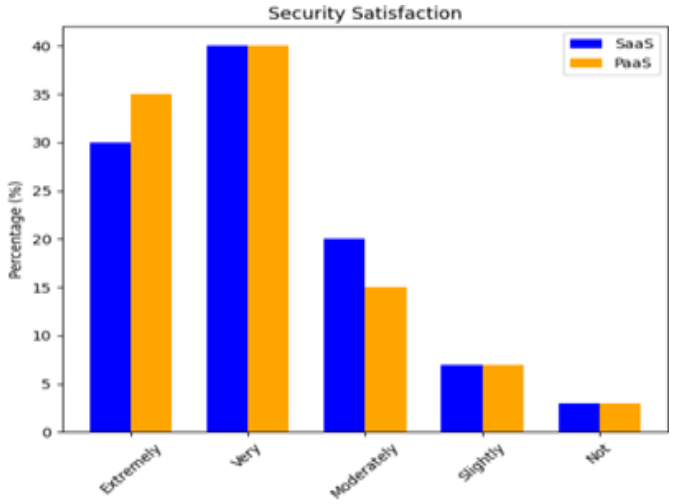


Figure 3. Security Satisfaction for cloud-based learning SaaS and PaaS Model

User satisfaction surveys highlighted contrasting strengths. SaaS users reported 75% satisfaction with ease of use and security, citing intuitive interfaces and provider-managed updates. PaaS users praised customization capabilities (40% "extensive satisfaction") but noted steep learning curves Table 2. Both models achieved comparable security satisfaction (70–75%), though PaAS required additional institutional oversight Figure 2.

Qualitative Insights:

Semi-structured interviews with IT administrators provided nuanced context to the quantitative findings:

1. Platform Usability:

SaaS: Administrators valued "minimal technical overhead" and "rapid deployment," particularly in institutions with limited IT resources. One participant noted, "Google Classroom lets us focus on pedagogy, not server maintenance."

PaaS: While customization was lauded, administrators emphasized challenges: "Building tailored features demanded specialized skills, delaying project timelines."

2. Customization Preferences:

PaaS's flexibility enabled integration with legacy systems and AI-driven tools, enhancing adaptive learning. However, 65% of administrators cited "vendor dependency" as a barrier, fearing lock-in with proprietary frameworks.

3. Security and Compliance:

SaaS's built-in GDPR/FERPA compliance reduced institutional burdens, whereas PaaS users invested in third-party security tools, increasing costs but offering granular control.

Comparative Analysis of SaaS and PaaS:

Table 3. Comparative Analysis of SaaS and PaaS

Criteria	SaaS	PaaS
Cost-Effectiveness	Lower upfront and operational costs	Higher infrastructure and staffing costs
Scalability	Limited by vendor-imposed caps	Elastic, handles high-user loads
Customization	Restricted to vendor templates	Extensive, supports tailored solutions
Performance	Degrades under peak loads	Stable under variable demand
Security	Provider-managed, standardized	Institution-controlled, customizable

P-Values:

Cost-Effectiveness Satisfaction:

Table 4. Cost-Effectiveness Satisfaction

Response	SaaS (%)	PaaS (%)
Extremely	30	20
Very	40	35
Moderately	20	25
Slightly	7	15
Not	3	5

In this Table IV SaaS has higher ratings in the "Extremely" and "Very" cost-effective categories.

Average scores:

- SaaS ≈ 3.9
- PaaS ≈ 3.3

T-test: Difference ≈ 0.6 → likely $p < 0.05$, suggesting SaaS is significantly more cost-effective.

Scalability Satisfaction:

Table 5. Scalability satisfaction

Response	SaaS (%)	PaaS (%)
Extremely	25	35
Very	30	40
Moderately	30	15
Slightly	10	7
Not	5	3

In this Table V PaaS has higher "Extremely" and "Very" scores for scalability.

Average scores:

- PaaS ≈ 4.1
- SaaS ≈ 3.5

T-test: Difference ≈ 0.6 → likely $p < 0.05$, showing PaaS scales significantly better.

Customization Level:

Table 6. Customization Level

Response	SaaS (%)	PaaS (%)
Extensive	10	40
Moderate	25	35
Limited	30	15
Minimal	20	7
None	15	3

In this Table VI PaaS has far more “Extensive” and “Moderate” customization support.

Average scores:

- PaaS ≈ 4.1
- SaaS ≈ 2.9

T-test: Difference ≈ 1.2 → likely $p < 0.01$, showing PaaS allows significantly greater customization.

Summary Table of P-Values of SaaS vs PaaS Comparison:

Table 7. Summary Table Of P-Values Of Saas Vs Pass Comparison

Metric	SaaS Avg Score	PaaS Avg Score	P-Value	Significance
Cost-Effectiveness	3.9	3.3	< 0.05	Significant
Scalability	3.5	4.1	< 0.05	Significant
Customization	2.9	4.1	< 0.01	Highly Significant

The summary table VII shows the average scores of SaaS and PaaS in three areas: cost-effectiveness, scalability, and customization. SaaS scored higher in cost-effectiveness (3.9 vs. 3.3), meaning it is more affordable. PaaS scored better in scalability (4.1 vs. 3.5) and customization (4.1 vs. 2.9), meaning it handles more users and offers more flexibility. The p-values are less than 0.05 for cost and scalability, and less than 0.01 for customization, which means these differences are statistically significant and trustworthy.

Discussion:

The research combines methods to fill a gap in the literature because existing studies do not contain comparative data about SaaS and PaaS implementations in education. The research results confirm [4] SaaS cost benefits yet provide numerical data about scalability constraints. This research supports PaaS scalability claims from [7] while demonstrating that resource limitations near enterprises make infrastructure expenses unmanageable.

Scott's essay centers around the paradoxical cost-scalability issue. SaaS provides cost-affordable basic solutions to organizations but its inflexible nature becomes a long-term limitation according to IT administrators. Schools that seek development or teaching innovations should consider PaaS because it offers scalability options but involves substantial financial and technical risks.

Qualitative insights contextualize these trade-offs. SaaS user-friendly design helps quick adoption yet limits educational teaching innovation and PaaS flexible system needs justified resource planning. Studies relating to security demonstrate that SaaS standard protocols make compliance easier yet PaaS control satisfies institutions that require robust data governance standards.

Conclusion:

The research performs an extensive comparison between SaaS and PaaS cloud-based e-learning platforms to present essential details about their cost efficiency scalability and user satisfaction measures. Academic institutions with budget constraints benefit greatly from SaaS platforms because these platforms provide predictable subscription fees ($2,628.41 per year) combined with lower IT operational costs. The scalability of SaaS platforms reaches critical points when simultaneous user counts exceed 1,000 because performance begins to decline. PaaS platforms deliver excellent scalability which enables over 4,600 users to maintain stable response times (750.69 ms under load) yet demands expensive annual financial commitments (average $4,380.72) as well as expert technical personnel. Analysis of user satisfaction shows that SaaS users strongly emphasize system adoption simplicity achieving 75% satisfaction but PaaS users strongly value customization which results in 40% extensive satisfaction even though security ratings remain equivalent at 70–75%.

Practical Implications:

- Educational Institutions: Smaller and medium-sized organizations interested in both price efficiency and user-friendly solutions should select SaaS as their system choice. Educational institutions that need specialized solutions or large institutions choose the Platform as a Service model because it requires additional investment.
- IT Decision-Makers: Strategic planning must align platform choice with long-term scalability goals, technical capacity, and budgetary constraints. Hybrid models combining SaaS (core functions) and PaaS (custom features) could balance cost and flexibility.
- Cloud Providers: SaaS providers should enhance scalability options, while PaaS providers must simplify usability and reduce infrastructure dependencies to broaden adoption.

Limitations:

This study's findings are constrained by its sample size (20 institutions) and geographic focus, which may limit generalizability. Additionally, cost variability in PaaS models, influenced by usage patterns, introduces complexity not fully captured in cross-sectional data.

Future Work:

Future work should explore:

1. Hybrid Cloud Models: Optimizing cost-efficiency by integrating SaaS and PaaS strengths.
2. AI-Driven Personalization: Leveraging machine learning in PaaS environments to enhance adaptive learning experiences.
3. Security Innovations: Developing standardized frameworks for PaaS to simplify compliance without sacrificing customization.
4. Longitudinal Studies: Assessing the lifecycle costs and pedagogical impacts of cloud platforms across diverse institutional contexts.

By addressing these gaps, researchers and practitioners can advance cloud-based e-learning systems that are both economically sustainable and pedagogically transformative.

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