The evolution of cloud computing in education: from Hype Cycle to mainstream adoption (2012-2024)

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Abstract. This paper presents a longitudinal analysis of cloud computing adoption in educational contexts from 2012 to 2024, examining how these technologies have progressed through Gartner's Hype Cycle stages to become mainstream educational tools. Building upon initial research conducted in 2012, we integrate recent scholarly developments to construct a comprehensive framework for understanding cloud technology integration in education. Through systematic analysis of adoption patterns, we identify regional variations between Eastern European and Western educational institutions, highlighting how the COVID-19 pandemic accelerated cloud adoption trajectories. Our original contribution includes the development of an integrated Cloud Education Readiness Framework (CERF) that synthesizes elements from Technology Acceptance Model, UTAUT, and Hype Cycle perspectives. The results reveal that while cloud technologies have largely reached the plateau of productivity in Western educational contexts, Eastern European institutions demonstrate distinctive adoption patterns characterized by later adoption timelines but accelerated implementation during the pandemic period. Security, privacy concerns, and institutional readiness remain significant barriers to adoption, while the integration of AI and edge computing represents the emerging frontier. This research provides valuable insights for educational leadership, technology planners, and policy makers seeking to optimize cloud technology investments and implementation strategies in diverse educational environments.

Keywords: cloud computing, education technology, Hype Cycle, technology adoption, UTAUT, digital transformation, COVID-19, Eastern Europe

1. Introduction

Cloud computing has fundamentally transformed educational technology landscapes over the past decade, evolving from an emerging innovation to an essential infrastructure component in modern educational environments. The trajectory of this evolution has followed distinctive patterns that reflect broader technological diffusion processes, institutional adaptations, and regional variations. Understanding these patterns provides critical insights for educational leaders, technology planners, and policy makers seeking to optimize technology investments and implementation strategies.

Building upon foundational research conducted in 2012 that examined the early stages of cloud computing adoption in education through the lens of Gartner's Hype Cycle [4], this study presents a comprehensive longitudinal analysis that tracks the evolution of cloud technologies in educational contexts through 2024. The Hype Cycle framework, while valuable for understanding technology adoption patterns, represents only one dimension of a complex socio-technical phenomenon that demands integration with complementary theoretical perspectives.

The significance of this research is amplified by two critical developments. First, the

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COVID-19 pandemic triggered unprecedented acceleration in educational technology adoption, compressing what might have been years of gradual implementation into months of urgent deployment [10, 17]. Second, the emergence of AI-enhanced cloud services and edge computing solutions has introduced new capabilities and challenges that educational institutions are only beginning to navigate [12, 16]. These developments have created both opportunities and tensions that merit scholarly examination.

This study addresses several key research questions:

1. How have cloud computing technologies in education progressed through the Hype Cycle stages from 2012 to 2024?
2. What differences exist between Eastern European and Western educational institutions in cloud technology adoption patterns?
3. How did the COVID-19 pandemic reshape cloud technology implementation trajectories in educational settings?
4. What theoretical frameworks beyond the Hype Cycle provide valuable insights into educational cloud computing adoption?
5. What emerging technologies represent the next wave of cloud-based innovation in education?

Our contribution to the field is threefold. First, we provide a longitudinal analysis that tracks cloud technology evolution in education across multiple Hype Cycle generations. Second, we develop an integrated theoretical framework that synthesizes Hype Cycle perspectives with Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and regionally sensitive adoption factors. Third, we identify distinctive patterns of adoption in Eastern European educational contexts compared to Western institutions, illuminating how regional factors shape technology implementation.

The paper is structured as follows: section 2 presents a literature review covering the evolution of cloud computing in education, theoretical frameworks for technology adoption, and the impact of COVID-19. Section 4 outlines our theoretical framework and methodology. Section 5 presents results and analysis, while Section 6 discusses implications, limitations, and directions for future research.

2. Literature review

2.1. Evolution of cloud computing in education (2012-2024)

The trajectory of cloud computing adoption in education has followed a distinctive path since early implementations began appearing in educational institutions in the late 2000s. Early research by Laru, Näykki and Järvelä [8] applied Gartner's Hype Cycle as a framework for understanding this evolution, identifying five sequential phases: the technology trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment, and plateau of productivity. This cyclical pattern has proven particularly relevant for understanding educational technology adoption, where institutional factors and pedagogical considerations create distinctive implementation dynamics.

In the early 2010s, cloud computing in education primarily focused on infrastructure solutions and basic productivity applications [2]. Educational institutions were attracted to cloud computing primarily for its potential cost savings and resource flexibility. By 2012, our initial research indicated that higher education institutions were beginning to explore cloud technologies but remained in early adoption stages, with significant variations between Western and Eastern European implementations [4].

The period from 2013 to 2016 represented a critical transition for cloud technologies in education. Prinsloo and Van Deventer [11] analyzed Gartner Hype Cycles from this period, finding that higher education institutions generally lagged behind industry in cloud technology adoption. Their research revealed that educational institutions typically waited until technologies had become commonplace in everyday applications before implementing them in educational contexts, indicating a more conservative approach to technology adoption than commercial sectors demonstrated.

By 2017-2019, cloud computing had begun to mature in educational settings, particularly in Western contexts. Muhairat, Abdallah and Althunibat [9] documented the shift from experimental implementations to strategic integration of cloud technologies in higher education institutions. Their case study at Al-Zaytoonah University in Jordan demonstrated how cloud resources improved access flexibility and collaboration effectiveness among learners and staff, indicating a transition into the "slope of enlightenment" phase of the Hype Cycle.

Figure 1 visualizes this evolution through the Hype Cycle framework, showcasing how different cloud technologies progressed through these stages between 2012 and 2024.

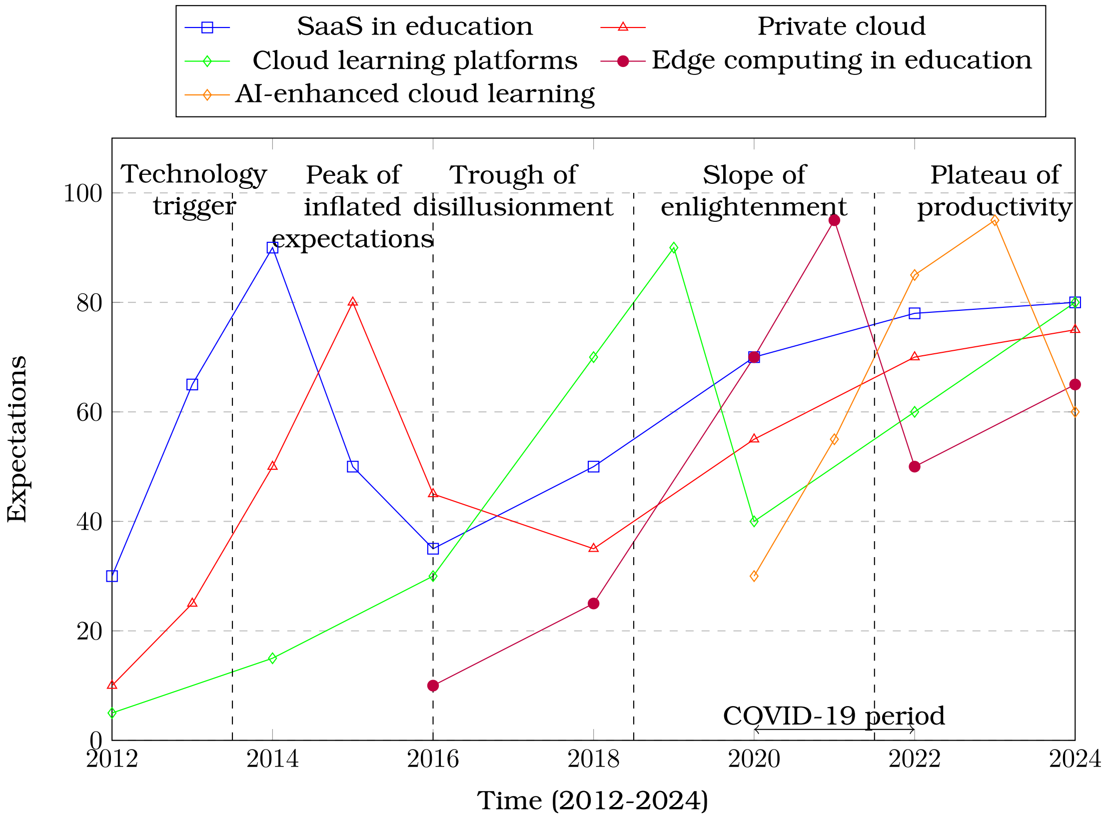

Figure 1: Evolution of cloud technologies in education through Hype Cycle stages (2012-2024).

2.2. Theoretical frameworks for technology adoption

While the Hype Cycle provides a valuable macro-level perspective on technology evolution, research on cloud technology adoption in education has increasingly incorporated additional theoretical frameworks to understand implementation at institutional and individual levels. Several frameworks have proven particularly valuable for explaining cloud adoption patterns in educational contexts.

The Technology Acceptance Model (TAM) has been extensively utilized to investigate factors influencing cloud adoption decisions in educational settings. Hussein and Hilmi [6] employed TAM to examine cloud-based e-learning adoption in Malaysian universities, finding that perceived usefulness and need significantly influenced adoption intentions, while innovativeness was not a significant factor. This research demonstrates TAM's utility for understanding the cognitive factors shaping stakeholder perceptions of cloud technologies.

The Unified Theory of Acceptance and Use of Technology (UTAUT) has emerged as another influential framework. Kabra, Ghosh and Joshi [7] extended UTAUT to investigate student perceptions of cloud technologies in Indian higher education institutions. Their findings revealed that social influence, performance expectancy, and facilitating conditions positively influenced attitudes toward cloud adoption, with perceived trust serving as a mediating factor. This research highlights the importance of institutional support structures and peer influence in shaping adoption decisions.

Beyond these individual-focused frameworks, organizational-level perspectives have provided complementary insights. The Technology-Organization-Environment (TOE) framework has been applied by researchers such as Santos et al. [13] to examine the multidimensional factors affecting cloud adoption in educational institutions. Their systematic literature review identified security, cost-effectiveness, scalability, interoperability, and regulatory compliance as critical factors shaping adoption decisions across educational and organizational contexts.

Figure 2 presents an integrated view of these theoretical perspectives, highlighting their complementary contributions to understanding cloud technology adoption in education.

2.3. Impact of COVID-19 on educational cloud computing

The COVID-19 pandemic represented an unprecedented catalyst for educational technology adoption, compressing what might have been years of gradual implementation into months of urgent deployment. Pejić Bach et al. [10] conducted a comparative study of e-learning adoption in European countries before and during the pandemic, finding that economically and digitally advanced countries led cloud-based educational technology adoption both before and during the pandemic. However, their response to pandemic conditions was less rigid than less advanced countries, which implemented stricter lockdown measures due to healthcare resource limitations.

In higher education contexts, Shakor and Shafiq Surameery [14] documented the pandemic's impact on cloud computing environments in Iraqi universities. Their research revealed that approximately 99% of respondents considered cloud applications to have played a crucial role in supporting research activities during pandemic restrictions. Availability and cost savings emerged as the most influential factors encouraging cloud service adoption, while performance issues and lack of user control represented significant barriers.

The pandemic-induced shift toward cloud technologies has had lasting implications beyond immediate emergency responses. Soto et al. [15] conducted a survey across 97 Japanese higher education institutions, finding that COVID-19 significantly influenced cloud adoption patterns, with 92% of institutions reporting increased awareness and usage of cloud technologies. Their research identified hybrid cloud models (56%) and Software as a Service (SaaS) solutions (96%) as the predominant implementation approaches, indicating a strategic preference for balanced approaches that combine institutional control with vendor capabilities.

The pandemic experience simultaneously accelerated adoption and exposed limitations in cloud implementations. Walker and Voce [17] analyzed post-pandemic learning technology developments in UK higher education, identifying increased investment in technology-enhanced learning services and an expanded core set of centrally managed tools. However, their findings suggested that the sustainability of innovative practices developed during emergency remote teaching remained uncertain, contingent on instructional competencies and staff capacity to support ongoing development.

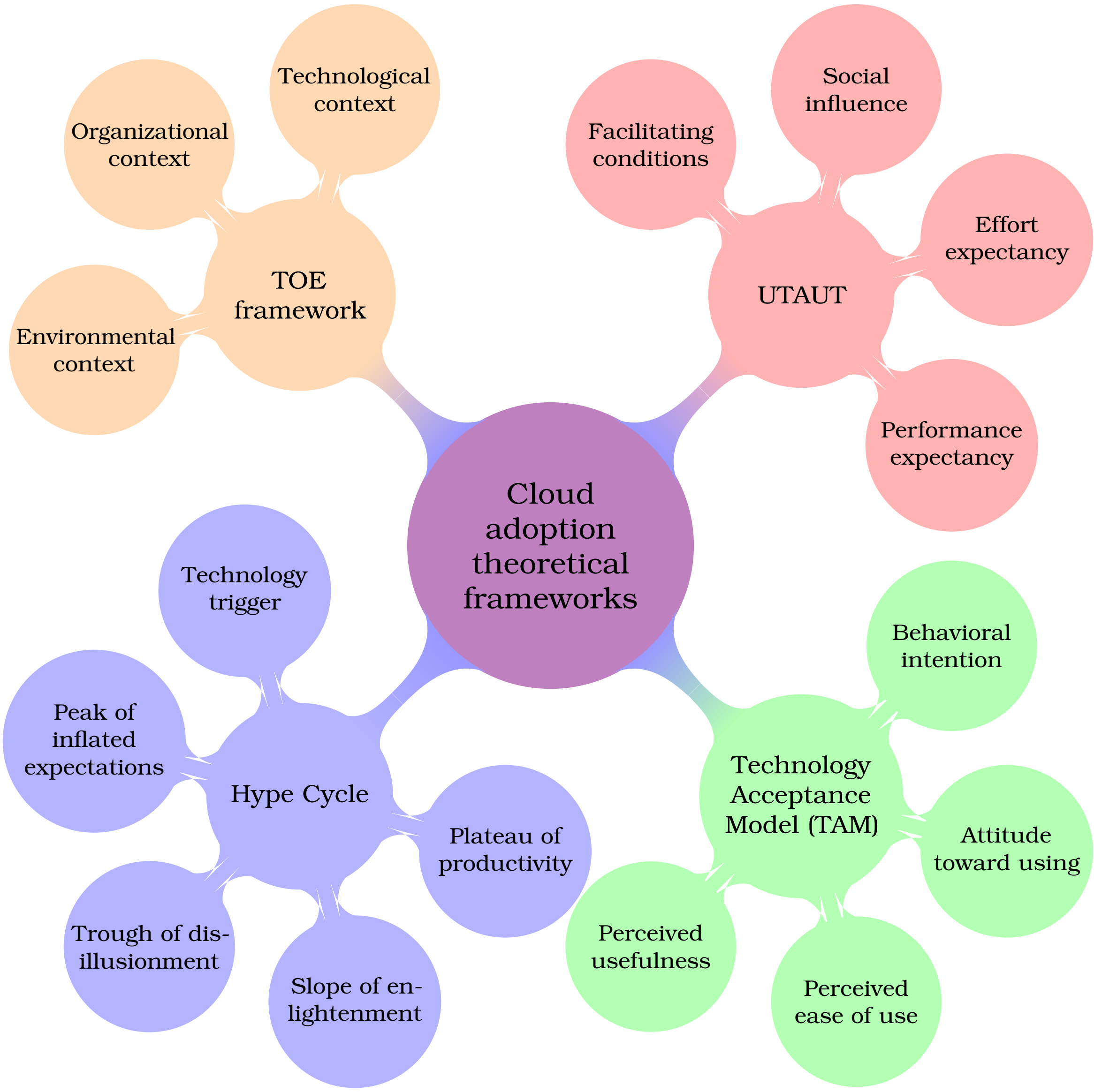

Figure 2: Theoretical frameworks applied to cloud technology adoption in education.

Table 1 summarizes key findings regarding pandemic impacts on educational cloud computing across various regional contexts.

2.4. Regional variations in cloud adoption

Significant variations exist in cloud technology adoption patterns between Eastern European and Western educational institutions. Zbořil and Svatá [18] conducted a comparative analysis of cloud service consumption in the Czech Republic, Visegrád Group, and broader European Union, finding that average cloud consumption in the EU exceeded levels in Eastern European countries. While the Czech Republic demonstrated slightly higher adoption rates than the broader Visegrád Group average, both lagged behind Western European implementation levels.

These regional disparities reflect broader economic and infrastructure factors. Brzozowska-Rup, Nowakowska and Zdradzisz [3] examined cloud computing adoption in Polish public administration, identifying substantial variation between voivodeships (provinces). Their research revealed significant correlations between cloud technology use in public administration and regional economic development levels and IT training

Table 1
COVID-19 impact on educational cloud computing across regions.

Region	Adoption changes	Primary benefits	Persistent challenges
Western Europe	• Increased investment in TEL services • Expanded core centrally managed tools • Strategic cloud integration	• Enhanced flexibility • Improved remote accessibility • Better continuity capabilities	• Staff capacity limitations • Instructional competency gaps • Sustainable innovation concerns
East Asia (Japan)	• 92% increased awareness • 56% hybrid cloud adoption • 96% SaaS implementation	• Efficient remote learning • Cloud-based resource access • Collaborative capabilities	• Data security (55% concerned) • Budget management issues • Technical expertise shortages
Middle East (Iraq)	• 99% recognized value for research • Accelerated adoption timelines • Focus on accessibility	• Cost reduction • Remote resource availability • Research collaboration	• Performance limitations • User control restrictions • Technical implementation barriers
Eastern Europe	• Strict response measures • Accelerated but less sophisticated adoption • Infrastructure limitations	• Educational continuity • Cost-effective scaling • Cross-border collaboration	• Digital divide concerns • Infrastructure inadequacies • Implementation skill gaps

investments, highlighting how economic factors shape implementation capabilities.

The evolution of cloud technology adoption in Eastern European educational contexts has followed a distinctive trajectory compared to Western implementations. While Western institutions typically progressed through Hype Cycle stages earlier, Eastern European adoption patterns have been characterized by later initial adoption but potentially accelerated movement through subsequent stages, particularly during pandemic response periods.

2.5. Research gap

Despite extensive literature on cloud computing in education, several critical gaps remain. First, while individual studies have examined specific Hype Cycle periods, limited longitudinal research tracks cloud technology evolution across multiple Hype Cycle generations, particularly in comparative Eastern European and Western contexts. Second, theoretical frameworks have typically been applied in isolation rather than integrated to provide comprehensive explanatory models. Third, the distinctive impacts of the COVID-19 pandemic on cloud technology adoption trajectories remain inadequately theorized, particularly regarding potential permanence of changes and regional variations.

This study addresses these gaps by developing an integrated theoretical framework that synthesizes Hype Cycle perspectives with TAM, UTAUT, and regionally sensitive adoption factors, applying this framework to analyze longitudinal cloud technology evolution in education from 2012 to 2024, with particular attention to Eastern European contexts and pandemic-induced transformations.

3. Theoretical framework and methodology

3.1. Integrated theoretical framework

To address the complex dynamics of cloud technology adoption in education, we propose an integrated theoretical framework that synthesizes elements from the Hype Cycle, Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and Technology-Organization-Environment (TOE) perspectives. This integrated framework, which we term the Cloud Education Readiness Framework (CERF), provides a comprehensive lens for analyzing cloud technology evolution across multiple levels of analysis: technological, individual, organizational, and environmental (figure 3).

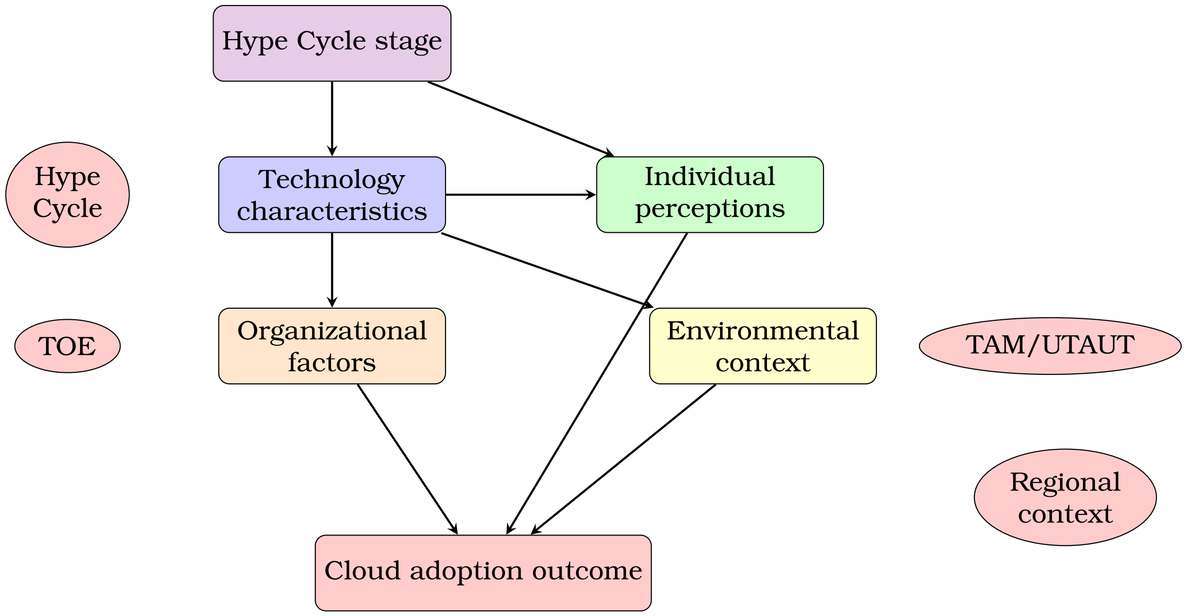

Figure 3: Cloud Education Readiness Framework (CERF).

The CERF framework posits that cloud technology adoption in educational contexts is shaped by the interaction of five key components:

1. *Hype Cycle stage* – the broader technological maturity level shapes expectations, perceived risks, and implementation approaches. Technologies at different Hype Cycle stages require different adoption strategies and generate different stakeholder responses.
2. *Technology characteristics* – specific attributes of cloud technologies, including relative advantage, complexity, compatibility, trialability, and observability, influence adoption decisions and implementation experiences.
3. *Individual perceptions* – stakeholder perceptions of usefulness, ease of use, performance expectancy, and effort expectancy shape attitudes and behavioral intentions regarding cloud technology adoption.
4. *Organizational factors* – institutional characteristics, including leadership support, IT infrastructure, staff expertise, and resource availability, enable or constrain cloud technology implementations.

5. *Environmental context* – external factors, including regulatory requirements, competitive pressures, regional infrastructure, and cultural expectations, create contextual conditions that influence adoption decisions.

The CERF framework provides an integrated perspective that facilitates analysis of cloud technology evolution across different time periods, regional contexts, and institutional types. It acknowledges that cloud adoption represents a complex socio-technical phenomenon shaped by multiple interacting factors rather than a simple linear progression.

3.2. Methodology

Our research methodology combines systematic literature analysis with comparative historical analysis to track cloud technology evolution across multiple time periods and regional contexts.

3.2.1. Data sources

We employed a search strategy using Scopus to identify relevant literature published between 2012 and 2024. Our search terms combined cloud computing concepts with educational technology terms (e.g., "cloud computing" AND "education" OR "e-learning" OR "educational technology"). Additionally, we specifically targeted studies examining Eastern European educational contexts by including regional search terms.

To ensure comprehensive coverage of relevant developments, we supplemented academic literature with Gartner Hype Cycle reports published between 2012 and 2024, focusing on both general emerging technology reports and education-specific analyses. These reports provided longitudinal data regarding technology positioning and maturity assessments across multiple time periods.

3.2.2. Analysis approach

Our analysis proceeded through several structured phases:

1. **Temporal analysis**: we tracked the evolution of key cloud technology components (e.g., SaaS, PaaS, IaaS, private cloud, public cloud) through successive Hype Cycle stages from 2012 to 2024, identifying transition points, acceleration periods, and potential recalibrations.
2. **Regional comparative analysis**: we mapped adoption patterns across Eastern European and Western educational institutions, identifying similarities, differences, and potential explanatory factors for observed variations.
3. **Theoretical integration**: we applied the CERF framework to interpret observed patterns, relating technology evolution to individual, organizational, and environmental factors across different contexts.
4. **Pandemic impact assessment**: we conducted focused analysis of COVID-19 impacts on cloud technology trajectories, examining pre-pandemic, pandemic, and post-pandemic patterns to identify potential permanent shifts versus temporary adaptations.

This multidimensional analysis approach enabled us to develop a comprehensive understanding of cloud technology evolution in education that accounts for technological, individual, organizational, and contextual factors across different time periods and regional settings.

4. Results and analysis

4.1. Temporal evolution of educational cloud technologies

Our analysis reveals a distinctive evolution pattern for cloud technologies in education, with different components progressing through Hype Cycle stages at varying rates between 2012 and 2024. Table 2 presents a longitudinal mapping of key cloud technologies across Hype Cycle stages based on our analysis of Gartner reports and academic literature.

Table 2
Longitudinal evolution of educational cloud technologies through hype cycle stages.

Technology	2012-2013	2014-2016	2017-2019	2020-2022	2023-2024
SaaS in education	Technology trigger	Peak of inflated expectations	Trough of disillusionment	Slope of enlightenment	Plateau of productivity
Private cloud	Technology trigger	Technology trigger	Peak of inflated expectations	Trough of disillusionment	Slope of enlightenment
Cloud LMS	Technology trigger	Peak of inflated expectations	Trough of disillusionment	Slope of enlightenment	Plateau of productivity
Virtual labs	Technology trigger	Technology trigger	Peak of inflated expectations	Trough of disillusionment	Slope of enlightenment
Cloud collaboration tools	Technology trigger	Peak of inflated expectations	Slope of enlightenment	Plateau of productivity	Plateau of productivity
Edge computing in education	Not on Cycle	Not on Cycle	Technology trigger	Peak of inflated expectations	Trough of disillusionment
AI-enhanced cloud learning	Not on Cycle	Not on Cycle	Technology trigger	Peak of inflated expectations	Peak of inflated expectations

Several key patterns emerge from this temporal analysis. First, basic cloud service models (SaaS) and fundamental applications (cloud collaboration tools) have progressed most rapidly through the Hype Cycle, reaching the plateau of productivity by 2023-2024. These technologies represent the most mature and broadly implemented cloud components in educational contexts.

Second, more complex implementations with greater institutional integration requirements (private cloud, virtual labs) have progressed more slowly through Hype Cycle stages, typically lagging 2-3 years behind simpler implementations. This pattern reflects the additional technical, organizational, and resource challenges associated with these implementations.

Third, newer technologies (edge computing, AI-enhanced cloud learning) entered the Hype Cycle more recently and currently remain in earlier stages. These technologies represent the emerging frontier of educational cloud computing, with significant potential but also substantial implementation challenges.

The COVID-19 pandemic, particularly during 2020-2022, appears to have accelerated movement through Hype Cycle stages for certain technologies. Cloud collaboration tools and cloud LMS demonstrated particularly pronounced acceleration, rapidly progressing from the Trough of disillusionment to the Plateau of productivity during this period. This acceleration reflects the urgent need for remote learning capabilities during pandemic restrictions.

4.2. Regional variations in cloud technology adoption

Our comparative analysis reveals distinctive patterns in cloud technology adoption between Eastern European and Western educational institutions. Figure 4 illustrates these differences for key cloud technologies as of 2024.

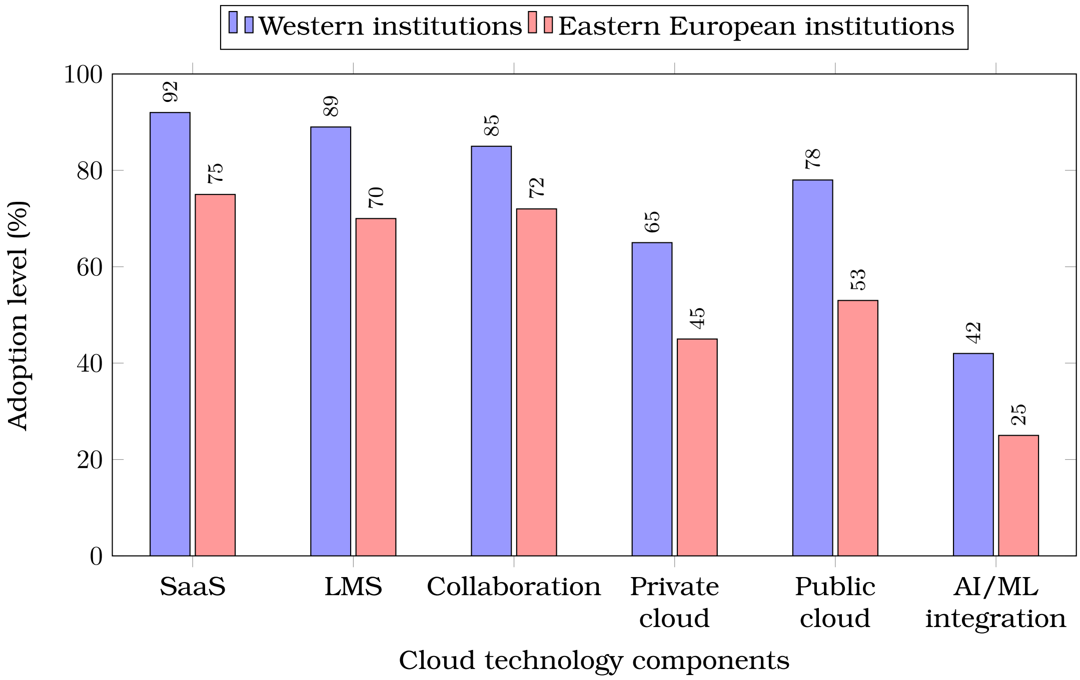

Figure 4: Comparative cloud technology adoption levels by region (2024).

These regional variations reflect broader patterns identified in our analysis. Western educational institutions generally demonstrate higher overall adoption rates across all cloud technology components. However, the adoption gap varies significantly by technology type, with smaller differences for basic collaboration tools (13 percentage points) and larger gaps for more complex implementations like private cloud (20 percentage points) and AI/ML integration (17 percentage points).

The reasons for these regional variations are multifaceted, as highlighted by Brzozowska-Rup, Nowakowska and Zdradzisz [3] and Zbořil and Svatá [18]. Economic development levels, IT infrastructure maturity, specialist expertise availability, and regulatory frameworks all contribute to these differences. Eastern European institutions often face additional challenges related to resource constraints, infrastructure limitations, and technical expertise shortages that influence adoption capabilities.

Interestingly, the pandemic response period produced temporary convergence in adoption rates for certain cloud technologies, particularly collaboration tools and cloud LMS. The urgent need for remote learning capabilities drove accelerated adoption across both regions. However, post-pandemic patterns suggest a potential return to pre-existing gaps, particularly for more advanced implementations requiring substantial infrastructure and expertise.

4.3. Impact of COVID-19 on cloud technology trajectories

Our analysis confirms that the COVID-19 pandemic significantly accelerated cloud technology adoption in educational settings across all regions, though with distinctive patterns and lasting impacts. Figure 5 illustrates adoption trajectories for key cloud technologies before, during, and after the peak pandemic period.

Several key patterns emerge from this analysis. First, the pandemic triggered substantial acceleration in adoption rates for technologies directly supporting remote

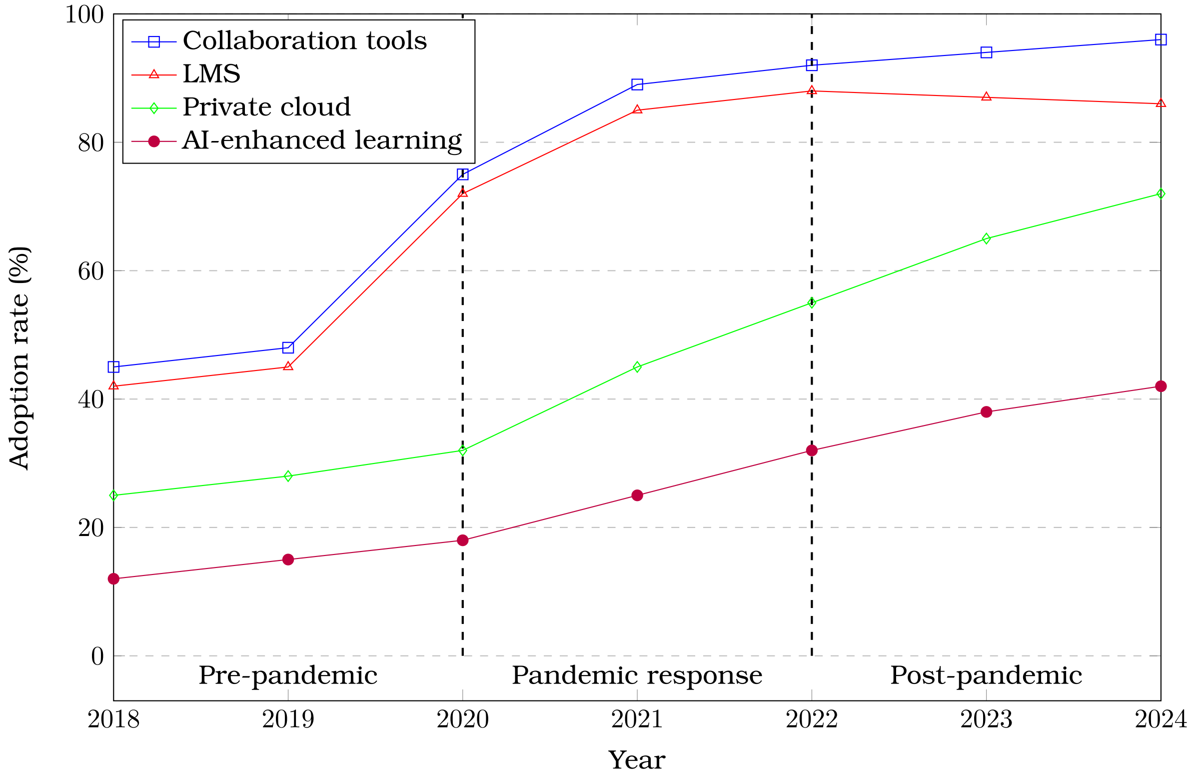

Figure 5: Cloud technology adoption trajectories before, during, and after COVID-19.

learning capabilities, particularly collaboration tools and learning management systems. These technologies experienced unprecedented adoption increases of 25-30 percentage points during the initial pandemic response period (2020-2021).

Second, the pandemic appears to have initiated lasting momentum for more complex cloud implementations, including private cloud and AI-enhanced learning solutions. While these technologies did not experience the same dramatic initial adoption spike, they have demonstrated sustained growth in the post-pandemic period, suggesting that pandemic experiences created institutional receptiveness to broader cloud transformation.

Third, post-pandemic trajectories reveal divergent patterns across technology types. Collaboration tools and LMS implementations have largely maintained their elevated adoption levels, with collaboration tools continuing modest growth while LMS implementations have slightly plateaued. This pattern suggests that fundamental remote/hybrid learning capabilities have become permanent features of educational environments rather than temporary emergency adaptations.

These findings align with research by Soto et al. [15] and Walker and Voce [17], who documented both immediate pandemic responses and evolving post-pandemic patterns in different regional contexts. The pandemic created what might be termed a "forced experiment" in educational cloud technology, compelling institutions to rapidly implement solutions that might otherwise have taken years to adopt gradually.

4.4. Emerging technologies and future trajectories

Our analysis identifies several emerging technologies that represent the next frontier for cloud computing in education. These technologies are currently in early Hype Cycle stages but demonstrate significant potential for educational applications based on early implementations and research trajectories.

AI-enhanced cloud services represent perhaps the most transformative emerging area. Venice et al. [16] and Saif Almuraqab [12] document the development of Personalized Learning Assistant (PLA) systems that leverage cloud infrastructure to deliver AI-driven adaptive learning experiences. These systems analyze educational data to develop comprehensive personalized learning models, generate tailored study plans, and implement adaptive learning based on performance feedback. While currently at the peak of inflated expectations stage, these technologies have demonstrated promising early results in supporting individualized learning experiences.

Edge computing solutions represent another emerging frontier, particularly for applications requiring low latency and continuous accessibility. Arun Kumar et al. [1] describes how edge computing can address connectivity and latency challenges in educational contexts, providing uninterrupted access to resources even in low-bandwidth environments. Edge computing approaches are particularly valuable for resource-intensive applications like virtual labs and simulation environments that benefit from local processing capabilities combined with cloud resources.

Blockchain technology integrated with cloud infrastructure is emerging as a potential solution for credential verification, assessment security, and educational record management. Dhakshan et al. [5] identifies blockchain as an important emerging technology for Education 4.0, enabling secure credential management and enhancing data integrity for educational records. While still in relatively early adoption stages, blockchain implementations demonstrate potential for addressing persistent security and verification challenges in educational contexts.

Table 3 summarizes these emerging technologies, their current Hype Cycle positions, and their potential educational applications.

5. Discussion

5.1. Implications for educational cloud computing theory

Our findings have implications for theoretical understandings of educational cloud computing adoption and evolution. First, our longitudinal analysis confirms the general utility of the Hype Cycle framework for understanding broad technology evolution patterns, but also highlights its limitations for capturing the complex socio-technical dynamics of educational technology adoption. The integrated CERF framework we propose addresses these limitations by incorporating individual, organizational, and environmental factors that shape adoption decisions and implementation experiences.

Second, our regional comparative analysis reveals important contextual influences on technology adoption that are inadequately addressed in universalist technology diffusion theories. Eastern European educational institutions demonstrate distinctive adoption patterns that reflect broader economic, infrastructure, and expertise factors. These findings suggest the need for regionally sensitive theoretical frameworks that acknowledge how contextual factors shape technology implementation capabilities and approaches.

Third, our analysis of pandemic impacts demonstrates how external shocks can fundamentally reshape technology adoption trajectories, accelerating movement through Hype Cycle stages and potentially creating permanent shifts in institutional practices. This finding highlights the need for dynamic theoretical models that can account for non-linear adoption patterns and external catalysts rather than assuming gradual, predictable diffusion processes.

5.2. Practical implications for educational institutions

Our findings provide several practical insights for educational leaders and technology planners navigating cloud technology decisions. First, the longitudinal tracking of cloud technologies through Hype Cycle stages offers guidance regarding implementation timing and expectations management. Technologies at different Hype Cycle

Table 3
Emerging educational cloud technologies: current stage and potential.

Technology	**Current Hype Cycle stage**	**Primary educational applications**	**Implementation challenges**
AI-enhanced learning	Peak of inflated expectations	• Personalized learning paths • Adaptive content delivery • Automated feedback systems • Learning analytics	• Data privacy concerns • Algorithm transparency • Integration complexity • Pedagogical alignment
Edge computing	Trough of disillusionment	• Low-latency applications • Resource-intensive simulations • Continuous access in variable connectivity • Mobile learning applications	• Infrastructure requirements • Management complexity • Cost implications • Technical expertise demands
Blockchain integration	Technology trigger	• Credential verification • Assessment security • Educational record management • Intellectual property protection	• Technical complexity • Regulatory uncertainty • Integration with existing systems • Resource demands
Federated learning	Technology trigger	• Privacy-preserving analytics • Cross-institutional collaboration • Personalized learning without centralized data • Secure research environments	• Implementation complexity • Performance considerations • Coordination requirements • Limited frameworks

stages require different adoption approaches, with early-stage technologies demanding greater risk tolerance and experimentation while mature technologies support more standardized implementation processes.

Second, the identification of regional variation patterns highlights the importance of contextually appropriate implementation strategies. Institutions in regions with less developed infrastructure or limited expertise availability may benefit from implementation approaches that prioritize robust foundational components and focused capability development before attempting more complex implementations.

Third, the analysis of pandemic impacts and emerging technologies provides guidance for strategic planning and investment prioritization. The demonstrated value of cloud technologies during pandemic disruptions underscores their importance for institutional resilience and continuity capabilities. Meanwhile, emerging technologies like AI-enhanced learning and edge computing represent promising areas for strategic investment and capability development.

5.3. Policy implications

Our findings have implications for educational technology policy at institutional, regional, and national levels. First, the documented regional variations in cloud technology adoption highlight the need for targeted policies that address specific barriers in different contexts. Eastern European educational systems would benefit from policies that specifically address infrastructure development, technical expertise building, and resource constraints that currently limit implementation capabilities.

Second, the acceleration of cloud technology adoption during the pandemic demonstrates the potential value of policy interventions that facilitate rapid technology transformation during periods of disruption. Policy mechanisms that reduce adoption barriers, provide implementation support, and facilitate knowledge sharing can help educational systems respond effectively to external challenges.

Third, the emerging technologies identified in our analysis suggest areas where proactive policy development would be beneficial. AI-enhanced learning applications, for example, raise important questions regarding data privacy, algorithm transparency, and pedagogical alignment that would benefit from thoughtful policy frameworks developed before widespread implementation.

5.4. Limitations and future research

Several limitations of our study should be acknowledged. First, while we have attempted to conduct comprehensive literature analysis, the rapid evolution of cloud technologies and the diversity of educational implementations mean that certain developments may not be fully captured in published research. Second, our regional comparative analysis relies on available literature, which may not provide complete coverage of all educational contexts, particularly less extensively studied regions. Third, the relatively recent nature of pandemic impacts and emerging technologies means that long-term patterns remain speculative rather than definitively established.

These limitations suggest several promising directions for future research. First, primary empirical research directly comparing cloud technology implementations across different regional contexts would provide valuable validation and extension of the patterns identified in our literature-based analysis. Second, longitudinal case studies tracking institutional cloud technology evolution through and beyond the pandemic period would offer deeper insights into adaptation mechanisms and implementation approaches. Third, focused research on emerging technologies like AI-enhanced learning and edge computing would help clarify their potential benefits, implementation challenges, and appropriate applications in diverse educational contexts.

6. Conclusion

This study has provided an analysis of cloud computing evolution in educational contexts from 2012 to 2024, examining how these technologies have progressed through Hype Cycle stages to become mainstream educational tools. Our findings confirm the utility of the Hype Cycle framework for understanding broad technology evolution patterns while also highlighting the importance of complementary theoretical perspectives that address individual, organizational, and environmental factors shaping adoption decisions and implementation experiences.

The integrated Cloud Education Readiness Framework (CERF) we have developed offers a valuable contribution to educational technology theory by synthesizing perspectives from the Hype Cycle, Technology Acceptance Model, Unified Theory of Acceptance and Use of Technology, and Technology-Organization-Environment frameworks. This integrated approach provides a more comprehensive explanatory framework for understanding the complex socio-technical dynamics of educational cloud computing adoption and evolution.

Our analysis has identified distinctive regional variations between Eastern European and Western educational institutions, with Western institutions generally demonstrating higher adoption rates across most cloud technology components. These differences reflect broader economic, infrastructure, and expertise factors that shape implementation capabilities and approaches. The COVID-19 pandemic represented a significant catalyst for cloud technology adoption, accelerating implementation timelines and potentially creating lasting changes in institutional practices.

Looking forward, emerging technologies like AI-enhanced learning, edge computing, and blockchain integration represent the next frontier for educational cloud computing. These technologies offer promising capabilities for personalized learning, enhanced accessibility, and improved security, though they also present implementation challenges related to technical complexity, resource requirements, and ethical considerations.

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