Cloud Computing in Education: A review of Architecture, Applications, and Integration Challenges

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ABSTRACT
Cloud computing has emerged in recent times as a disruptive technology that has favourably influenced the functioning of many businesses, organizations, and institutions. The utilisation and prevalence of cloud computing arise from an on-demand model that provides computing services via the internet. Several academic institutions have incorporated cloud computing into the educational process to enhance pedagogical outcomes. The review aims to examine cloud computing in education and the need for educational institutions to comprehend its primary advantages. In this review, we discussed the architectural integrations of cloud computing services in education, encompassing Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) models. The outcome of this study includes a visual representation of the educational trends in cloud computing, the impact of cloud educational technologies, and the major challenges facing its adoption. This review will augment literature on cloud computing, its application in educational institutions, and anticipated challenges.

Keywords
Cloud Computing; Cloud of Educational Technologies; Educational Cloud Architectures; Artificial Intelligence; Education 4.0.

1. INTRODUCTION
Before the advent of cloud computing, traditional computing models were prevalent. These traditional models depended primarily on local storage and on-premises technology. However, conventional computing models has constraints regarding flexibility, cost-efficiency, scalability, and accessibility [1], [2]. Cloud computing emerged as a disruptive solution to these constraints, providing on-demand computer resources, pay-as-you-go pricing, increased collaboration, and global accessibility via the internet [3], [4]. It transformed the storage, management, and accessibility of data for individuals and organisations, ultimately improving technological integrations and cost-efficiency. Cloud computing is integral in the 21st century because of its widespread adoption and beneficial impact. Cloud computing refers to the provision of computing services such as software, networking, databases, servers, storage, and analytics [5], [6]. Instead of keeping files locally, cloud computing uses remote storage systems, which provide benefits such as speed, availability, productivity, efficiency, performance, and security [7], [8]. According to Edge Delta [79], almost 90% of organisations globally use cloud services. A study conducted by Exploding Topics [80] reveals that 60% of corporate data is stored in the cloud. The figure has doubled, rising from just 30% in 2025. As shown in Figure 1, the projected revenue of the public cloud market is estimated to reach USD773.30 billion in 2024. This figure will double to USD 1,567 billion by 2028 [81]. The staggering growth rate of cloud computing has prompted numerous research initiatives and focal points across diverse sectors from the educational sector to agriculture.

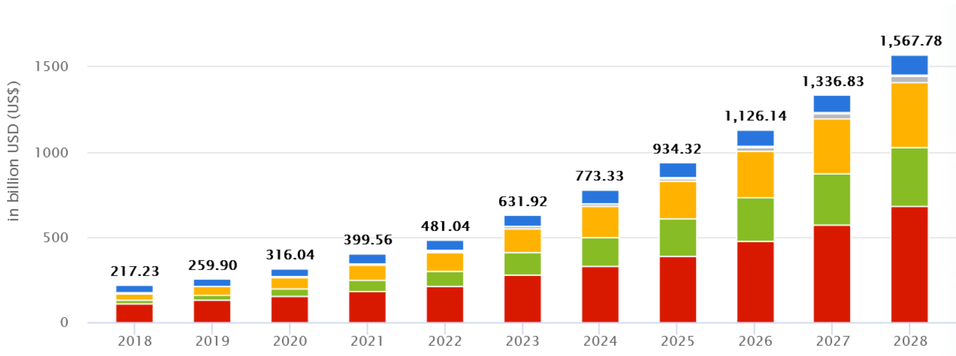

Fig 1: Projected Revenue of Public Cloud Market [81]

1.1 Technological Sector and Cloud Computing
The technological sector has seen a significant transformation as a result of cloud computing, which has revolutionised the storage, access, and management of data and applications. Alam [9] provide evidence that the scalability, flexibility, and cost-effectiveness of cloud services have enabled organisations to dynamically expand their infrastructure, eliminating the need for significant capital investments in physical servers and data centres. This transformation has increased access to robust computing resources, levelling opportunities for startups and established firms [10], [82]. The cloud has also fostered a new era of technological improvement and organisational agility, paving the way for innovations such as big data analytics,

artificial intelligence (AI), and Internet of Things (IoT) applications [11]–[13].

1.2 Finance, Banking and Cloud Computing

Cloud computing has transformed the finance and banking sector by modernising their operations, increasing efficiency, and encouraging creativity. This paradigm change includes frictionless access to financial services, cost savings through scalable infrastructure, and increased data analytics capabilities [14], [15]. Financial institutions can securely store and handle substantial data volumes on the cloud, facilitating real-time transaction processing and analysis for risk management and fraud detection. Moreover, the cloud has facilitated broader access to advanced financial products, enhancing financial inclusion for marginalised communities [16]. Finally, cloud computing has solidified its role as a cornerstone in the banking and financial sectors by enhancing agility, security, and client focus. Cloud computing has significantly transformed the finance and banking sectors by modernising processes, enhancing efficiency, and promoting creativity [17], [18]. The seamless access to financial services, cost efficiencies through scalable infrastructure, and enhanced data analytics capabilities are examples of this paradigm change.

1.3 Agriculture and Cloud Computing

The agricultural sector has experienced a significant transition due to cloud computing, enhancing productivity, data management, and decision-making. Agricultural producers and organisations can utilise cloud-based platforms to access extensive real-time data, such as weather forecasts, soil conditions, and crop performance, enabling informed decisions about planting, irrigation, and pest management [19], [20]. This data accessibility has reduced resource waste and environmental impact while enhancing crop yields. Additionally, cloud computing has aided the development of precision agriculture practices, allowing farmers to optimise their operations, save resources, and boost sustainability. In conclusion, cloud computing has altered the agricultural industry by providing the tools and knowledge needed for a more lucrative, efficient, and sustainable farming sector [21]–[23]

1.4 Manufacturing and Cloud Computing

Cloud computing has transformed the commercial and manufacturing sectors by providing scalable, cost-effective, and flexible IT solutions. This technology revolution has enabled industrial businesses to improve operational efficiency through real-time data analytics and remote equipment monitoring, resulting in predictive maintenance and reduced downtime [24], [25]. Manufacturers utilising cloud services can access manufacturing and production resources, including computer numerical control (CNC) machines, 3D printers, and assembly links on an on-demand basis. This practice enhances manufacturing output by augmenting capacity, reducing costs, and facilitating adaptive responses to consumer demands [25]. In addition, cloud-based technologies have simplified supply chain management, allowing businesses to optimise inventory levels and improve demand forecasting [26], [27].

1.5 Energy Grid and Cloud Computing

Cloud computing has transformed the operation and efficiency of the energy and utility industries. Organisations in this business can optimise energy generation, distribution, and consumption by leveraging big data analytics, IoT devices, and real-time monitoring via cloud-based solutions. This has increased client satisfaction, enhanced grid management, and reduced downtime [28], [29]. Cloud-based predictive analytics enable utilities to anticipate and respond to power outages more effectively [30]. Furthermore, utilities can adjust their computer capacities as required with cloud computing, which reduces infrastructure expenses and enhances flexibility. In summary, cloud computing has enhanced the energy and utility industries, facilitating a more sustainable and reliable energy supply while accommodating the evolving demands of consumers.

1.6 Entertainment Industry and Cloud Computing

Cloud computing has significantly revolutionised the entertainment industry by offering scalable and cost-effective solutions for content creation, distribution, and consumption. The delivery of high-quality content to global audiences by streaming services such as Netflix and Disney+, which utilise cloud technology to store vast collections of films and television programs, exemplifies this transformation [31], [32]. Moreover, cross-border collaboration among filmmakers and content creators is now feasible due to cloud-based production tools such as Adobe Creative Cloud and Avid Media Composer, which have optimised the creative process. The shift to cloud computing has fostered innovation and variety in the entertainment sector by democratising content creation and distribution while reducing infrastructure expenses [33].

1.7 Educational Sector and Cloud Computing

Cloud technology in education refers to the storing and retrieval of student information and course materials. By using the software for online lesson management, email management, calendar management, and other tasks. Using ubiquitous devices and the cloud, it is possible to learn while not physically present in a particular location [34], [35]. Cloud computing in education is altering the classroom by using internet-based technology to store, manage, and access data and instructional resources. Cloud-based platforms provide flexible and tailored learning experiences from anywhere with an internet connection. They also allow for seamless collaboration between students, teachers, and administrators. Cloud-based learning management systems (LMS) enable students to access course materials, coursework, and communication tools from anywhere with an internet connection. This accessibility has benefited nontraditional students in particular, such as working adults and students from remote locations [35], [36]. Cloud-based tools and software have enabled collaborative and interactive learning between students and teachers. For instance, real-time collaboration on documents and presentations is possible with Google Workspace for Education. As a result, the traditional classroom has been transformed into a lively and participatory learning environment. Additionally, cloud-based video conferencing services have enabled international collaboration and virtual classes. Cloud computing has also led to cost savings for educational institutions. Universities and colleges can reduce capital expenditures by contracting with cloud service providers to manage their IT equipment and applications. This allows them to dedicate more funds to improving educational standards [37], [38]. The ability to scale is a significant advantage of cloud computing. Educational institutions can rapidly adjust their IT resources in accordance with demand. This is particularly advantageous while executing data-intensive operations or during times of elevated enrolment. Education institutions are becoming more effective because of their improved resource management. Cloud computing has highlighted concerns regarding data security and privacy in education [39], [40]. This has become a prominent theme in recent research on how cloud service providers might use technology and protocols to secure sensitive educational data.

This study focused on cloud computing in education, emphasising educational benefits, cloud-based architecture for pedagogical use, cloud-supported educational applications, and significant difficulties. In line with the objectives, we pose the following research questions (RQs) to guide the study:

1. What is cloud computing? What are the potential benefits for diverse sectors?
2. What are the emerging trends and architecture in cloud computing for education, and how are they affecting the future of educational technology?
3. How does cloud-based educational technologies influence learning outcomes, student performance, engagement, and overall educational effectiveness?
4. What are the challenges associated with the implementation of cloud-based educational technologies, and what barriers will educational institutions face when adopting and integrating cloud solutions into their existing infrastructure?

The rest of the paper is organised as follows: First, section 2 discusses the methodological procedure. Second, section 3 examined and surveyed the reviewed literature. Third, section 4 discusses educational trends and areas of interest. Section 5 covers discussion, integrations, and limitations. Finally, section 6 covers the conclusion.

2. METHODOLOGY

This study was based on the seven steps to a comprehensive literature review by Onwuegbuzie & Frels [83]. The model is an iterative model with all steps interdependent on one another. As shown in Figure 1, the model applies three main phases, including the exploration phase, interpretation phase, and communication phase.

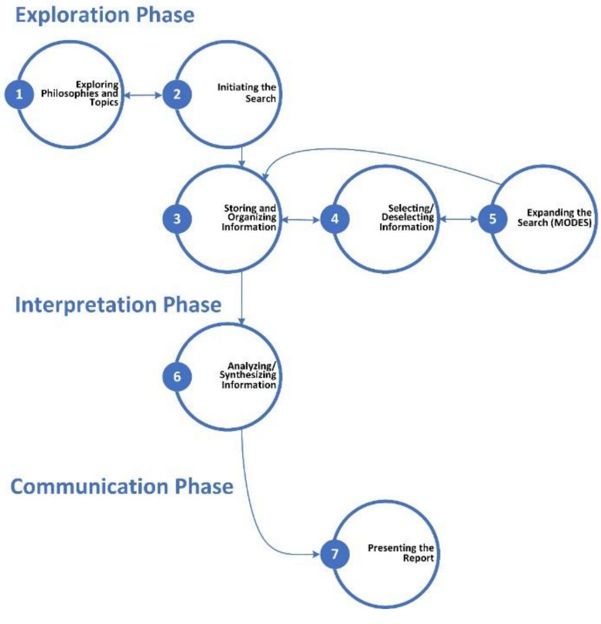

Fig 2: The seven steps to comprehensive literature review

2.1 Exploration Phase

The exploration phase consists of five steps. The purpose is to explore the topic and gather information. The first step involves exploring philosophies and topics to gather an initial understanding broadly, which is later narrowed as the literature review progresses. The step was conducted by acquiring knowledge through informal queries from Google and other relevant search engines to get a general knowledge of cloud computing and future trends in education. The initiating the search step involves reflecting on the results from these searches to provide a holistic overview of the topic and highly relevant keywords for searching further literature. We obtained scholarly papers, dissertations, and books from search engines and online academic databases such as ACM Digital Library, Google Scholar, ScienceDirect, Scopus, ResearchGate, and Springer. White papers and technical reports were also obtained through Google searches.

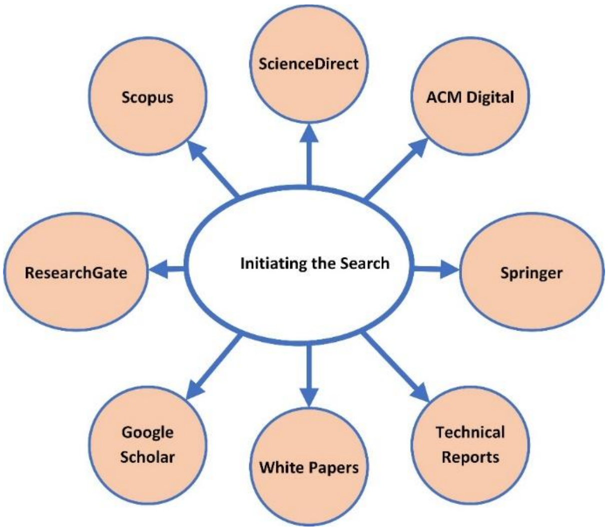

Fig 3: Initiating the Search

Steps 3, 4, and 5 includes storing and organising information, selecting/deselecting information, and expanding the search modes. Figure 4 shows the how the articles were selected and organised to arrive at the 53 articles that were relevant to the objectives. This is based on the Systematic Reviews and Meta-Analyses (PRISMA) [41] method. In Step 4, we employed combinations of the following keywords as a strategy for literature search. The keywords and potential combinations were: To search for cloud computing: "Cloud computing", "cloud technologies", in education. To investigate prospective developments in cloud computing: "future trend of cloud computing", in education. For searching for challenges of cloud computing: "cloud computing challenges", in education. We documented our findings and stored them locally in designated folders for Step 3.

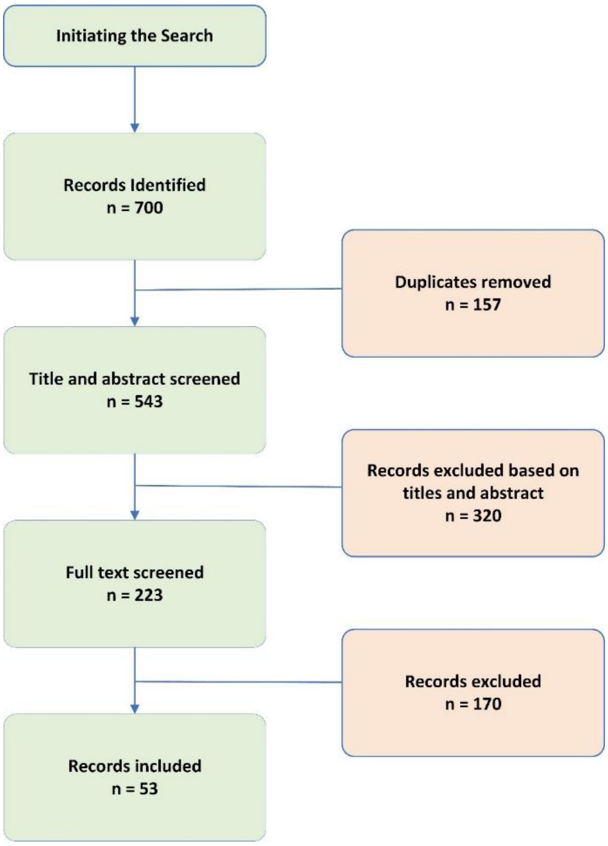

Fig 4: Organising Information, Selecting/Deselecting using Page et al. [41] method

The main purpose of the inclusion criteria for this study is to select previous studies (published from 2010 to 2023) on cloud computing and future trends in education.

The article selections that were included:

- Journal articles that describe information on cloud computing and future trends.
- Academic studies of impacts and challenges with the implementation of cloud computing.
- White papers, reports that are technical, a dissertation, or websites with focus on cloud computing.

The scrutiny we applied was qualitative and the central focus was on trusted article sources.

We excluded articles using the following criteria:

- Artiles written in other language apart from English or with poor grammatical expressions.
- Studies that has topics on cloud computing but content not related to the topic
- Studies published in 2009 or older

2.2 Interpretation Phase

The sixth phase of the thorough and extensive literature research represents the interpretation of the extracted material, which includes assessing and synthesising it. The literature search may produce a significant number of results, and the majority of the job will be investigating prospective information and books. We ranked the results accordingly, prioritizing academic sources over books, technical reports, and white papers. Companies seeking financial gain typically create technical reports, white papers, and similar materials. Despite their potential to contain legitimate data, companies may use them to promote or advertise a service. The literature study gathered and synthesized statistical data on cloud computing and future trends in education.

2.3 Communication Phase

The final step is to present the systematic or extensive literature review report. This is essentially a communication phase. This phase outlines the presentation and dissemination of the preceding steps' results. Our primary method has been to group findings by common theme and give references.

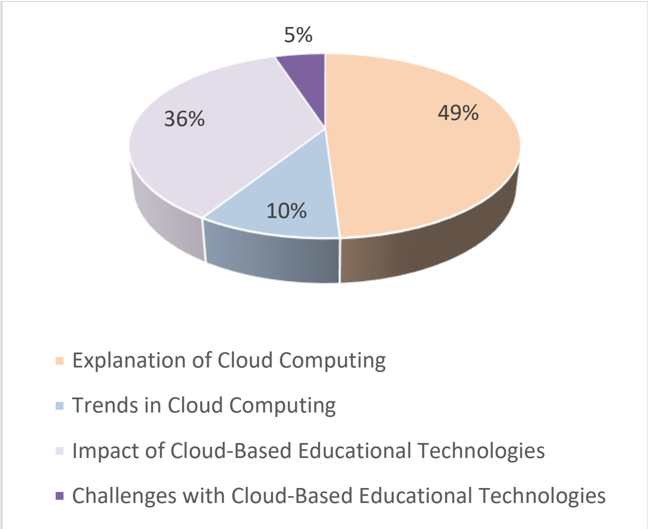

Fig 5: Percentage of Literature

In addition, we summarised the major findings at the end of each study to address the research questions. As illustrated in Figure 5, the visualisation graph reveals that 49% of search results were related to the explanation of cloud computing, 36% to the impact of cloud-based educational technologies, 10% to trends in cloud computing, and 5% to challenges associated with cloud-based educational technologies.

3. CLOUD COMPUTING MODELS

In today's digital landscape, traditional on-premises infrastructure has been replaced by cloud computing services, which offer greater flexibility, scalability, and efficiency. These services include a wide range of resources available over the internet, such as computing power, storage, databases, networking, and software. Cloud computing manifests itself in three types of services: an application provided for users, a platform of tools provided for testing and running applications, and an infrastructure for storage capacity shared among multiple applications via virtualisation techniques enabling users to access internet-based services [38], [42]. As a result, users are not need to install, acquire software and hardware, maintain or upgrade them, or pay for server administration [43]. The majority of the papers assessed focused on three major services: software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS). Others, however, captured more complex cloud service concepts, such as Artificial Intelligence as a Service (AIaaS), Database as a Service (DBaaS), Distance Education as a Service (DEaaS), Network as a Service (NaaS), and Security as a Service (SEaaS). Figure 6 depicts the cloud service models that are referenced in literature. Four of the most compelling cloud computing models are elaborated upon further.

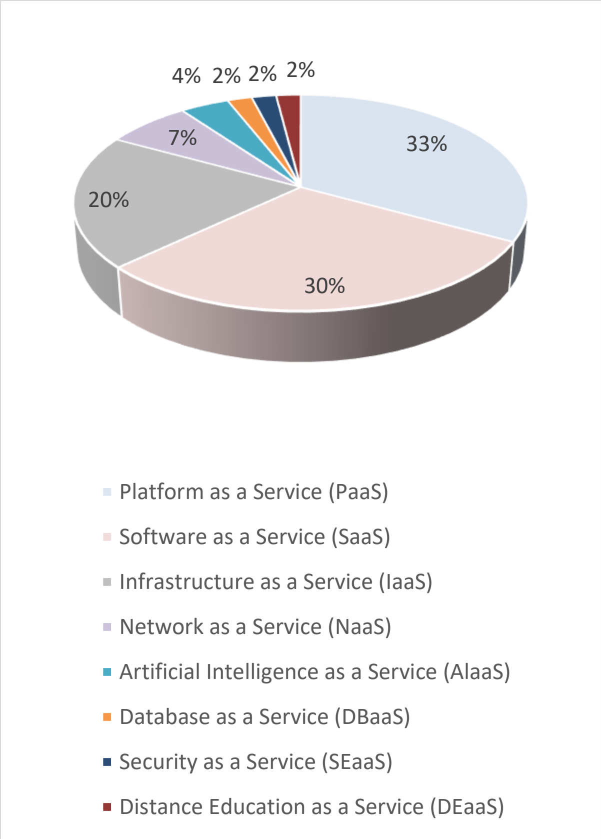

Fig 6: Cloud Services Model

3.1 Software as a Service (SaaS)

This is a common cloud service paradigm that consumers may access using a web browser or any mobile application software. This upper layer includes fully functional internet-accessible applications. SaaS model offers software applications as services through the internet rather than as software bundles that individual users must acquire. As all processes and applications are hosted on cloud infrastructure, these service models necessitate no hardware for installation or maintenance. The majority of software-as-a-service models are free; however, some may require a monthly or yearly subscription charge to access full services. SaaS models include Salesforce, Amazon Web Services (AWS), Google Cloud, Dropbox, and Google Workspace [84], [85]. Figure 7 shows the use cases of SaaS model.

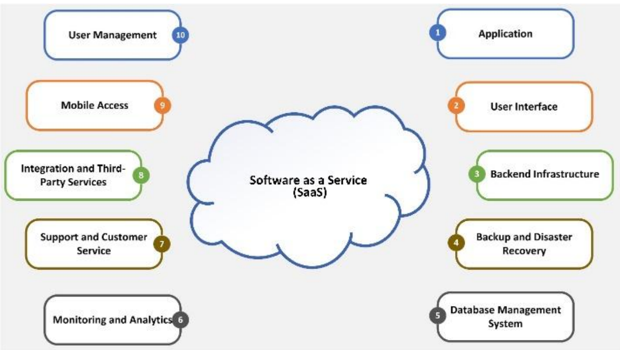

Fig 7: The Use Cases of SaaS

3.2 Platform as a Service (PaaS)

Platform as a Service (PaaS) offers an operating system, hardware, and network infrastructure to support the complete application development lifecycle, encompassing design, implementation, debugging, and testing. The development environment is Internet browsers [47]. This intermediary layer further simplifies complexity by providing developers with a platform and environment for building, distributing, and managing apps. It encompasses tools, middleware, and development frameworks. The PaaS architecture enables software developers and web designers to build websites without the use of software. The PaaS paradigm also enables developers to completely design, test, share, maintain, and upgrade apps, resulting in a life-cycle model. Cloud developers provide businesses with application software, web services or networks, and business strategy. Furthermore, because the platform as a service model is self-managed, the developer, who is also a user, can reduce material expenses while effectively administering the cloud system [48], [49]. Commonly used PaaS models include EC2 (Amazon), Google Apps and Salesforce.com [84], [85]. Figure 8 shows the use cases of PaaS model.

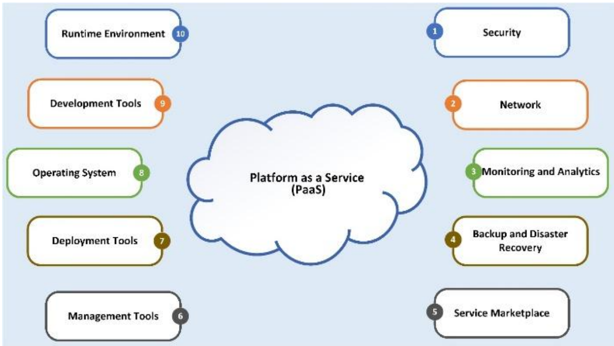

Fig 8: The Use Cases PaaS

3.3 Infrastructure as a Service (IaaS)

The lowest layer is infrastructure as a service, which offers virtualised computer resources including virtual machines, storage, and networking. Users can access the virtualised resource's operating systems, software, and configurations. This cloud service offers individuals and businesses hardware resources, including networks, servers, data storage, and other essential computing equipment, to ensure optimal performance of their software and systems. Customers can rent these resources instead of purchasing dedicated servers and networking equipment [50], [51]. The IaaS also allows businesses to obtain access to a wide range of internet platforms and applications without investing in larger cloud infrastructures. Cloud IaaS designers verify that the cloud model's operating system and virtualisation meet the specifications of the computer model or other technical equipment [50]. Cisco and IBM hardware services, as well as S3 (Amazon), are the most popular IaaS options [84], [85]. Figure 9 shows the use cases of IaaS model.

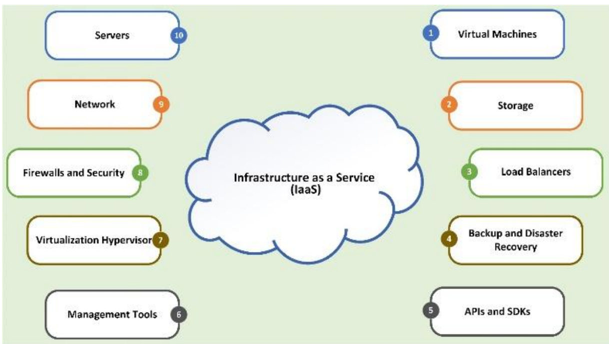

Fig. 9: The Use Cases IaaS

3.4 Artificial Intelligence as a Service (AIaaS)

AI as a Service (AIaaS) is a cloud computing service enabling enterprises and individuals to acquire artificial intelligence (AI) capabilities via a subscription or usage-based basis [51], [52]. This type of service is aimed at enterprises and individuals who lack the skills, funding, infrastructure, or willingness to create and implement AI systems on their own. The level of technical knowledge required to use AI cloud services varies. Some vendors offer low-code/no-code (LCNC) services, which hide the complexities of designing and deploying AI models behind a simple drag-and-drop interface. These vendors include Wipro Holmes, Huawei Cloud AI, Oracle Cloud AI, IBM Watson, and Salesforce Einstein Cloud [86]. Figure 10 shows the use cases of AIaaS model.

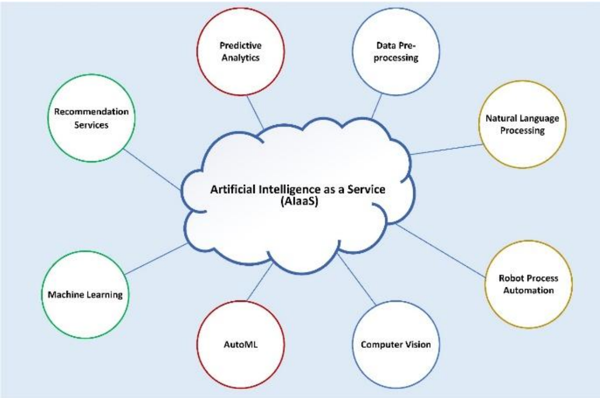

Fig 10: The Use Cases AIaaS

4. CLOUD-BASED LEARNING MODELS FOR EDUCATION

The incorporation of cloud computing technology in education has created various opportunities in the sector. Cloud computing has emerged as a viable solution for numerous areas, including education, owing to its dynamic scalability and the provision of virtualised resources as a service over the Internet. Scholars have been investigating the use of cloud computing in the educational sector since 2008. Plummer et al. [87] and Kim [54] illustrated how cloud computing was a significant service provider that would help future generations in early 2008–2009. From 2010 to 2015, the focus was on developing a cloud computing infrastructure for education. Niall [88] and [55] aimed to develop information technology skills and knowledge through education. Thus, cloud computing offers higher education institutions a new type of environment in which classic services are now delivered as online resources. This allows higher education institutions to create and use resources in a more flexible way. Furthermore, cloud-based applications allow for improved management of educational and technical activities. Academic institutions will oversee content generation, management, and delivery, whilst cloud service providers will be responsible for constructing and managing online systems [56]. The proposed cloud-based educational technology model must effectively address the requirements of administrative personnel, including those in student affairs, finance and accounting, purchasing, and procurement. It must also address the educational, training, and research requirements of students and academic personnel primarily engaged in educational institutions. Students, instructors, school administrators, tutors, academics, and service providers are the primary users of these cloud-based educational technology platforms. The SaaS model will provide all users with interfaces over the internet, removing the need to install software on client PCs. Bulla [89] conducted a survey to assess the usage of cloud computing in educational settings. They examined the usage of cloud computing platforms as solutions for educational institutions. They also illustrated the enormous influence of cloud computing on new teaching and learning environments. Chandra & Borah [57] conducted an analytical study on the function of cloud computing in education. The report discusses the use of SaaS in school education and cloud computing in distance education. They also explained the Virtual Computing Lab (VCL) idea, the VCL Community, and presented a case study from Ben-Gurion University. Ercan [58] illustrated the application of cloud computing within educational organisations. The study examined the cloud computing infrastructure in education and analysed the advantages of prevalent apps for students and educators.

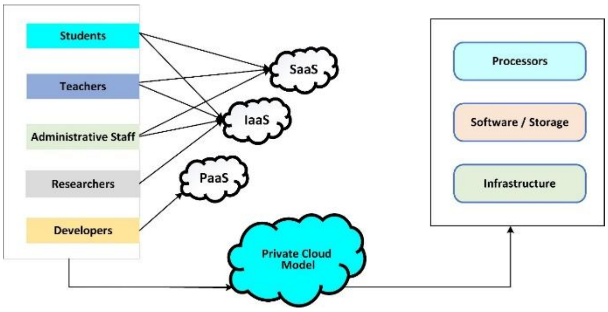

Fig 11: Cloud Computing Service Models for Education [59]

Mathew [60] and Navish Samyan & Flour [59] discussed the relevance of the three primary cloud computing models, SaaS, PaaS, and IaaS for education. As shown in Figure 11, they suggested that while institutional developers can use the PaaS to create their own applications, other staff members, such as administrators, students, teachers, and researchers, use the IaaS and SaaS for common infrastructure needs and application support. In addition, institutions can leverage their existing resources to create a private cloud model devoid of privacy concerns and security breaches.

El Mhouti et al. [61] also proposed a standard architecture of cloud-based learning system as shown in Figure 12. The model comprising of the physical layer, the services layer, and the content management layer. The physical layer denotes the informational infrastructure and resources. It encompasses pertinent computer elements, including the central processing unit (CPU), random access memory (RAM), and storage. The services layer comprises IaaS, SaaS, and PaaS. These are virtual machines that provide cloud services integrated into the system. The topmost layer is the cloud management system. It facilitates the incorporation of e-learning applications into the cloud computing framework. This layer functions as an interface for an e-learning system comprising multiple subsystems for all participants [61].

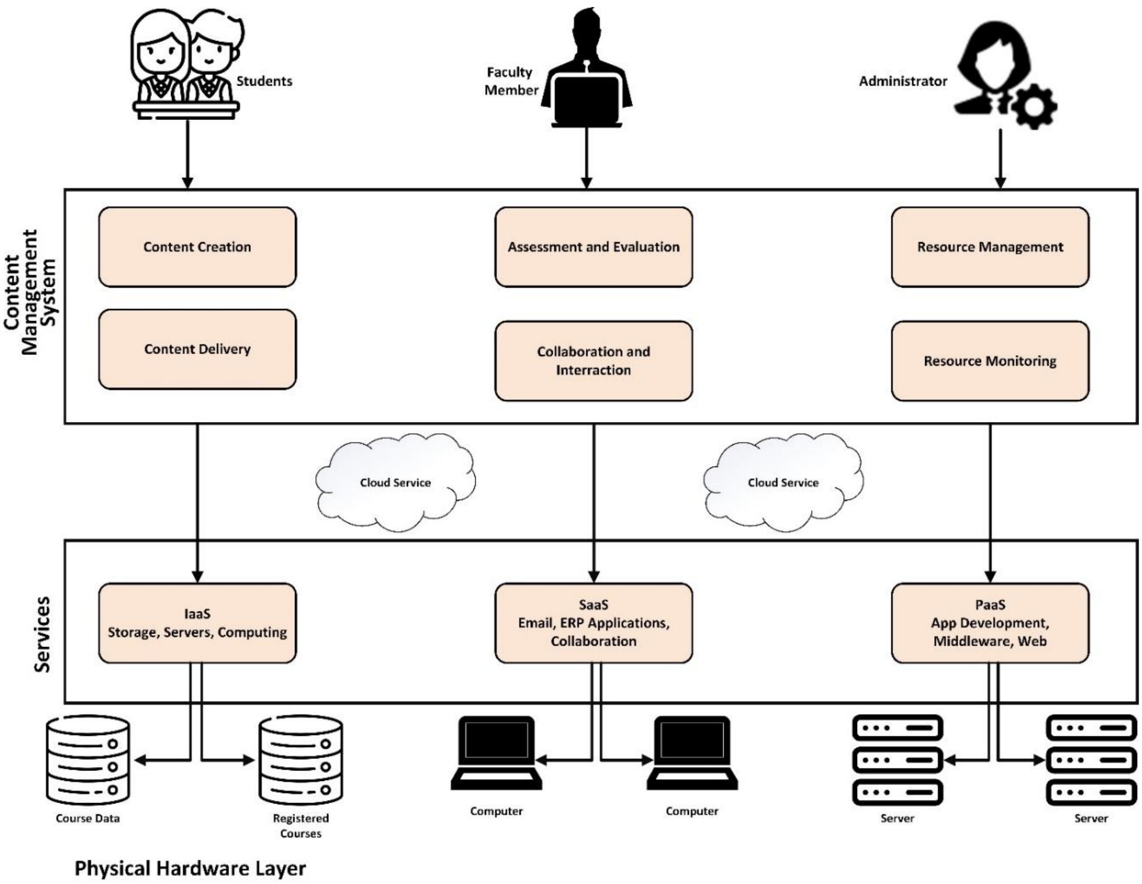

Fig 12: Common architecture of the cloud-based e-learning systems [61]

5. EDUCATIONAL TRENDS IN CLOUD COMPUTING

The contemporary educational landscape is experiencing a significant transformation, with cloud computing serving as a crucial catalyst in redefining student learning and institutional operations. The incorporation of cloud computing in educational settings offers the potential to free institutions from the challenges of intricate IT infrastructure [62]. Embracing cloud technology enables educational institutions to focus their efforts on promoting research and learning opportunities. Cloud computing applications in education are establishing the groundwork for future IT progress in the area, including both hardware and software innovations. Educational institutions can leverage cloud computing to meet the increasing demand for high-quality education and manage the issues of information overload. This integration leverages rapid improvements in IT and the SaaS trend, improving instructional materials, decreasing costs, meeting green energy requirements, strengthening data security, and streamlining system maintenance and operation. Cloud computing integration has received global attention, with some educational institutions in different countries recognizing its potential to improve efficiency, reduce costs, and increase convenience in the education sector. There are several aspects of this trend towards cloud computing usage [63]. For example, institutions have begun to rely on third-party suppliers for services like student email systems, using platforms such as Microsoft's Live@edu or Google Apps for Education [64]. These platforms offer students access to essential tools such as email, office suites, and collaborative features without the need for individual purchases. Shi et al. (2014) discovered that cloud computing trends in education are focused on five key areas: conceptual and pedagogical aspects, educational applications, information and resource processing, the benefits and drawbacks of cloud computing, and the integration of database management systems with cloud-based services. This broad scope highlights the multifaceted impact of cloud computing in educational settings.

5.1 Cloud of Educational Technologies (CET)

Technology has emerged as a transformative force in the rapidly evolving landscape of education, reshaping the acquisition, sharing, and experience of knowledge. One of the most groundbreaking innovations in this realm is Cloud of Educational Technologies (CET), a paradigm that leverages cloud computing to revolutionize learning environments and empower educators and learners alike. CET does not only facilitate seamless access to a wide array of educational tools and resources but also enhances collaboration, scalability, and flexibility in educational settings. This aspect of the review explores the concept of CET, its significance, and its architecture through an illustrative diagram. The CET is a comprehensive ecosystem that harnesses cloud computing infrastructure to provide educators, students, and institutions with a dynamic and versatile learning environment. Similar to other cloud-based systems, CET relies on remote servers to store, manage, and process data, allowing users to access educational resources and applications from anywhere with an internet connection. What sets CET apart is its specific focus on tailoring cloud services to meet the unique demands of education. CET tackles various issues encountered by conventional education systems, including restricted resource access, geographical obstacles, and inflexible learning frameworks. By transitioning educational tools and materials to the cloud, CET prevents these obstacles, facilitating a more accessible and adaptable learning experience. Students can obtain educational resources, collaborate on assignments, and participate in interactive activities irrespective of their geographical location. Educators get the flexibility to create and present dynamic curriculum, monitor progress, and offer customised feedback. A plethora of cloud computing programs currently exists, many of which possess considerable utility in educational settings. These applications include numerous instruments vital to the educational industry, as noted by [66]. Significant examples encompass systems such as Google Slides, Apple Pages, Apple Keynote, Microsoft Word, Microsoft PowerPoint, OneDrive, Dropbox, Google Drive, Google Docs, Capture to Cloud, Apple iCloud, Amazon Cloud Drive, Memopal, and SugarSync.

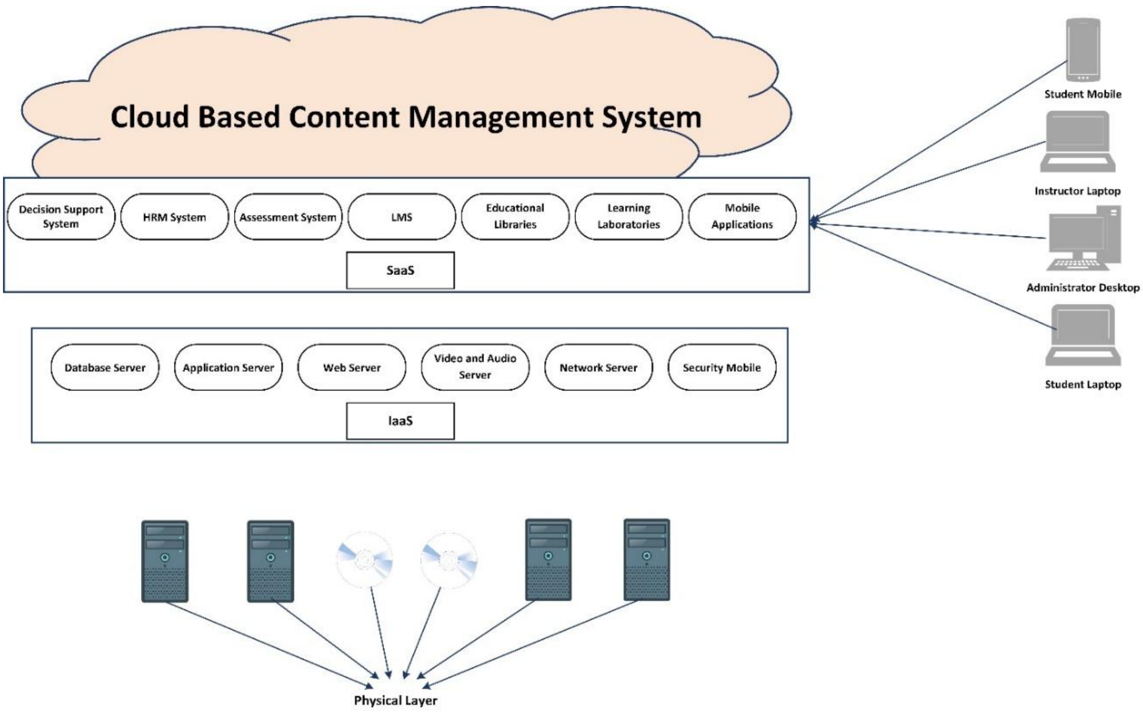

Fig 13: A visual representation of the CET Architecture

As shown in Figure 13, the CET architecture comprises of the physical layer, the IaaS layer, and the SaaS layer. The CET architecture provides the following robust benefits:

Cloud Servers: These are the backbone of the CET, hosting a wide range of educational resources, applications, and tools. Servers are distributed across data centres to ensure reliability, scalability, and efficient resource allocation.

Educational Content Repository: This repository houses a vast collection of digital learning materials, including textbooks, videos, simulations, and interactive modules. The repository is accessible to both educators and students, which facilitates easy content sharing and customization.

Collaboration Tools: CET incorporates tools for real-time collaboration, enabling students and educators to work together on projects, share ideas, and engage in discussions. Virtual classrooms, video conferencing, and interactive whiteboards enhance engagement and interaction.

Personalized Learning Platforms: These platforms use data analytics and artificial intelligence to deliver personalized learning experiences. Students receive tailored recommendations, assessments, and resources based on their learning styles, progress, and preferences.

Assessment and Feedback Systems: Cloud-based assessment tools allow educators to design and administer quizzes, tests, and assignments. Automated grading and detailed analytics provide timely feedback to both students and educators.

Security and Privacy: A robust security framework ensures data protection and compliance with privacy regulations. User authentication, encryption, and secure connections safeguard sensitive information.

Scalability and Resource Allocation: The cloud's scalability enables seamless resource allocation, ensuring that educational institutions can accommodate varying numbers of users without compromising performance.

This innovative paradigm provides a flexible and inclusive learning environment that transforms the interaction between educators and students with educational resources. CET's architecture, engineered for collaboration, personalisation, and scalability, is positioned to advance the future of education, empowering both learners and educators in their educational pursuits. Educational technologies are divided into two core domains: administration and teaching and learning, which cover many aspects of education. The administrative domain includes Human Resource Management (HRM) and decision support systems. Assessment systems, learning management systems, library systems, admission systems, laboratory systems, and mobile applications are all examples of teaching and learning technologies.

5.1.1 Cloud of Educational Decision Support Systems

Cloud computing has significantly influenced educational decision support systems. These systems employ cloud platforms to deliver critical insights and information to educators, administrators, and policymakers, thereby improving educational quality and facilitating informed decision-making [67]. Educational Decision Support Systems (EDSS) aid educational institutions in making data-informed decisions to better student outcomes, improve instructional methods, and optimise resource allocation. Cloud computing provides the infrastructure and tools essential for EDSS to collect, evaluate, and display data in real-time. This enables educators and administrators to access precise and current information, resulting in more informed decision. A primary advantage of cloud-based EDSS is its scalability and flexibility. Educational institutions can readily adjust their scale according to their requirements without necessitating costly and time-intensive hardware enhancements. This adaptability is especially crucial in the ever-evolving field of education, where alterations in curriculum, student demographics, and pedagogical approaches are prevalent. Additionally, cloud-based EDSS allows educators to customise learning experiences for students. Through the analysis of data regarding student performance, engagement, and behaviour, educators can discern trends and patterns that guide instructional practices. For instance, if the data indicates that a specific cohort of students is encountering difficulties with a particular idea, instructors might customise their instructional strategies to meet those distinct requirements. Furthermore, cloud-based EDSS can enhance communication and collaboration among diverse stakeholders within the educational ecosystem. Educators, administrators, students, and parents can access the system remotely and at any time, facilitating the smooth exchange of information and insights. This transparent communication cultivates a cooperative atmosphere in which all stakeholders collaborate to attain shared educational objectives. Cloud-based educational decision support systems have revolutionised the methods by which educational institutions collect and analyse data for informed decision-making. The scalability, adaptability, and customisation features of these systems promote student performance and improve instructional methodologies. With the ongoing advancement of technology, the use of cloud computing in education is expected to increasingly influence the future of learning. Figure 14 shows cloud of educational support system architecture with common SaaS middleware applications.

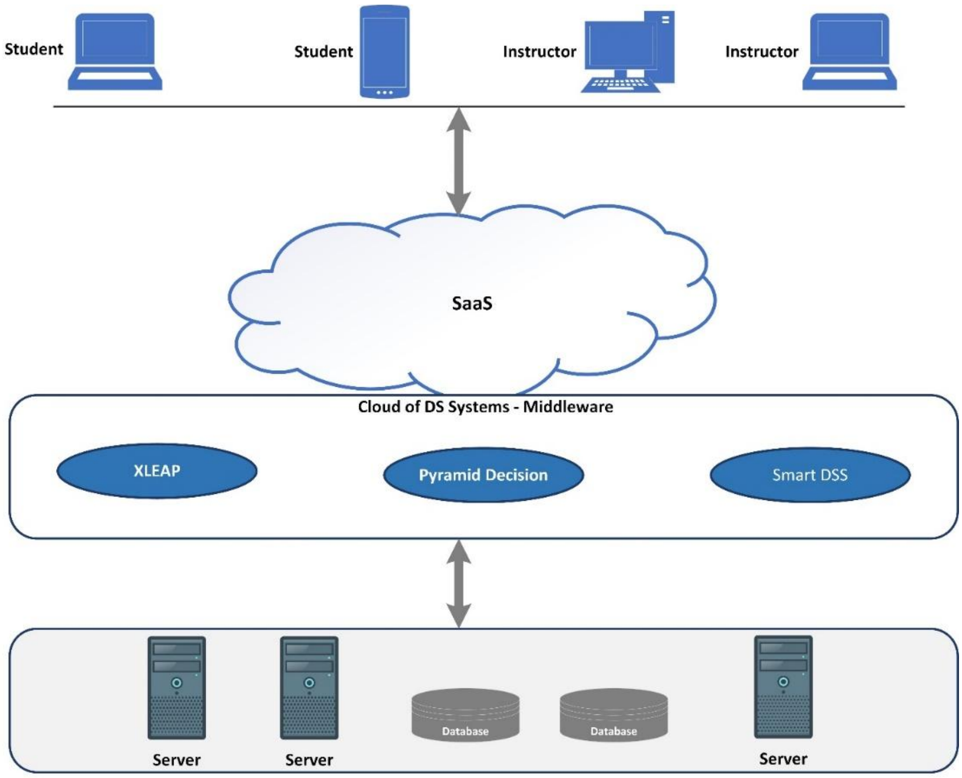

Fig 14: Cloud of Educational Decision Support System

5.1.2 Cloud of Educational Assessment Systems

In this context, cloud computing has been utilised in various aspects of the examination process, including accessing electronic answer scripts via cloud platforms, administering soft-copy tests, performing online assessments, and facilitating live viva-voce examinations [66]. A primary advantage of cloud-based educational assessment systems is the ease they provide to both students and educators. Students can readily access examinations and courses using cloud platforms, enabling them to fulfil assignments and evaluations remotely. This is especially advantageous for students with additional obligations or constraints that hinder their ability to attend tests or classes in person. Additionally, cloud-based evaluation systems facilitate electronic submission of assignments by students, thereby obviating the necessity for physical documentation and mitigating the environmental consequences of printing. Educators can utilise cloud computing to effectively administer courses and assess students' performance. They can upload and disseminate course materials, develop online tests, and furnish prompt response to students. Cloud-based evaluation systems enhance communication between educators and students, enabling prompt resolution of issues or concerns. This real-time interaction enhances the learning experience and fosters a collaborative environment. Furthermore, cloud-based assessment methods may improve evaluation accuracy and fairness. Educators can readily track changes and updates to students' work when it is stored digitally on cloud platforms, decreasing the possibility of plagiarism or unauthorised cooperation. This improves assessment integrity and guarantees that students are evaluated on their own merits [66]. Cloud computing has altered educational assessment systems by providing a convenient and efficient platform for both students and teachers. Cloud-based assessment systems provide various benefits that improve the learning experience, including access to tests and courses, assignment submission, and feedback. As technology advances, the use of cloud computing in education is anticipated to become more widespread and impactful. Figure 15 shows the cloud educational assessment system module with common SaaS middleware applications

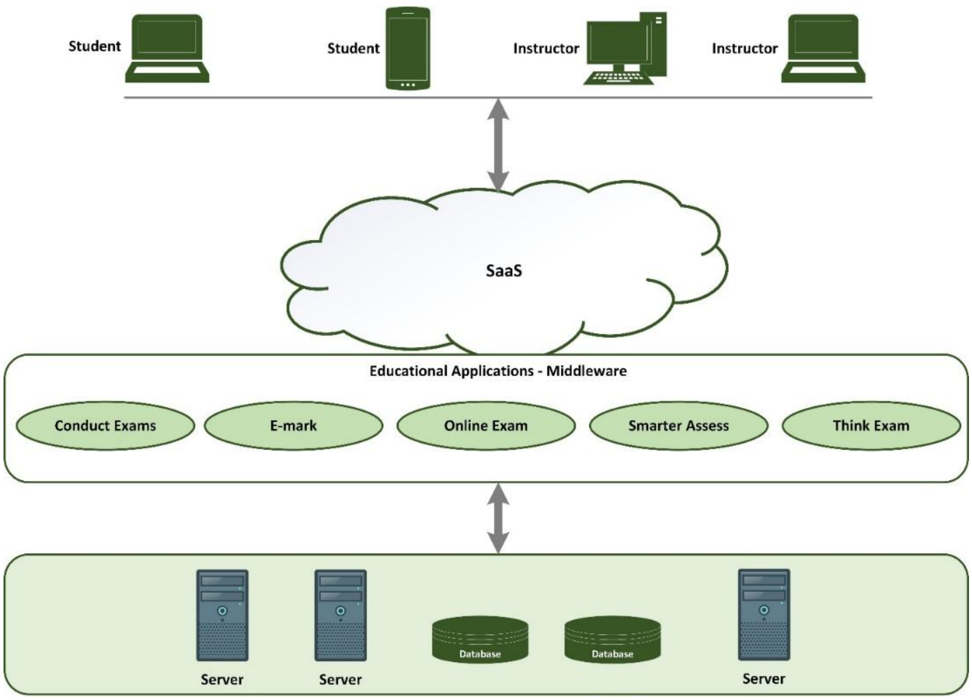

Fig 15: Cloud Educational Assessment System

5.1.3 Cloud of Educational Libraries

Cloud architectures are increasingly crucial in managing both traditional and digital libraries in schools and universities. Libraries are seen as a hub for collecting and disseminating knowledge, hence they are a prominent focus in educational institutions. Cloud computing and virtualisation approaches have had a considerable impact on traditional library administration systems, such as document management, barcode scanning, and RFID operations. These technologies have also aided in the creation, maintenance, and management of digital libraries [68]. Cloud architectures have transformed the way educational libraries operate and distribute resources to students. As illustrated in Figure 16, users, including students and staff, access information via the Library Administrator’s System with this architecture. The administrator verifies the accessor and retrieves materials from both internal and cloud storage via the networked resources.

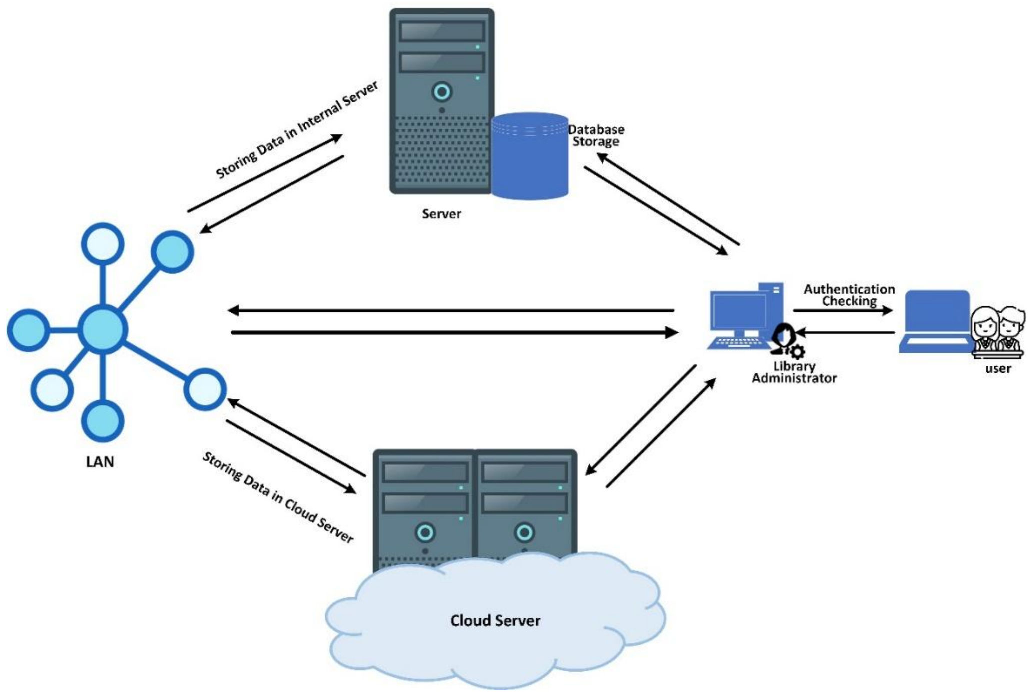

Fig 16: Cloud Educational Libraries

5.1.4 Cloud of Students Monitoring Systems

Cloud

Every institution attempts to consistently monitor its students' behaviours. This necessitates the deployment of technology capable of improving the efficacy of student monitoring. Numerous universities continue to employ manual marking of attendance sheets, a conventional method for verifying student attendance [70]. However, thanks to technological advancements, there are numerous solutions available to help teachers relieve their workload. Radio frequency identification (RFID) is one example. Combining RFID and Internet of Things (IOT) technology could provide automatic attendance tracking. The cloud of student monitoring systems includes cloud infrastructure such as Azure, data integration such as LMS and attendance records, analytics and reporting tools, user interfaces such as mobile apps, and notification systems that deliver alerts to instructors and parents [71]. Figure 17 illustrates how the camera captures an image and the RFID gathers information to determine a student's attendance status. The cloud will then store the details.

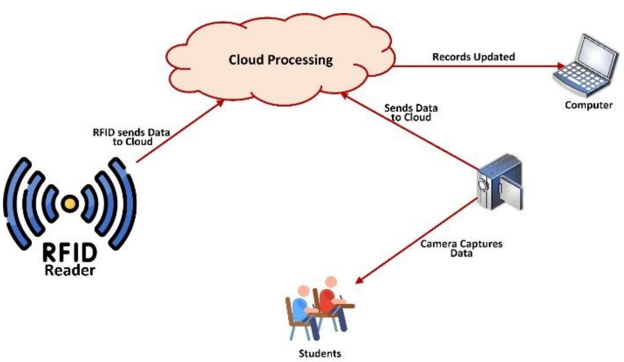

Fig 17: Architecture of Cloud of Students Monitoring System

5.1.5 Cloud-based Laboratories

Cloud-based learning laboratories refer to systems that provide students with remote virtual laboratories to improve their experimental skills and serve as platforms for practical exercises [38]. Cloud-based learning laboratories have emerged as a transformative tool in modern education, allowing students to participate in hands-on experiments and practical exercises via distant virtual platforms. These platforms use cloud computing technologies to make a wide range of experiments available and executable from any location with an internet connection. This learning methodology has garnered considerable popularity in recent years, as it addresses the shortcomings of conventional physical laboratories, including spatial restrictions, equipment accessibility, and time limitations. Figure 18 depicts the architecture of cloud-based learning laboratories with common SaaS middleware applications

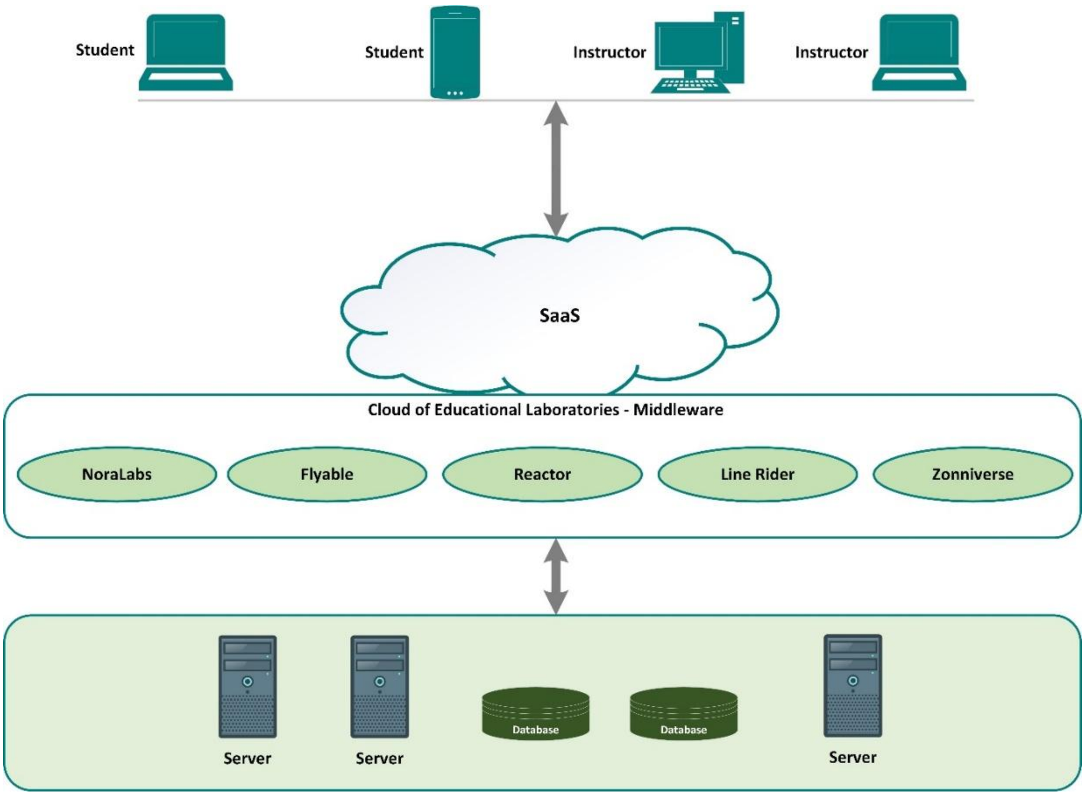

Fig 18: Architecture of cloud-based learning laboratories

6. IMPACT OF CLOUD EDUCATIONAL TECHNOLOGIES

The significant effects of cloud technologies on education and the swift progress of cloud computing have transformed the operations, collaboration, and content delivery of educational institutions. Cloud technologies have emerged as a revolutionary influence across multiple sectors, including education. The integration of cloud computing in education has initiated a novel epoch of flexibility, accessibility, and efficiency. Let us examine the significant effects of cloud technology on the domain of education.

6.1 Improved Accessibility

Improved accessibility is one of the most significant impacts of cloud technology on education. Students can access educational resources at any time and from any location due to cloud-based learning management systems (LMS). Students can access course materials, submit assignments, and engage in conversations through computers or mobile devices using platforms such as Canvas and Moodle. This accessibility allows remote and non-traditional learners to pursue education irrespective of their location, which is highly beneficial for them.

6.2 Personalised Instruction

Cloud technologies provide personalised learning experiences through data analytics and adaptive learning algorithms. Learning management systems can track students' progress and customise curriculum to meet their specific requirements. The provision of individualised guidance and materials enhances engagement and outcomes [72].

6.3 Partnership and Participation

Students exhibit heightened engagement and collaborative learning when utilising cloud-based collaboration platforms such as Microsoft Teams and Google Workspace for Education. These systems enable students to collaborate in real-time on assignments, presentations, and group discussions, transcending geographical barriers and fostering a sense of community [73].

6.4 Cost-effectiveness

Cloud technology have streamlined administrative operations in educational institutions. Employing cloud technology for data management and storage reduces the necessity for expensive on-site infrastructure and IT maintenance. Institutions may reallocate resources to enhance educational delivery and student support services. Cloud computing with a dependable Internet connection facilitate the sharing of hardware, software, systems, platforms, databases, and networks [74]

6.5 Flexible and Scalable

The scalability provided by cloud services allows educational institutions to rapidly adjust to fluctuations in resource requirements. Cloud-based systems can expand during peak registration periods to accommodate increased traffic and subsequently contract during off-peak hours. This versatility ensures efficient operations throughout the year.

6.6 Novel Pedagogical Techniques

Cloud technology have catalysed innovation in educational techniques. Educators may experiment with innovative methodologies such as gamification, flipped classes, and virtual simulations. To engage students and improve learning outcomes, these innovative strategies utilise cloud-based applications and resources. Figure 19 illustrate the major impact of cloud educational technologies.

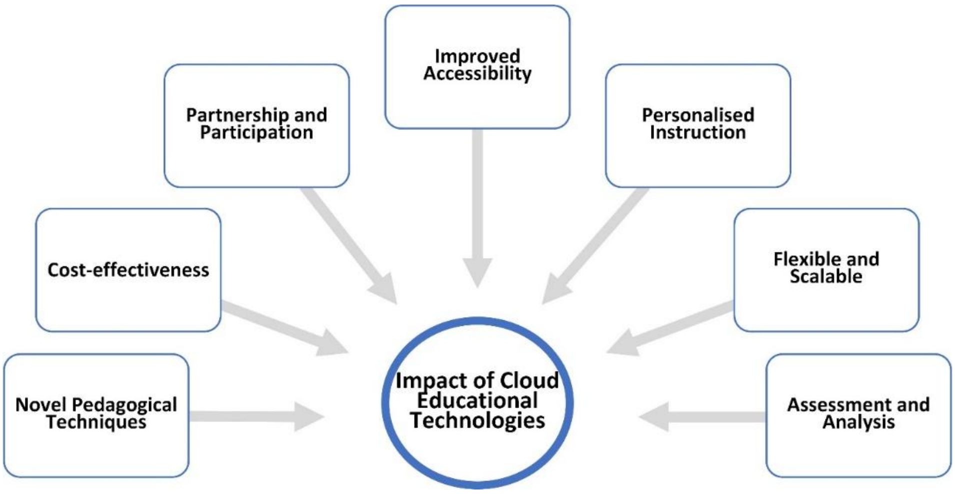

Fig 19: Impact of Cloud Educational Technologies

7. CHALLENGES OF IMPLEMENTING CLOUD EDUCATIONAL TECHNOLOGIES

Cloud-based educational technologies possess the capacity to transform teaching and learning, so its integration into modern educational institutions offers numerous benefits. Nonetheless, the implementation of these technologies presents certain challenges. At this aspect of the study, we examined the significant challenges that educational institutions must address to implement cloud-based educational technologies.

7.1 Security Issues

One of the most difficult aspects of using cloud education technologies is the security of sensitive data. Higher education institutions handle vast amounts of private data, such as student records, research data, and proprietary materials. Concerns about data breaches, unauthorised access, and data loss occur while keeping this data in the cloud. Security breaches can have major consequences, such as reputational damage and legal concerns [75]. To prevent these dangers, institutions must use robust security measures such as encryption, multi-factor authentication, and frequent security audits [76]. It is also critical to choose cloud service providers who have a proven track record of data security and industry standard compliance.

7.2 Privacy

Privacy concerns are intimately linked to security issues. When using cloud-based educational technologies, educational institutions must ensure that instructor and student privacy is respected. These challenges could involve the collection and storage of personally identifiable information (PII), biometric data, and learning analytics. To address privacy concerns, institutions must have strict data protection policies and follow relevant laws, such as the Family Educational Rights and Privacy Act (FERPA) in the United States [90]. Furthermore, when collecting sensitive data, institutions should obtain express consent and set clear data usage guidelines [91].

7.3 Facility Readiness

The success of cloud-based educational technology relies heavily on the institution's IT infrastructure. Many educational institutions, particularly smaller ones, struggle with the infrastructure that they already have. This includes internet connectivity, hardware compatibility, and network bandwidth. Institutions should conduct thorough assessments to identify gaps in infrastructure readiness and make the necessary investments to improve their infrastructure [77], [78]. It may also be helpful to collaborate with cloud service providers to improve platform performance.

7.4 Development Capacity

Modifications to pedagogical and administrative protocols are often requisite when implementing cloud-based educational systems. Faculty, staff, and students must undergo training to utilise these resources efficiently. The efficient implementation of cloud technologies may be hindered by inadequate training and capacity-building efforts. Institutions ought to allocate resources for comprehensive training programs and provide continuous support to staff and educators [68]. Facilitating peer-to-peer learning and the dissemination of best practices can enhance the institution's capabilities.

7.5 Budgetary Restrictions

Cost constraints provide a substantial hurdle when incorporating cloud educational tools. Despite the substantial initial investment, these technologies may yield long-term cost savings through reduced hardware and maintenance expenses. Expenses for data migration, licensing, and ongoing subscriptions are incorporated. Institutions ought to do a cost-benefit analysis to ascertain the long-term advantages of cloud technology for effective budget management [34]. Furthermore, exploring open-source and cost-effective options might alleviate financial burdens. In summary, addressing the pertinent issues is crucial for effective implementation. A primary challenge that institutions must address is financial constraints. Additional considerations encompass security and privacy concerns, infrastructure preparedness, capacity development, and training. Educational institutions can overcome these challenges and fully leverage cloud education technology by implementing robust security protocols, ensuring data privacy, modernising infrastructure, providing adequate training, and meticulously monitoring expenditures. Institutions must be vigilant and adaptable in their implementation of cloud technology as the educational landscape evolves.

Figure 20 illustrates the challenges of implementing cloud educational technologies and the introduction of educational policy will greatly create awareness of these challenges.

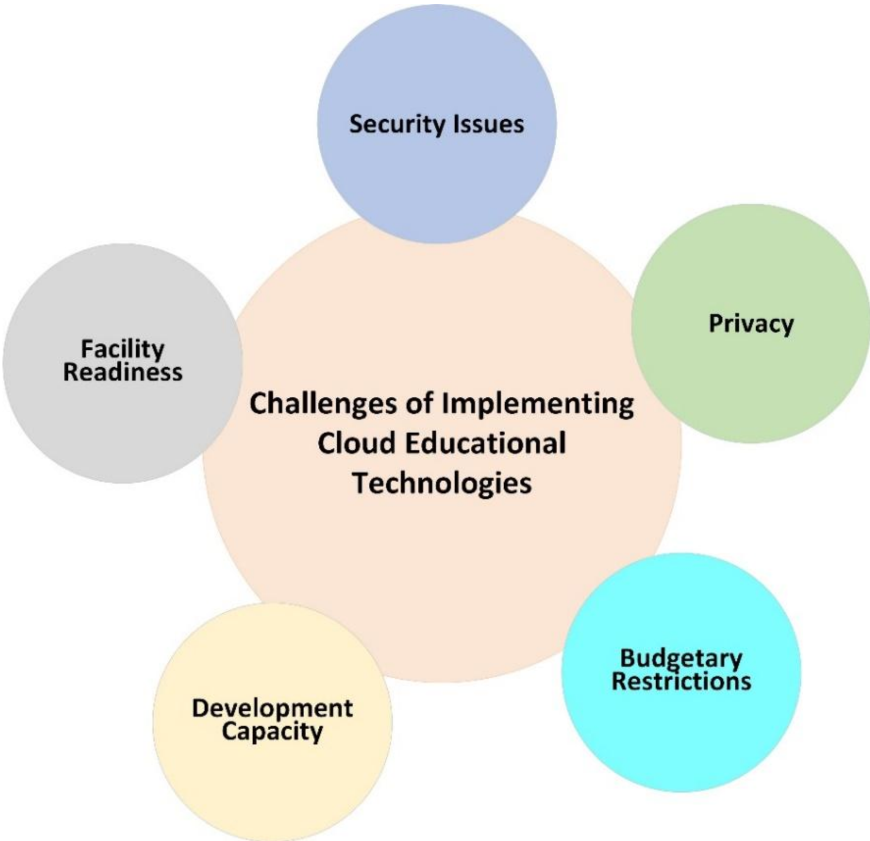

Fig 20: Challenges of Implementing Cloud Education Technologies

8. CONCLUSION

Cloud computing has emerged as a transformative force in education, ready to redefine the learning environment and institutional functions. This thorough examination of cloud computing's impact on education has revealed its several advantages, including cost efficiency, improved collaboration, personalisation, and scalability.

Despite the existence of challenges, they can be overcome by careful considerations and strategic planning. The future of cloud computing in education presents significant potential. It signifies not just a trend but a paradigm change that empowers both instructors and learners. The influence of cloud computing on education will transform the distribution and acquisition of knowledge as technology advances, heralding a new epoch of learning and innovation. The disruptive impact of cloud computing in education is permanent, and its evolution has only commenced.

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