Cloud Computing Paradigm in Academics

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Abstract

Cloud computing has gained significant popularity due to its convenience and accessibility, especially with the surge in remote work arrangements during the global lockdown. Integrating cloud computing with education offers a unique and high-quality experience for educators, administrative staff, parents, guardians, and students. This paper emphasizes the importance of embracing a cloud computing paradigm in educational institutions, backed by extensive research in ed-tech cloud-based concepts. The study examines the intricacies associated with adopting cloud computing, with a focus on the initial decision-making process. Furthermore, the paper conducts a comparative analysis of the three leading cloud computing platforms to identify the most suitable and optimal choice for implementing the suggested model. By leveraging cloud services, educational institutions can enhance their capabilities and provide an enriched learning environment for all stakeholders.

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I. Introduction

Many procedures, concepts, and goals in modern society have been streamlined by computers. No one could have predicted that the capability provided by a straightforward wooden contraption in Babylonia in 2400 BC would set the

groundwork for the finest 'innovation' known to humankind, namely computers. However, at this time, the available processing power is starting to become insufficient for the reasons for which it is being used. Existing computer processing power has limitations that pose challenges for complex computational tasks and data-intensive applications in educational institutions. Scientific research, for instance, faces obstacles due to the constraints of on-premises computing infrastructure. As a result, John McCarthy's 1961 concept of "publicized computing" has never been clearer [1]. The need for immense computational resources to process large datasets and perform complex simulations often exceeds the capabilities of traditional systems. As a solution, educational institutions are turning to cloud computing, which offers scalable resources and high-performance capabilities. Cloud platforms like AWS, Azure, and GCP provide opportunities for collaborative research, data-driven decision-making, and innovative educational approaches. However, successful adoption requires careful planning and addressing specific challenges. The development of "Big Data" and the issues it raises is a legitimate explanation for the surge in demand for computer capacity. The fact that educational institutions are likewise embracing technology has further strengthened them. However, all of these problems can be solved by cloud computing. This phrase's underlying concept is similar to paying your power bills. The national grids' personnel or information systems (if automated) manage all maintenance while we receive our bills based on the meters installed in our homes. Most significantly, customers do not have to worry about any hard lifting.

The cloud provider takes fantastic care of all the heavy work when it comes to cloud computing, including growing both horizontally and vertically, maintaining the underlying hardware and architecture, and maintaining security. Many cloud service providers offer publicly accessible cloud-based services, making them accessible to anybody with a subscription and a support plan. However, trust is something to consider when selecting a cloud service. It is crucial to be aware of their TOCs (Terms of Conditions), FUPs (Fair Use Policy), and Privacy Policies before providing your company or organization with any personal or corporate information. Any of the possible cloud-based installations can be chosen. This paper tries to thoroughly discuss all necessary features of cloud computing in the context of educational technology.

A. Guidelines for Successful Adoption of Cloud Computing in Educational Institutions

Embracing the cloud computing paradigm can bring numerous benefits to educational institutions, but it requires careful planning and execution. To ensure a successful transition, institutions should begin by defining clear objectives for adopting cloud computing. Whether it is cost savings, scalability, enhanced collaboration, improved data security, or advanced analytics, having an unobstructed vision of the desired outcomes will guide the cloud adoption strategy. Before fully migrating to the cloud, institutions should conduct a thorough assessment of their readiness. This includes evaluating existing IT infrastructure, network capabilities, security requirements, data governance policies, and staff skills. Identifying any gaps or challenges early on allows institutions to address them proactively, ensuring a smoother transition.

Developing a well-defined cloud strategy is crucial for successful adoption. This strategy should consider factors such as the selection of cloud computing platforms, choice of services, data migration plans, security measures, and governance policies. Alignment with the institution's long-term IT roadmap and educational objectives is essential for a strategic and sustainable cloud adoption plan. To gain practical experience and build confidence, starting with a pilot project is

recommended. By selecting a non-mission-critical application or workload, institutions can assess the feasibility, scalability, and performance of the cloud environment. This approach provides valuable insights, allowing them to refine their approach and identify best practices before scaling up to larger deployments.

Choosing the right cloud provider is a critical decision. Factors such as service offerings, pricing models, security measures, compliance certifications, reliability, scalability, and customer support should be carefully evaluated. Institutions should seek providers with a strong record, an extensive service portfolio, and a commitment to security and compliance.

Data security and privacy should be prioritized throughout the adoption process. Robust security measures, including encryption, access controls, and user authentication, should be implemented to safeguard sensitive information. Compliance with relevant data protection regulations and the establishment of clear data governance policies ensure control and compliance in the cloud environment. Providing comprehensive training programs to staff members is essential. Educating them on cloud computing concepts, best practices, and security protocols ensures they have the necessary skills to effectively leverage cloud technologies. Ongoing support and a culture of continuous learning foster the successful integration of cloud computing into daily operations.

Cloud-based collaboration tools should be leveraged to enhance communication and teamwork among students, faculty, and staff. Platforms for document sharing, project management, and virtual meetings promote seamless collaboration and knowledge sharing, fostering engagement, productivity, and innovation within the educational community. Monitoring and optimizing costs are crucial to ensure cost-effectiveness. Regularly reviewing resource utilization and implementing cost optimization strategies, such as leveraging auto-scaling capabilities, helps institutions manage expenses and maximize resource utilization.

Lastly, institutions should continuously evaluate and evolve their cloud strategy. Cloud computing technology and services evolve rapidly, and staying updated on emerging trends and new features offered by cloud providers is essential. Revisiting the cloud adoption roadmap, adjusting strategies based on changing needs, and embracing a culture of continuous improvement and innovation contribute to long-term success in the cloud computing paradigm. By following these recommendations and guidelines, educational institutions can successfully embrace the cloud computing paradigm. This will lead to improved scalability, collaboration, data security, operational efficiency, and enhance teaching, learning, and administrative processes.

B. Challenges

Adopting a cloud computing paradigm in academia can bring numerous benefits, but it also presents certain intricacies and challenges. Here are some specific intricacies and challenges associated with adopting cloud computing in academia:

1. **Data Security and Privacy:** Academia often deals with sensitive research data and personally identifiable information (PII). Entrusting this data to a cloud service provider raises concerns about data security, privacy, and compliance with relevant regulations. Institutions must carefully evaluate the cloud provider's security measures, data encryption

protocols, access controls, and compliance certifications to ensure data protection.

2. **Data Governance and Ownership:** When data is stored and processed in the cloud, questions regarding data governance and ownership may arise. Clarifying ownership rights and establishing data governance policies become crucial to ensure that the institution retains control over its data and maintains compliance with institutional policies and legal requirements.
3. **Vendor Lock-In:** Migrating academic resources and applications to the cloud involves a certain level of dependency on the chosen cloud service provider. Vendor lock-in refers to the challenges associated with switching to another provider or bringing services back in-house if necessary. Institutions must carefully assess the interoperability and portability options offered by cloud providers to avoid being locked into a specific vendor's ecosystem.
4. **Cost Management:** While cloud computing offers scalability and flexibility, it also requires careful cost management. Cloud costs can vary based on resource utilization, storage requirements, data transfer, and other factors. Institutions need to monitor and optimize their cloud resource usage to avoid unexpected expenses and ensure cost-effectiveness.
5. **Network and Connectivity:** Reliable and high-speed internet connectivity is crucial for utilizing cloud services effectively. Academic institutions, especially those located in remote areas or with limited network infrastructure, may face challenges in accessing and utilizing cloud resources due to network limitations. Adequate network infrastructure and backup connectivity options must be in place to ensure smooth cloud adoption.
6. **Training and Skill Development:** Transitioning to a cloud computing paradigm requires the necessary skills and knowledge among academic staff and researchers. Institutions need to invest in training programs to upskill their workforce, educate users about best practices, and promote effective utilization of cloud services to maximize the benefits and minimize potential pitfalls.
7. **Service-Level Agreements (SLAs):** When adopting cloud services, institutions rely on service-level agreements provided by the cloud provider. These agreements outline the level of service availability, performance guarantees, support response times, and data backup policies. Institutions need to carefully review and negotiate SLAs to ensure they align with their requirements and provide adequate protection in case of service disruptions or data loss.

C. Research Objectives

The main key objectives of this paper are to:

- Propose a cloud computing paradigm in academics that can offer a unique and high-quality experience for all stakeholders, including educators, administrative staff, parents, guardians, and students.
- Identify the most suitable and optimal choice for the suggested model by comparing the three leading cloud computing platforms, namely Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP).
- Address the pivotal question of choosing cloud computing, which significantly impacts institutions and organizations.
- Discuss all necessary features of cloud computing in the context of educational technology.

II. Literature Review

Despite [2] noting that application service providers have been disseminating their services over the internet ever since the internet came into existence, many people still have the misconception that cloud computing is a novel idea. All that has changed is the form. While earlier systems relied solely on XML, SOAP, or comparable forms, there are now a wide variety of data formats from which providers can pick. By virtue of the services and experience it offers, cloud computing can ease the standard of the standard operating procedures in educational institutions. Virtualization, which can split physical capabilities into comparatively small pieces and then distribute these pieces to meet demand, is the heart and soul of cloud computing [3]. It is also clear that a lot of educational institutions play a significant part in other economic operations. For instance, the University Sains Malaysia's business section offers consulting, consultation, and testing services [4]. It is also evident that such a luxury needs a robust computer network. As previously noted, virtual computers can satisfy this demand. However, we must remember that running numerous virtual machines (VMs) on the same host might cause performance problems, as investigated by authors of [5][6][7]. As shown by [8], a study that raised worries about numerous prominent websites secretly gathering substantial amounts of personal information led to fear and panic among many users. Privacy has always been a major worry for many users.

For this strategy to be successful, more cloud-based apps are required. According to Amazon, the biggest cloud service provider, building applications for the cloud is no longer a tedious task to do. Either brand-new apps or cloud versions of currently existing applications may be developed and deployed with ease. One issue drives the logical next important thing: Would the faculty and students be able to use those applications? Yes, it is the solution. Clients do not have to worry as much about technological details using the cloud [3]. Furthermore, the cloud may make the technological staff nimbler. More than that, the institutions may take advantage of Google Cloud services as a starting point. According to [9], the G Suite enterprise provides all the capabilities needed by both instructors and pupils. Several of its traits are listed below:

- **Enable Collaboration:** Collaboration is made possible by the G Suite's features, which allow students and teachers to work together on the same papers and projects both inside and outside of the classroom, increasing student productivity.
- **Simple scaling:** Whether you have 10 students or 10,000, there are many different APIs accessible to meet your needs. You can even add third-party software apps to your ed-tech ecosystem.
- **Getting started with G Suite is simple:** A unified platform is provided for students, teachers, and IT personnel to manage and arrange their roles and responsibilities appropriately. Through the Google Cloud Platform, Google furthermore provides a trial version of the vast majority of its services. Where can one try these services out? If the experience is in line with what the firm is looking for, one can subscribe.

The underlying institution may secure the intricate infrastructure by using the cloud to enable disaster recovery and business continuity in case of unforeseen disasters. Additionally, the Ed-tech industry benefited from cloud solutions. One such situation is described below. Clever [10], a digital learning platform for schools, has made it easier for students to use information systems by offering functionality like single sign-on and federated identity along with the following features:

- All information is simply available since the innovative platform, which offers free services to all the schools in a district, has a single sign-on function for the whole institution that uses it.
- The digital classrooms are the center of every educational technology hub. The entire school community may maintain contact with the children's and their families' lives through smart classrooms.
- With Clever, you may access an extensive network of 600 partners that are trying to give safe access. More importantly, Clever makes sure that it never sells or rents the private or public data of its customers and does not allow advertising on its platforms.

III. Cloud Services for Education Technology

This section examines the cloud services relevant in the context of education technology and forms the basis of the proposed work discussed in a later section. The bigger the cloud provider, the bigger the range of services offered. As mentioned earlier the world's top three cloud providers are Amazon, Microsoft, and Google. We examine in detail a few of the services that can help institutions to build a cloud-based environment. Whether a platform is on-premises or in the cloud, storage is the most crucial component. We require more storage as technology advances and our reliance on electronic gadgets grows. One such instance is Google Drive [11] Its free tier (or trial version) provides around 15 gigabytes of storage per user, however for business use, there are four price options to consider as per [12]:

- **The Business Starter package** is the basic plan which offers free trial at the cost of Rs 136.90 per user per month for 1 year commitment with 30 GB storage, more security and management control. In addition to, 100 participants video meetings.
- **The Business Standard package,** which costs Rs 736 per user per month in India, offers personalized email addresses, 150-person virtual meetings with recording capabilities, 2 Terabytes of storage per user, as well as support services.
- **The Business Plus Plan,** which has all the features of the starting plan and costs Rs 1380 per user per month in India, also has a participant capacity increase to 500 people with recording and attendance monitoring. The 2 TB cap has been raised to 5 TB.
- **Enterprise plan** for big institutions. Google recommends contacting the sales representative for details on this plan as it can be customized as per the business needs.

Apart from Google Cloud, Amazon web services also offer its storage services like Amazon Simple Storage Service (S3) which allows users to store data objects of all sizes suitable for all purposes. The high performance, high availability and security features are the most opportune for settling the requirements of education technology. Below are some of the benefits of the service as described by Amazon [13]:

- **Scalability:** When it comes to big academic institutions, the need for their IT resources varies greatly. When utilization reaches its peak, in such a case, extra resources would be needed on-demand. In order to prevent further charges, we would also like the excess resources to be released when consumption returns to normal. In the context of Amazon

Web Services, this capability is referred to as elasticity.

- **Storage Classes:** The S3 service offers distinct types of storage classes to fit your business needs for instance:

1. **Standard Storage:** This storage class is the most popular class for your data objects as a business. It offers high durability and availability and is the best option to store frequently accessed data.
2. **Intelligent Tiering:** This is the most advanced storage class that uses machine learning methods to shift your data between other storage classes depending upon the frequency of accessing it. By doing so, it is able to save a lot of expenses.
3. **S3 Standard Infrequent Access (IA):** The mentioned storage class is the optimal choice for long-term storage, thus the term infrequent access. It offers high availability and durability and also has a low billing price as compared to its counter-part standard storage.
4. **S3 One Zone Infrequent Access:** This storage class is similar to the S3 IA storage class but has a major difference in the fact that it does not replicate your data objects to provide redundancy which comes in handy when a problem occurs. Thus, the term One Zone is used as it only stores your data in one availability zone.
5. **S3 Glacier:** It provides inexpensive storage for archiving data. The S3 Glacier features three retrieval modes that allow the retrieval time to vary from a few minutes to a few hours depending on your company's needs. Aside from this, your company has the choice of either explicitly uploading data items to the S3 Glacier service or having them uploaded to the service automatically when specific criteria are satisfied. The S3 lifespan is utilized in this strategy.
6. **S3 Glacier Deep Archive:** Despite being a different version of the S3 Glacier service, this storage class provides storage at the lowest prices. But there is a cost involved. If your company wants inexpensive storage, your retrieval times will be longer. For regulatory purposes that need enterprises to retain data from the last n years, where the number of n depends on the company and regulatory requirements, the S3 Glacier Deep Archive service is the best option. It is also a suggested service for your disaster recovery plans, although it might start at 12 hours to fulfill a data retrieval request.

- **Security, compliance, and audit capabilities:** Simple Storage Service offers better security practices than its competitors as it happens to be the only storage service that allows a business to block public access to the data objects as a whole on either on a bucket level or on the account level. S3 is also follows various compliances like:

1. **Health Insurance Portability and Accountability Act:** In 1996, the federal government passed HIPAA, requiring the countries that adopted it to uphold strict requirements for securing and safeguarding patients' sensitive Personal Health Information (PHI). To put into practice the stated act's proposal, the US Department of Health and Human Services published the HIPAA privacy regulation [2].
2. **Payment Card Industry Data Security Standard:** American Express, MasterCard Worldwide, JCB International, Discover Financial Services, and Visa Inc. created the PCI-DSS, a well-known security standard. All organizations that oversee or process cardholder and sensitive authentication data must adhere to this specific standard (CHD & SAD). All merchants, processors, acquirers, issuers, and service providers are included under the word "entities" in this context. The highest known certification to date for PCI-DSS compliance is level-1, which is held by Amazon

Web Services [14].

3. **European Union Data Protection Directive:** The aforementioned directive, which took effect in May 2018, protects personal data, and establishes rules for the transfer of such sensitive data for commercial reasons. Protecting user privacy, which is no less than a fundamental right, is essential as the expanding connectivity converges into a unified digital market.

- **Data access and management controls:** With the help of the straightforward storage service, your company can simply regulate prices, data security and protection, and access control, which enables you to specify who has access to and who does not have access to your underlying data objects. Since the S3 service operates on the principle of serverless computing, activities like activity tracking, alert management, and workflow automation have become simple. The replication function of the service provides high availability and durability. Additionally, you may make your data objects version able.
- **Data Analytics with S3:** With the business data objects stored within S3 buckets (storage unit for the service) one can utilize the query in place service set for running analytics. This maneuver works best when combined with Athena. In other words, Amazon Athena is especially optimized for working with S3. It allows you to query your data objects using SQL standard.

Fig 1. provides a high-level overview of the cloud computing platforms, and the suitability of each platform may vary depending on the specific requirements and priorities of an educational institution. It is essential to evaluate each platform in more detail based on your specific needs and conduct thorough research before deciding.

Aspect	AWS	Azure	GCP
Market Dominance	Market leader with a large customer base	Strong presence and integration with Microsoft products	Known for advanced analytics and machine learning capabilities
Service Offering	Vast array of services across computing, storage, databases, analytics, and more	Comprehensive set of services including virtual machines, storage, databases, AI, and analytics	Wide range of services including compute, storage, databases, AI and machine learning, and analytics
Global Infrastructure	Operates in numerous regions globally, with multiple availability zones	Global presence with data centers in various regions	Expanding global infrastructure, with multiple regions available
Pricing Model	Pay-as-you-go, reserved instances, spot instances, and additional pricing options for specific services	Flexible pricing options, including pay-as-you-go, reserved instances, and hybrid benefits	Competitive pricing options, including sustained use discounts and committed use contracts
Security and Compliance	Robust security features, extensive compliance certifications, and tools for encryption and access controls	Comprehensive security measures, compliance certifications, and tools for identity management and threat detection	Emphasizes security and compliance, with features for encryption, access controls, and compliance certifications
Integration and Ecosystem	Wide range of integrations with third-party services, mature ecosystem with extensive documentation and community support	Seamless integration with Microsoft tools and services, leveraging existing Microsoft infrastructure	Integration with Google services and products, including AI and machine learning capabilities
Developer Tools	Offers a wide range of developer tools and services for application development and deployment	Provides a comprehensive set of developer tools, including Visual Studio and Azure DevOps	Offers various developer tools and services, with emphasis on AI and machine learning capabilities
Customer Support	Extensive documentation, community support, and enterprise-level support options	Provides comprehensive documentation, community support, and various support plans	Offers documentation, community support, and support plans for different levels of customer needs

Figure 1. Comparison of Cloud Computing Platforms for Education Technology

IV. Proposed Model

This section outlines a suggested high-level cloud-based architecture that makes use of the vast majority of services offered by Amazon Web Services due to its acceptance and popularity in the community.

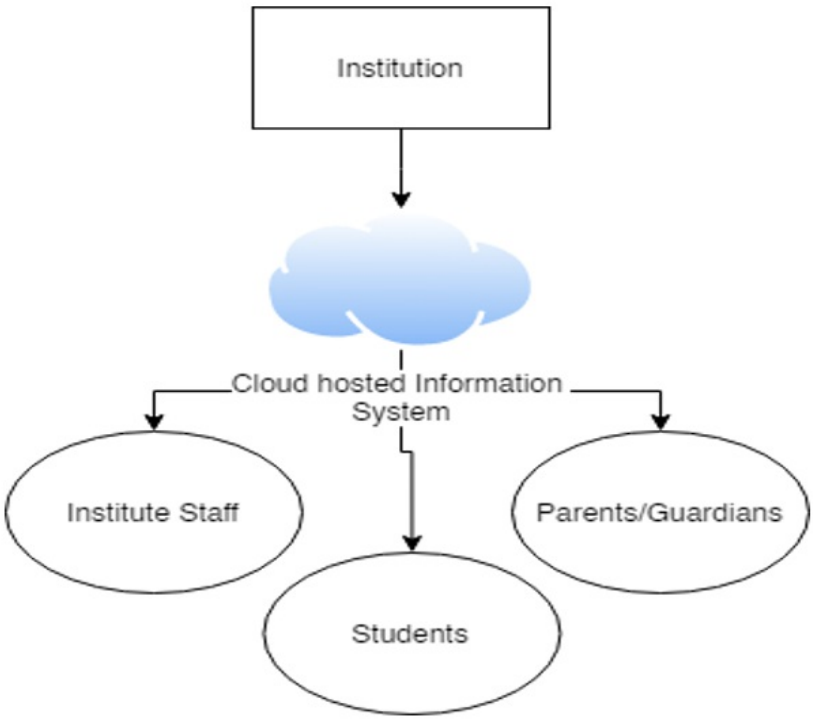

Figure 2. Users/Actors of the cloud-based platform.

The actors who will engage with the cloud-based application or platform are described in Fig 2. Deep specifics are not considered because the goal of this study is to give a high-level overview of a cloud-based model for the education sector (or education technology). The three main characters are the institute staff members who will use the program every day to check or update student data. The student information is understood to include all of the student's grades for all semesters, including both internal and external evaluation. The accomplishments of the student should also be mentioned (if appropriate). They will be able to see their Performa, which would be developed by committed data analysts and workable futuristic insights produced by virtue of machine learning algorithms, so students may use this programme as well, but with restricted access.

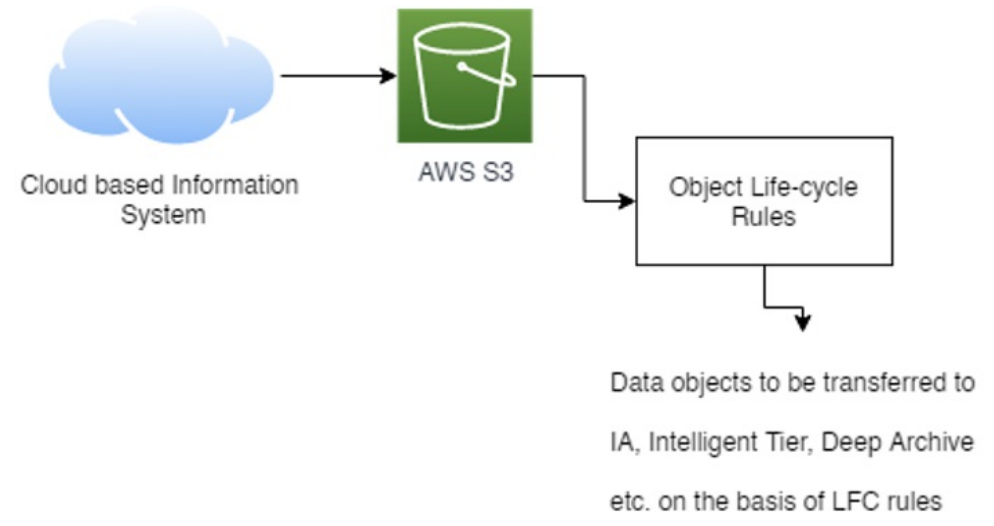

Figure 3. Amazon Web Services S3 Usage

To maintain data security while it is at rest, the majority of the data will be kept on Amazon S3 buckets as specified in Fig 3., with the appropriate encryption rules. Because of its broad support from the community and inherent ease, Amazon S3 has been chosen. The AWS S3 may be set with Life Cycle rules that would regulate the activities to be made with the data, even though the data wouldn't be in the same location forever. It can be moved between any of the classifications previously described in this paper.

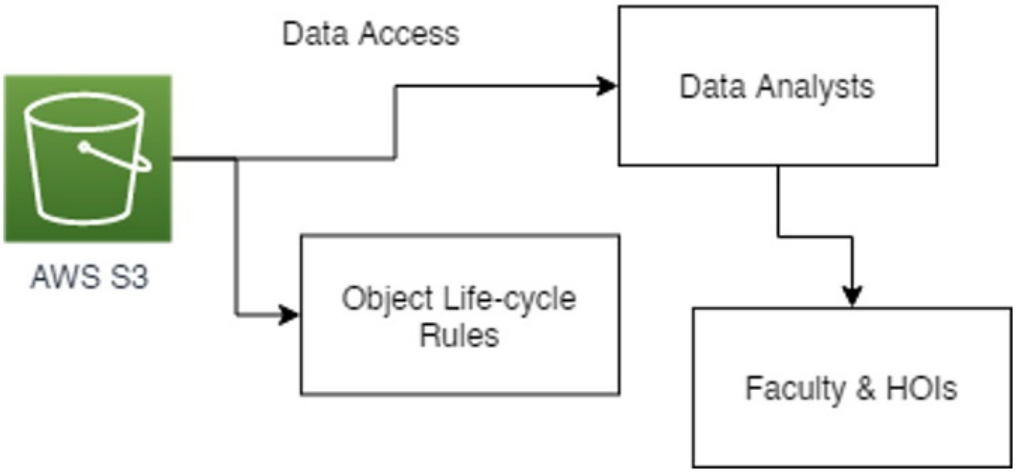

Figure 4. S3 Data Usage scenario

Fig 4. shows how three different entities might utilize and consume the student data stored in the Amazon Simple Storage Service. Data analysts would conduct exploratory data analytics on the underlying student test score data to finally produce reports that were simple to grasp and read and included graphs and other visual elements. The faculty members and institution heads would then be informed of all this information. The student will also be given a portion of the pertinent report so that they may examine the performa and get an understanding of their own strengths and opportunities for development. If necessary, the faculty and institution's head may also share all of this information with the parents or guardians.

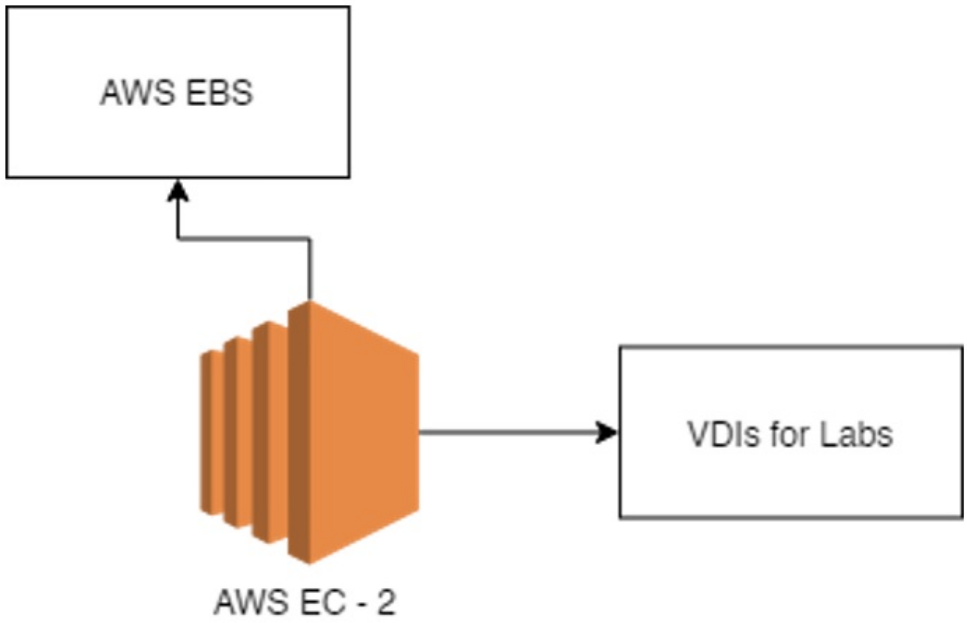

Figure 5. Amazon EC-2 Scenario

The usage of Amazon Elastic Compute 2 instance(s) to give students and staff virtual desktop interfaces is explained in Fig 5. Many courses need that computer laboratories be set up and equipped with all the required equipment. It also necessitates a significant amount of additional time and financial effort. The institutions can build up virtual computers using EC-2 according to their needs, because they are so customizable. Additionally, one may find the necessary VMs on the AWS market at reasonable prices.

V. Practical Implementation

The paper proposes a cloud computing paradigm in academics that can offer a unique and high-quality experience for all stakeholders, including educators, administrative staff, parents, guardians, and students. The practical implications of this paper are as follows:

- Educational institutions can leverage the vast array of cloud services to enhance their teaching and learning experience.
- Cloud computing can provide a cost-effective solution for educational institutions to manage their IT infrastructure and resources.
- The proposed cloud computing paradigm can enable remote learning and work-from-home options, which have become increasingly important in the current global pandemic situation.
- The study compares the three leading cloud computing platforms AWS, Microsoft Azure, and GCP which can help educational institutions choose the most suitable and optimal choice for their needs.
- The proposed paradigm can improve collaboration and communication among stakeholders, leading to better decision-making and outcomes.

Overall, the paper's practical implications suggest that the integration of cloud computing and education can offer significant benefits to educational institutions and their stakeholders.

VI. Conclusion And Future Work

The paper proposes the integration of cloud computing and education to offer a unique and high-quality experience for all stakeholders, including educators, administrative staff, parents, guardians, and students. The paper suggests that educational institutions should embrace a cloud computing paradigm to leverage the vast array of cloud services. The study compares the three leading cloud computing platforms and aims to identify the most suitable and optimal choice for the suggested model. However, the proposed paradigm involves certain intricacies, and the initial stages of the study address the pivotal question of choosing cloud computing, which significantly impacts institutions and organizations. The implementation of such a paradigm may require significant investment in terms of infrastructure, training, and maintenance. Additionally, there may be concerns regarding data privacy and security when using cloud services, which need to be addressed adequately.

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