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Evaluating Cloud Computing Service Models for Educational Institutions: A Focus on the Education Sector

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Abstract. Cloud computing has gained significant attention in the field of information systems development, offering organizations various advantages such as resource pooling, fast elasticity, and wide network access. Its increasing use is driven by benefits such as cost reduction, increased availability, and flexibility. To ensure the successful adoption of cloud computing, it is crucial to understand the factors that influence organizations' adoption rates, particularly in the educational environment where specific requirements need to be met for effective use and maximum benefit. The Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) models are essential components of cloud computing, particularly in the context of e-learning where academic study and management heavily rely on these services and applications. In this article, we present an analysis of these cloud computing tools and their contributions to the education sector. Among the service models, SaaS stands out with a remarkable 98% effectiveness in its processes, followed by PaaS with an 87% effectiveness in terms of accuracy and precision. The Infrastructure as a Service (IaaS) model demonstrates 48% effectiveness in parametric tests. To ensure effective control of these service models, it is recommended to develop an action plan for continuous improvement, optimizing service processes for clients. This article provides insights into the applicability and benefits of cloud computing service models in the education sector.

Keywords: SaaS, PaaS, IaaS, Cloud computing, education, TIC.

1. Introduction

In recent years, the educational field has gone through a great transition, due to Covid-19, so the reception and functional development of technological tools had considerable precipitation (Rodríguez and Figuera, 2022; Hernández et al. 2022). In this sense, proposals such as the cloud and its multiple disciplines are essential for the protection of information from educational schools, but it is necessary to consider that it contributes to multiple users to be able to facilitate activities with tools that can provide a teaching and learning space (Valencia and Bravo, 2022; Gonzalez, 2019). Likewise, cloud education is a process of digital inclusion that promotes the use of new technologies as a tool to improve the quality of useful and transformative education, in addition to abandoning the paradigms of traditional education (Rodríguez and Figuera, 2022; Valencia and Bravo, 2022).

As a result of the above, this phenomenon is called "cloud computing" or "cloud", which is nothing more than the technology used to store and maintain all our data on remote or remote servers (Carrasco and De La Cruz, 2022; Bedoya, 2022); that is, the user has access to certain files and programs stored on web servers (of which we do not know their geographical location), hence the term cloud, since they are always available to us no matter where we are (Fidalgo, Sein and García, 2022). Today, new technological trends are affecting the way information is consumed and knowledge is generated (Pérez, Jiménez, & Álvarez, 2018). Individuals and organizations face the challenge of managing files and data centers remotely with a variety of applications, provided they have Internet-enabled technology that allows users to install them on their computer or other device, plus file access from anywhere (Thavi et al., 2022; Ivan et al., 2019).

Cloud education also had a relevant impact during the pandemic stage due to the new coronavirus, allowing educational institutions to take action on the matter and choose to apply this technology allowing them to improve their technological infrastructures and teaching processes (Raza and Khan, 2022), although this was a challenge since not everyone is used to remote work or learning, as mentioned by Alanya et al. (2021) distance education during the Covid-19 pandemic is a difficult situation for both teachers and students, as both must adapt to distance education; However, despite teachers' best efforts, the results of student engagement do not always meet expectations (Alanya et al., 2021). On the other hand, according to some studies, we can talk based on cloud education and its benefits and impact, which is why Báez and Clunie (2020) detailed that new information technologies have brought important changes in the way of accessing information in the current region, where these changes have created new dynamics, including information technologies in education (Báez and Clunie, 2020). In addition, technologies such as mobile learning and generalized learning are being successfully incorporated into teaching/learning processes around the world, allowing these approaches to grow and expand in scope (Báez & Clunie, 2020).

In another aspect, Quezada and Suárez (2021) mentioned that new technologies, especially computer models, can be applied in many different fields, including education (Quezada and Suárez, 2021). This fact makes it possible to design, research, represent, share, and reuse educational objects since technology allows them to store, organize, reproduce, distribute, and transform; a hands-on approach that saves teaching time and resources (Quezada and Suárez, 2021). It also emphasizes the usefulness of these technologies as support for the formative process of web development, concluding that the use of NC in higher education focuses on the teaching of Internet programming that integrates skills and abilities and connects teachers, researchers, and students to create knowledge (Quezada and Suárez, 2021). That is why serving today's students requires open and flexible educational models that promote the development of relevant competencies at career and life levels while allowing reuse, use, and access to lifelong learning (Quezada and Suárez, 2021). Quezada and Suárez (2021) conclude that the inclusion of new cloud-based technologies in computer science curricula increases motivation for learning, and encourages teamwork as it provides an environment that allows students to interact with information and create content, improving the efficiency and productivity of the developed code (Quezada and Suárez, 2021).

Finally, through this article we will analyze the highlights of cloud education, The software models to be evaluated are: SaaS (Software as a Service), PaaS (Platform as a Service) and IaaS (Infrastructure as a Service) are key requirements when applying Cloud Computing and even more so if we talk about e-learning since the services provided or applications based on academic study and management, are based on the above, throughout this article we will see an analysis of the tools presented today and their help in the education sector (Han and Trimi, 2022). To conclude, the general problem was: How do cloud service models focus on education influence?

2. Methodology

When creating a problem-solving approach in academic and business management, the steps of qualitative research are followed, corresponding to the initial entry into the field, the classification of sensitive organizational information and the proposal of protocol to protect the integrity of the organization, the investment in the technological infrastructure, in which the use of cloud computing technology is established (Gallardo et al., 2020).

To this end, the study reviews the state of the art, using various primary and secondary sources, to substantiate the proposed solutions. The deductive method is used, starting from specific places with identification of the symptoms of the problem, focusing on the concepts treated around the sector of internet service providers (Gallardo et al., 2020). Gallardo et al. (2020) mentioned that to develop a well-developed literary journal article, the PDIOO approach proposed by Cisco Systems can help formalize the network lifecycle into five stages: Planning, Design, Deployment, Operation, and Optimization. Each stage fulfills a specific function and is related to its predecessor and ancestor.

Fig. 1: PDIOO methodology (Gallardo et al., 2020)

3. Result

For the following results, a comparison is made between the different services that each cloud-based platform can provide, for A comparison will be made between the service models, from which, it indicates the activities of the consumer, activities of the provider, and applications in service.

3.1. Consumer activities in the cloud

Table 1.Benchmarking Service Models

Service models	Consumer activities	Supplier activities	Applications in service
SaaS (Software as a Service)	Uses applications or services to support business processes (Díaz, Morales, and Fernández 2020; Bresfelean et al., 2021)	Software as a service provider hosts applications and makes them available to users over the Internet. With SaaS, companies don't need to install or load software into their existing IT infrastructure. SaaS ensures that users are always running the latest software versions. The SaaS provider handles maintenance and support (Pérez, Jiménez, & Álvarez, 2018; Al Gehani, 2023).	Google Docs, Salesforce, Dropbox, Gmail, Basecamp.
PaaS (Platform as a Service)	Develop, test, deploy, and manage applications hosted on a cloud system (Vera, 2018; Ganesan et al., 2021).	Platform as a Service provides developers with a platform for developing and deploying software on the Internet, giving them access to up-to-date tools. PaaS provides a framework that developers can use to build custom applications. The PaaS organization or cloud provider manages the servers, storage, and network, while developers manage the applications (Vanstrahlen and Bayona, 2019).	Google App Engine
IaaS (Infrastructure as a Service)	Install, manage, and monitor IT infrastructure operations services.	Infrastructure as a service is used by companies that do not want to maintain their on-premises data centers. IaaS provides virtual computing resources over the Internet. An IaaS cloud provider hosts infrastructure components that typically exist in an on-premises data center, including servers, memory, and networking hardware, as well as a hypervisor or virtualization layer (Zúñiga, 2019).	Amazon Web Services

3.2. Assessment Design: Service Tools in Cloud Computing

Table 2. Cloud Computing Platforms Comparison

Parameters	Amazon Web Service	Microsoft Azure	Google App Engine
Services	Provides PaaS e IaaS	Proporciona IaaS, PaaS and SaaS	Provides PaaS and SaaS
Computation	Amazon provides an environment of virtual machines or preconfigured devices that can be created and resized as needed so that users and businesses can scale devices as they wish (Guala, 2021).	It allows you to create virtual machines on Windows or Linux with the necessary infrastructure to run your applications and includes an identity solution that provides Active Directory-compatible administrative security for secure access to applications (Herrero, 2023).	It has a wide range of products that enable customers to develop and operate applications and websites. It allows users to store and analyze data in Google's infrastructure (Guayas, 2023).
Storage	Amazon Web Services introduced Elastic Block Store (EBS), a block-centric storage service that can be used by multiple instances of Amazon's cloud, Amazon Elastic Compute Cloud (EC2). Containerized enterprise applications can be deployed on Amazon Simple Storage Service (Amazon S3) EBS to store objects up to 5 GB and 1 GB to 1 TB (Gallegos, 2022).	It provides a place to store large amounts of unstructured data. The cloud has blob storage that provides storage for native and mobile apps. There are two types of blob storage. Block blobs are most efficient for sending large blobs up to 4 MB in size, while page blobs are ideal for storing sparse index-based data structures such as disks, systems, virtual machines, and databases (Arrieta and Ospino, 2022).	You have a default 10 GB disk running in a virtual machine. Developers can store objects and files up to TB in size and have control over their data. GAE can grow dynamically, regardless of the number of active users or the amount of data (Charne, 2021).
Supported Language	Any programming language can be used (Valero, 2019).	Supports VB.NET, C#, PHP, JavaScript, Python, .NET and Node.js (Santiago, 2020).	Java, Ruby, Go, Python, C#, Node.js or PHP, or other language environments (Ventura et ál., 2020).
Security	It has identity and access management capabilities. Multi-factor authentication (MFA) is an additional layer of security in addition to usernames and passwords. AWS Key Management Service (KMS) enables you to easily create and manage encryption keys and control how AWS applications and services use them. AWS CloudHSM is a cloud-based hardware security module (HSM) that makes it easy to create and use your encryption keys in the AWS Cloud (Omaza, 2020).	Azure Active Directory provides Azure role-based access control and identity management (RBAC) that helps control who can access Azure resources, what they can do with those resources, and which domains they can access. There is multi-factor authentication. There is a security center. BYOK users can configure their clients with their private key instead of using the master key generated band Microsoft (Tena, 2021).	Google App Engine is a secure system. Web application security issues are automatically scanned and detected by a system implemented in a so-called security scanner. This instantly identifies the threat and prevents false positives. (Ortega, 2018).
Payment Mechanisms	Pay per use (Omaza, 2020).	Payment for use of the platform. Charging per minute (Tena, 2021).	Pay only for resources used outside of the free allocation. Beyond the free fee, the cost depends on the amount of traffic your app receives. (Ventura et ál., 2020).

3.3. Service Model Metrics Procedure

For the test stage, the characters were considered, to this group of data where each group captures the data analysis of each service model pronounced within the research. Therefore, the predict method was applied and an estimate was granted for each class, the estimate will be in the range of 0 to 1, in addition, the argmax method will be applied to return the class with the highest estimate. Thus, you only get 0 (bad) and 1 (good).

Table 3. Service Software Report (SaaS)

		Accuracy score	
Predicted label	Bad	89	1
	Well	2	8
		Bad	Well
		Real Etiquette	

Table 3 shows the results of the Confusion Matrix for the SaaS service model, correctly corrected 89 and 8 times for Bad and Good respectively. However, you also get 2 false positives and 1 false negative; i.e. 2 times predicted it was bad when it was really good, and 8 times predicted it was good when it was bad.

Table 4. Confusion Matrix for the Service Software Model

	Precision	Exhaustiveness	F-value
Bad	0.978	0.988	0.982
Well	0.88	0.8	0.838
Accuracy			0.982

Therefore, we can calculate the precision and completeness of each class and with it the F1-scores for each label: The F1-score is the harmonic average of precision and completeness, where the F1-score reaches its best value at 1 (representing perfect accuracy and completeness) and its worst value at 0. It is defined using the F1-score equation:

F-Value =2x(PrecisionxCompleteness)/(PrecisionxCompleteness)

In this way, you have the following formulation to be able to find the precision, completeness, F-Value, and accuracy as it is:

Precision=TP/(TP+FP)

Completeness=TP/(TP+FN)

F-value=2X(PrecisionxCompleteness)/(PrecisionxCompleteness)

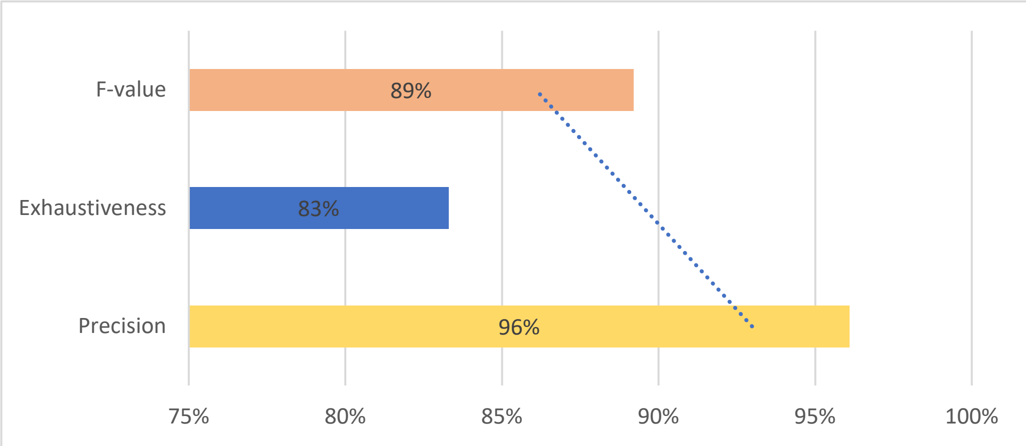

Fig. 2: Performance evaluation in the training stage and validation of positive accuracy metrics for the service software model (SaaS)

In this way, Fig. 2 determines the positive value equivalent to 0,

Accuracy = 89 / (89+2) = 0.978

Completeness = 89 / (89+1) = 0.988

F-Value = 2 x (0.978x0.988) / (0.978+0.988) = 0.982

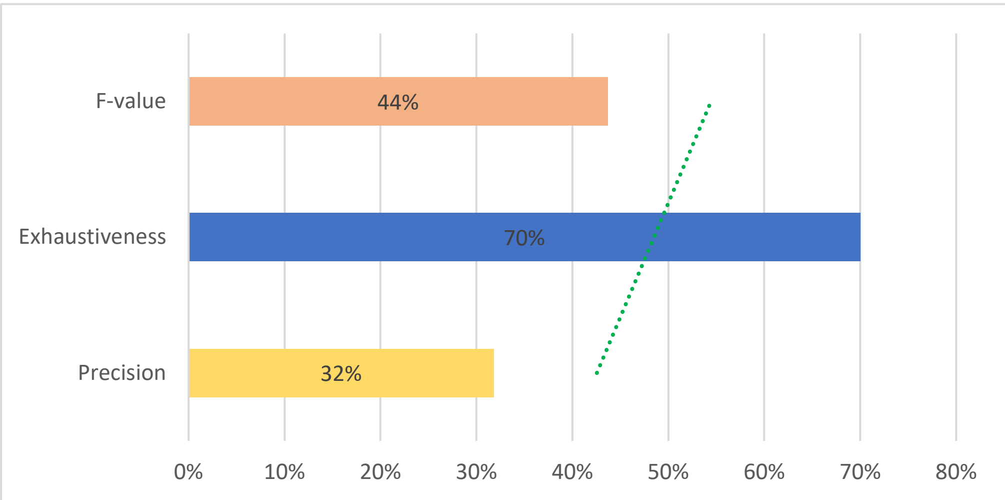

Fig. 3: Performance evaluation in the training stage and validation of negative accuracy metrics for the service software model (SaaS)

In this way, Fig. 3 determines the negative value equivalent to 0,

Precision = 8 / (8+1) = 0.88

Completeness = 8 / (8+2) = 0.8

F-Value = 2 x (0.88x0.8) / (0.88 +0.8) = 0.8380

Subsequently, you have the final result of the accuracy of the SaaS service model, which has been obtained from the negative values as positive in the F value which will help to get the result of the accuracy.

(0.982x10) + (0.838x90) / 10+90=0.8462

Table 5. Service Software Report (PaaS)

		Accuracy score	
Predicted label	Bad	88	2
	Well	1	9
		Bad	Well
		Real Etiquette	

Table 5 shows the results of the Confusion Matrix for the service platform, correctly correcting 88 and 9 times for Bad and Good respectively. However, you also get 1 false positive and 2 false negatives; i.e. 1 times predicted it was Bad when it was really good, and 2 times predicted it was Good when it was Bad.

Table 6. Confusion Matrix for the Service Platform Model

	Precision	**Exhaustiveness**	**F-value**
Bad	0.988	0.977	0.982
Well	0.818	0.9	0.857
Accuracy			0.8695

In this way, Fig. 4 determines the negative value equivalent to 0,

Accuracy = 88 / (88+1) = 0.988

Completeness = 88 / (88+2) = 0.977

F-value = 2 x (0.988x0.977) / (0.988+0.977) = 0.982

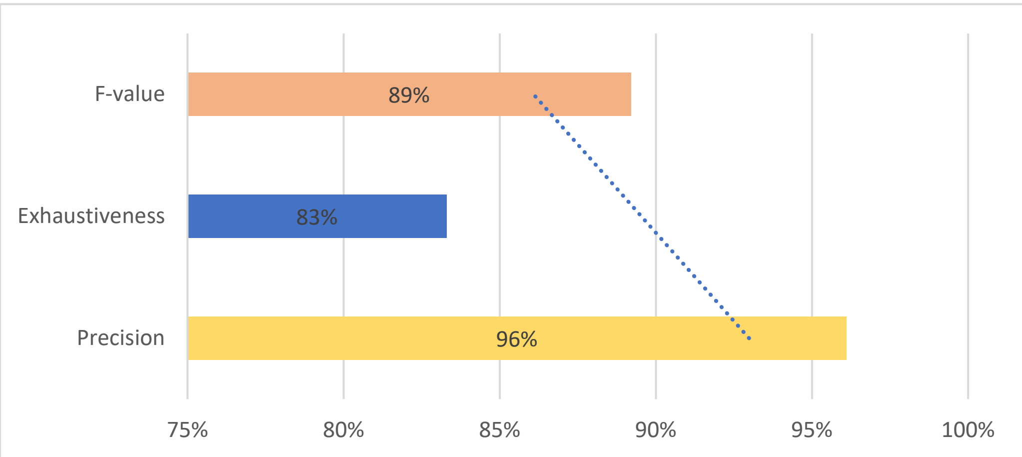

Fig. 4: Performance evaluation in the training stage and validation of positive accuracy metrics for the service platform model

In this way, in Fig. 5 the positive value equivalent to 0 is determined,

Precision = 9 / (9+2) = 0.818

Completeness = 9 / (9+1) = 0.9

F-value = 2 x (0.818x0.9) / (0.818+0.9) = 0.8570

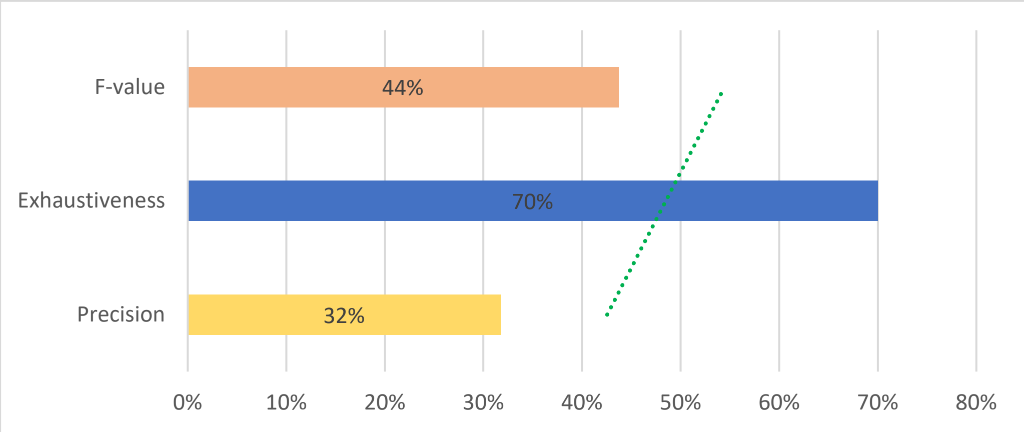

Fig. 5: Performance evaluation in the training stage and validation of negative accuracy metrics for the service platform model (PaaS)

On the other hand, there is the final result of the accuracy of the service platform model (PaaS), which has been obtained from the negative values as positive in the value F that will help to get the result of the accuracy.

(0.982x10) + (0.857x90) / 10+90 = 0.8695

Table 7. Service Software Report (IaaS)

		Accuracy score	
Predicted label	Bad	75	15
	Well	3	7
		Bad	Well
		Real Etiquette	

Table 7 shows the results of the Confusion Matrix for the service infrastructure, correctly corrected 75 and 7 times for bad and good respectively. However, it also has 3 false positives and 15 false negatives; that is, 3 times predicted that it was bad when it was really good, and 15 times predicted that it was good when it was bad.

Table 8. Confusion Matrix for Service Infrastructure (IaaS)

	Precision	**Exhaustiveness**	**F-value**
Bad	0.961	0.833	0.892
Well	0.318	0.70	0.437
Accuracy			0.4825

In this way, Fig. 6 determines the negative value equivalent to 0.

Accuracy = 75 / (75+3) = 0.961

Completeness = 75 / (75+15) = 0.833

F-value= 2 x (0.961x0.833) / (0.961+0.833) = 0.892

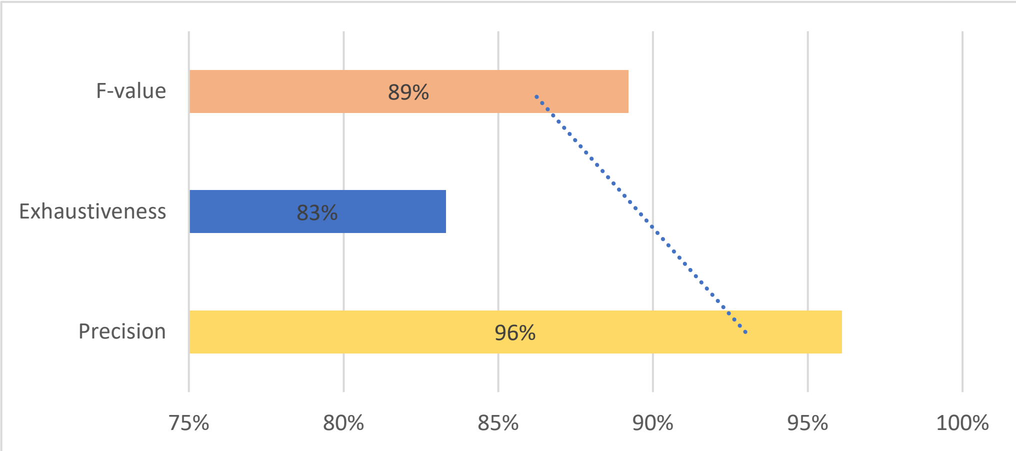

Fig. 6: Performance evaluation in the training stage and validation of positive accuracy metrics for the service infrastructure model (IaaS)

In this way, Fig. 7 determines the positive value equivalent to 0.

Precision = 7 / (7+15) = 0.318

Completeness = 7 / (7+3) = 0.70

F-value= 2 x (0.318x0.70) / (0.318+0.70) = 0.437

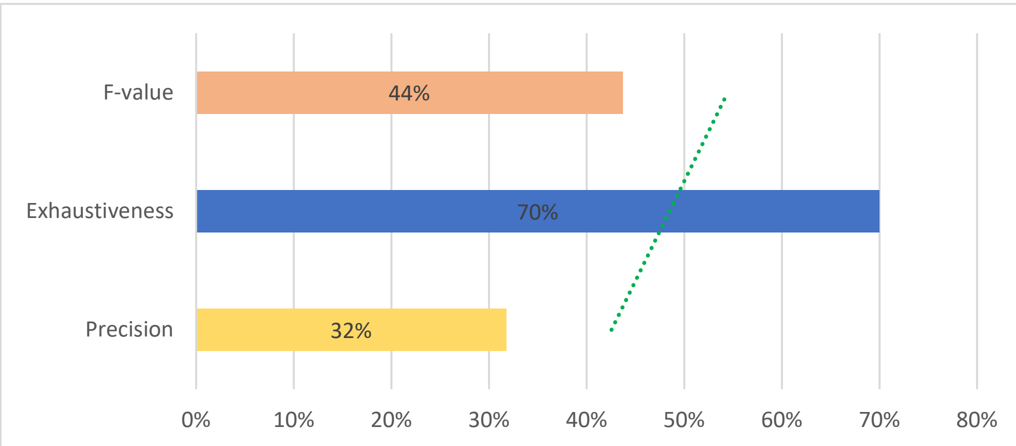

Fig. 7: Performance evaluation in the training stage and validation of negative accuracy metrics for the service infrastructure model (IaaS)

Finally, there is the final result of the accuracy of the IaaS service model, which has been obtained from the negative values as positive in the F value that will help to get the result of the accuracy.

(0.892x10) + (0.437x90) / 10+90 = 0.4825

Table 9. Confusion Matrix for Service Model

Service Model	Class	Accuracy	Precision	Exhaustiveness	F-value
SaaS	Bad	0.98	0.98	0.98	0.98
	Well		0.88	0.80	0.84
Paas	Bad	0.87	0.99	0.98	0.98
	Well		0.82	0.90	0.86
IaaS	Bad	0.48	0.96	0.83	0.89
	Well		0.32	0.70	0.44

Detailing the confusion matrix explains the calculation of the accuracy, precision, completeness, and F-value metrics of each service model used for this study. We can see the results in Table 9, each model has demonstrated high performance, but SaaS has obtained better results for each metric, followed by PaaS, which by a narrow margin approaches its result, finally, you have IaaS where you get a result low to the two previous models. That is why, we have the accuracy results for each model evaluated within the research on the focused data analysis of education in the cloud.

In summary, the service models that were taken into account for the statistical results were considered by three very noteworthy models for the study of the research, where it is worth highlighting the difference of each style that is used. Therefore, the applicability of any of the models can be fully considered.

4. Discussion

As you can see in the full article, as technology advances, these advances have been introduced in the field of education to create new learning scenarios and optimize training processes. To provide a correct application of cloud services focused on education, certain requirements must be met. Luna (2018) indicates that, for the introduction of the e-learning ecosystem, cloud computing service models such as PaaS, IaaS, and SaaS are each a technological foundation aligned with educational principles. If one of these models does not exist as a technological base, it cannot comply with the four educational pillars, which he was able to demonstrate in his social cloud project.

Fulfilling the aforementioned Herrera, Gelvez, and López (2019) indicate that SaaS LMS has become an outstanding strategy for incorporating e-learning into learning processes, and the selection of these tools must follow a methodically planned process and oriented to the analysis of aspects such as the business, the target audience, the types of training given, the organization's requirements and configuration management aspects that the organization chooses to implement. For this, having the results obtained within the results have obtained three very appropriate ranges where the service model is obtained as SaaS which is the most outstanding by 98%, there is also a similarity in the PaaS model with 87% that obtains better precision and accuracy. In addition, the IaaS tool has been evaluated in its service infrastructure, where the decreasing result was obtained for the others that were encouraged to have a high percentage in their commercial use of the service model.

Finally, Mohammed and Zeebaree (2021) conducted a comparative study of cloud services considering the three most important criteria within the computing field (IaaS, PaaS, and SaaS) taking into account: software, the platform and infrastructure as a service detailing information on the method, objective and justification of each theoretical basis that addresses the different indicators of cloud computing services, In addition, being able to obtain data and information necessary by multiple companies with the sole purpose of making decisions of the service more structured and that fits the requirements of the user, against this, in Table 9 of this study, a high performance has been demonstrated; SaaS has obtained better results for each metric, followed by PaaS, which by a narrow margin approaches its result, finally, there is IaaS where a result is obtained by low standard of execution of processes in the educational field. That is why, we have the accuracy results for each model evaluated within the research on data analysis.

5. Conclusions

Cloud computing is becoming more and more imposed, providing growing solutions so that more and more users are integrated into this way of working.

As a new style of computing, cloud computing has become a new technological trend. This new trend allows users to access their programs using cloud providers, hosting, and development platforms using a variety of devices over the Internet, providing the same benefits such as cost savings, high availability, and scalability. Cloud computing focused on the educational environment supports the traditional study process, which is why the appropriate way is sought to include this technology that is in constant development for its respective exponential growth in the aforementioned.

In the development of the research you have the cloud services model is designed for a specific purpose, presenting advantages and disadvantages at different levels. Infrastructure as a Service (IaaS), the backbone of cloud computing is the facility that provides complete configuration and management of the entire hardware and software interface, allowing other service models to be deployed from there and to some extent determining how they will work, the time to configure and create.

Platform as a Service (PaaS) is more oriented towards software development and management, where you can configure the environment to the customization you want, its disadvantage is the advantage of the previous model, efficiency The capacity of the platform is limited depending on how you place it in the infrastructure configuration.

In short, cloud computing focuses on multiple disciplines that benefit the customer through its services. Being able to use and manipulate the utilities at the request of the end user is to be able to provide a platform that adapts to the needs and/or requirements of a product, that said, cloud services such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) are exceptional for that complex task. Being able to have information at hand, utilities, repositories, services such as immediate attention, search, information data through an intelligent service, deductive storage, work models, and interacting with the user for problems with the platform are the revolution of technology coupled to the education sector. It is necessary to consider that educational institutions, educational emporiums, and similar fields are coupling technology to a greater scope to outline the new foundations and rules of cloud computing services.

6. Recommendations

Cloud services are constantly updated where they can be in any application model. Especially in the case of the SAAS model, this will allow access to applications, email, and others where it is available at the time necessary to work. On the other hand, it is good to consider that to have control of the service models it is necessary to have an action plan of continuous improvement for the client optimizing the service processes. It has been seen that the services of the present study maintain a potential increase of 30% annually for their administration processes and ICT in the cloud, focusing on innovation and versatility of the business is therefore, advisable to have a market study meeting the needs of the business, technology, and development of internal processes to obtain scalability, Personalization and contribution to the resources of the entity.

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