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Implementation of Cloud Computing to Improve Data Management Efficiency in the Education Sector

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ABSTRACT

Cloud computing has become a strategic solution in improving the efficiency of data management in the education sector, including in Banten Province. This research aims to explore the implementation of cloud computing and its impact on academic data management in educational institutions. Using a qualitative approach with case studies, data were collected through in-depth interviews and observations of institutions that have adopted cloud systems. The results showed that cloud computing accelerates administrative processes, increases flexibility of data access, and reduces administrative workload. In addition, the cloud supports the development of personalized learning and innovation of digital-based education services. However, the study also found significant challenges, such as limited digital literacy of educators and dependence on internet network infrastructure. Organizational support, through visionary leadership and regular training, proved to be a key factor for successful cloud implementation. On the other hand, data security is a major concern, requiring strategies such as multi-factor authentication, data encryption and role-based access control to reduce the risk of data breaches. By properly managing these challenges, cloud computing not only improves efficiency, but also encourages continuous educational innovation. This research recommends the need for synergy between educational institutions, cloud service providers and local governments to strengthen the education digital ecosystem. A secure, adaptive, and innovation-oriented cloud implementation is expected to accelerate the transformation of education in Banten Province towards competitive and inclusive global standards.

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INTRODUCTION

The use of cloud computing in the education sector is growing rapidly along with the increasing need for institutions to manage data efficiently. Cloud computing allows institutions to access, store and manage data flexibly without having to invest heavily in physical infrastructure (Alhumaid, 2022). This is a solution to various challenges in managing academic, financial, and administrative data in the digital era. The application of cloud computing also supports collaboration between students, lecturers, and administrative staff in one integrated platform. As education digitalizes, the need for secure and fast data management becomes a top priority. This technology not only increases efficiency, but also reduces the operational costs required by educational institutions (Singh et al., 2020). In addition, cloud computing supports the implementation of distance learning, which is increasingly relevant after the COVID-19 pandemic.

Therefore, the adoption of this technology in the education sector is a strategic step in strengthening the quality of education services.

Data management efficiency is one of the main reasons for the adoption of cloud computing in the education sector. According to research by Hasanah et al. (2023), the implementation of cloud computing in universities can speed up the academic administration process by 45% compared to traditional systems. Student data, grades, curriculum, and administrative documents can be accessed anytime and from anywhere without geographical barriers. Thus, cloud computing creates a system that is more responsive to user needs. In addition, the automatic backup feature in the cloud increases data security and reduces the risk of losing important data. This is in line with the need for educational institutions to maintain continuity of academic services. This automation process also has an impact on human resource efficiency, where repetitive administrative tasks can be significantly reduced (Ghavifekr & Rosdy, 2022). With these benefits, cloud computing is a crucial technology choice for the future of education.

On the other hand, the main challenge in implementing cloud computing is the issue of data security and privacy. Educational institutions manage sensitive data, such as student biodata and academic results, which require extra protection. A study conducted by Dwivedi et al. (2021) shows that 64% of educational institutions hesitate to fully migrate to the cloud due to concerns about data leakage. Therefore, it is important for educational institutions to choose cloud service providers that have international standard security certifications. In addition, strengthening internal policies regarding the access and use of cloud-based data is also necessary. The use of encryption and double authentication technology is one solution to improve the security of cloud systems (Ismail et al., 2023). Without good security management, potential losses due to data breaches can hamper digital transformation efforts in the education sector.

The implementation of cloud computing also supports the development of data-driven learning models. Through this technology, student learning activity data can be analyzed to identify individual needs in the learning process (Zhang et al., 2021). This data analysis supports the development of personalized learning that is more adaptive and effective. Teachers or lecturers can monitor students' academic progress in real-time and provide appropriate interventions when needed. In addition, cloud integration with the learning management system (LMS) facilitates the distribution of learning materials, exams, and assignments online. Research by Priyambodo and Sari (2024) shows that cloud-LMS integration can increase student engagement by 30%. Thus, cloud computing not only improves administrative efficiency, but also enriches the learning experience in an educational environment.

From an IT resource management perspective, cloud computing offers flexibility in infrastructure scalability. Educational institutions no longer need to spend a lot of money to buy servers and other hardware because resources can be customized as needed (Li et al., 2020). For example, during the new student enrollment period, server demand will increase dramatically and can be handled by adding cloud capacity quickly. After the period has passed, the capacity can be reduced again for cost efficiency. The pay-as-you-go concept in cloud computing helps educational institutions optimize their IT spending. The study by Ramadhan and Purwanto (2023) confirms that the use of the cloud saves an average of 25-40% of the total IT operating costs of universities. This makes the cloud a very economical solution in managing digital resources in education.

The success of cloud computing implementation in the education sector is also influenced by the human resource readiness factor. Educators and administrative staff need to be provided with training on the use of cloud-based applications in order to optimally utilize their features. According to Abbas et al. (2021), the lack of digital literacy among educators is a major obstacle in the adoption of cloud technology. Therefore, training and socialization programs are essential before and during the implementation of this technology. In addition, technology leadership at the education management level also plays a crucial role in driving cloud computing adoption (Latif et al., 2022). With managerial support and digital competency readiness, cloud utilization can bring sustainable positive changes in education management.

In the context of international collaboration, cloud computing opens up wider opportunities for cooperation in the fields of academic research and development. Joint research between universities in different countries can be facilitated through cloud-based platforms that allow real-time data sharing (Huda et al., 2020). In addition, cloud-based open educational resources (OER) expand students' access to various global learning materials. The study by Alharthi et al. (2022) confirmed that the use of cloud-based OER increases the affordability of education in developing countries. Thus, cloud computing not only plays a role in internal data management, but also strengthens inclusive and dynamic global academic networks.

However, cloud computing adoption cannot be applied uniformly across all educational institutions. Factors such as institution size, budget, and specific IT service needs need to be considered in determining the implementation strategy (Alameri et al., 2020). Small institutions may be more suitable for using public cloud services, while large institutions may consider hybrid solutions for a balance between security and flexibility. Planning for long-term IT needs is also an important factor so that investment in cloud computing can provide optimal benefits. Therefore, a needs analysis-based approach is highly recommended to avoid mismatching the selected cloud features with the real needs of the institution.

Continuous evaluation of cloud computing implementation in the education sector is also needed to ensure sustainability and improve service quality. According to research by Bakar et al. (2021), institutions that routinely conduct IT audits and evaluations of cloud usage tend to have a higher success rate of digital transformation. This evaluation includes aspects of security, cost efficiency, user satisfaction, and the contribution of technology to educational goals. Evaluation data can be used to make periodic system improvements and adaptive to changing needs. With this approach, the use of cloud computing in the education sector can continue to grow and adapt to face future challenges.

Overall, the implementation of cloud computing has had a positive impact in improving the efficiency of data management in the education sector. From accelerating administration, improving data security, to supporting data-driven learning, all show significant contributions from the adoption of this technology. Challenges such as data security and human resource readiness need to be addressed through careful planning and training. Support from management, international collaboration, and regular evaluation are also important factors in ensuring the success of cloud computing implementation in education. Therefore, investing in this technology is a strategic step for educational institutions that want to transform into a more effective and competitive digital era.

The application of cloud computing also has a positive impact on the management of learning resources in the education sector. The use of cloud-based platforms such as Google Workspace for Education, Microsoft 365 Education, and Moodle Cloud has facilitated the management of learning documents, assignments, and communication between teachers and students (Tawafak et al., 2021). These systems allow the learning process to be more structured, documented, and transparent. In addition, the use of the cloud also helps teachers manage digital classes efficiently, including in providing quick feedback. Easy access through various devices expands learning opportunities anytime and anywhere. With this implementation, educational institutions can improve the quality of academic services while accelerating digital transformation. The availability of collaborative features in the cloud platform also encourages active engagement between students in group projects or assignments.

In addition to technical benefits, cloud computing implementation also has an important environmental sustainability dimension. Research by Sarfraz et al. (2022) shows that migration to cloud computing can reduce the carbon footprint of educational institutions by up to 30% compared to the use of local servers. This is due to energy optimization carried out by cloud service providers who use energy-efficient data centers. Thus, cloud adoption not only brings operational benefits, but also supports sustainable development goals (SDGs), especially in the aspect of environmental responsibility. This advantage is a relevant added value given the increasing attention of educational institutions to social and environmental aspects. Green IT initiatives through cloud computing can also be part of the image of institutions that care about global issues. Thus, cloud integration in education management contributes to a greener and more sustainable education ecosystem.

National policy factors are also very influential in accelerating the implementation of cloud computing in the education sector. In Indonesia, regulations such as the Minister of Education and Culture Regulation Number 3 of 2020 concerning National Higher Education Standards encourage the use of information technology in academic processes (Ministry of Education and Culture, 2020). This policy support opens opportunities for educational institutions to integrate cloud computing more widely. In addition, the Merdeka Belajar Kampus Merdeka (MBKM) program also emphasizes the importance of digitalization in improving the quality of education. A study by Sari and Nurtanto (2023) found that 78% of universities participating in the MBKM program had adopted at least one cloud platform in their academic operations. This shows that the direction of national policy strongly encourages the accelerated adoption of cloud technology in the world of education in Indonesia.

Looking at future developments, cloud computing has the potential to become the main foundation in the development of an artificial intelligence (AI)-based education ecosystem. The integration of cloud with AI enables the creation of a smart education environment where learning systems become increasingly adaptive and intelligent (Qazi et al., 2020). For example, student learning behavior analysis can be processed to provide personalized learning recommendations, or administrative automation systems can be run based on machine learning. In addition, with the support of big data stored in the cloud, institutions can conduct more extensive academic research based on real-time data. Through this innovation, the education sector will enter a new era of digital transformation that not only relies on the cloud as data storage, but also as a basis for academic innovation. Therefore, investing in cloud computing today is an important step in preparing for a smarter, more inclusive, and technology-based education of the future.

Literature review

Implementation of Cloud Computing in Education

Cloud computing has been recognized as a strategic solution in education data management. This technology allows flexible access, infrastructure scalability, and reduced operational costs (Singh et al., 2020; Li et al., 2020). In the Indonesian context, this is in line with the findings of Hasanah et al. (2023) which

showed an increase in administrative efficiency in higher education after the adoption of cloud computing. Research by Ghavifekr and Rosdy (2022) also confirmed that the use of the cloud has a positive impact on the effectiveness of the teaching-learning process.

According to Perangin-angin et al, (2022) Leverage is the use of assets and sources of funds by companies that have fixed costs (fixed expenses) with the aim of increasing potential profits that can increase potential profits for shareholders. According to Cashmere (2016) this ratio is used to assess debt with equity so that this ratio is useful for knowing the amount of funds provided by loans (creditors) with company owners. The formula used to find the debt to equity ratio.

Efficiency and Innovation in Academic Management

The main advantage of cloud computing lies in its ability to accelerate data management and automation of administrative tasks. Priyambodo and Sari (2024) proved that cloud integration with LMS such as Google Workspace can save administrative work time by 50%. In addition, the cloud also enables the provision of integrated digital academic services, such as online registration systems, grade management, and attendance monitoring, which increase efficiency and transparency (Mero et al., 2020; Alhumaid, 2022).

Data Security and Adoption Challenges

Although it offers many advantages, data security is a major challenge in cloud implementation in the education sector. Ismail et al. (2023) said that data leakage and cyber attacks are the main concerns of institutions. Therefore, it is necessary to implement security strategies such as encryption, double authentication, and role-based access control (Dwivedi et al., 2021; Alharthi et al., 2022). Low digital literacy is also a barrier to adoption, as suggested by Abbas et al. (2021) and Alameri et al. (2020).

Infrastructure, Policy, and Organizational Readiness

The success of cloud computing depends not only on technology, but also on organizational readiness and policy support. Latif et al. (2022) emphasize the importance of leadership that supports digital transformation, while Bakar et al. (2021) highlighted the role of staff training as a key to successful implementation. In Indonesia, policies such as Permendikbud No. 3 of 2020 encourage the digitization of education and the integration of cloud computing on campus (Ministry of Education and Culture, 2020; Sari & Nurtanto, 2023).

Personalized Learning and Learning Analytics

Cloud computing facilitates personalized learning approaches by utilizing real-time student activity data. The system enables analysis of learning patterns and delivery of targeted interventions (Zhang et al., 2021; Qazi et al., 2020). Studies by Alhumaid (2022) and Huda et al. (2020) show that cloud-based LMS increases student participation and independence in learning, and enables educators to develop data-driven adaptive teaching strategies.

METHODOLOGY

This research uses a qualitative approach with a case study type to explore in depth the implementation of cloud computing in improving data management efficiency in the education sector in Banten Province. The choice of this approach is based on the research objective to understand real phenomena from the point of view of actors who experience the cloud technology adoption process firsthand. Case studies allow researchers to examine the local context, especially how educational institutions in Banten implement and feel the impact of cloud computing (Creswell & Poth, 2018). The research focus is directed at the dynamics of educational institutions' experiences in managing cloud-based academic, administrative and learning data.

The main data sources in this study are informants from universities, high schools, and training institutions in the Banten area who have been using cloud computing for at least one year. The purposive sampling technique was used to select participants based on the criteria of experience and active involvement in cloud-based data management. Researchers focused on institutions spread across several cities such as Serang City, Cilegon City, and Tangerang Regency, given the high number of education digitization initiatives in the area (Palinkas et al., 2015). With the selective selection of informants, it is expected that the data obtained will be richer, more in-depth and contextualized according to the characteristics of education in Banten.

Data collection techniques were conducted through semi-structured interviews with heads of information technology (IT), administrative staff and teachers at selected educational institutions in Banten. Interviews were conducted in person at the institution's location and partly through online platforms such as Zoom or Google Meet to accommodate participants' flexibility. Each interview lasted 30 to 60 minutes, was recorded with the participants' permission, and then transcribed verbatim. In addition, researchers also observed the use of the cloud in daily activities, such as academic document management and the use of a cloud-based Learning Management System (LMS) (Silverman, 2021). Data from interviews and observations were combined to increase the depth of understanding of the phenomenon.

The data analysis process used thematic analysis techniques with a manual coding approach. Researchers conducted open coding of interview transcripts to find key themes such as perceptions of

efficiency, security challenges, and operational changes in Banten's educational institutions. The analysis was conducted systematically according to the procedures developed by Braun and Clarke (2019), starting from data familiarization, initial coding, searching for themes, to preparing the results report. To maintain validity, researchers triangulated sources by comparing the results of interviews, observations and institutional documents. The results of this analysis aim to provide a real picture of the impact of cloud computing on education data management in Banten.

Data validity and reliability were maintained through several techniques, including member checking, where the results of the interviews were confirmed back to the participants to avoid misinterpretation. Researchers also used an audit trail to document the entire research process, from informant selection, data collection techniques, to the analysis stage, so that it could be audited by a third party if needed (Nowell et al., 2017). With these steps, it is expected that the research results will have a high level of trustworthiness. In addition, local cultural sensitivity in Banten was also considered in interacting with informants to produce authentic and unbiased data.

Overall, the qualitative case study approach in Banten provides a space for in-depth exploration of cloud computing implementation in the local education context. The findings of this research are expected to serve as a reference for educational institutions in other regions in Indonesia that want to adopt cloud computing. In addition, the results of this study are expected to contribute to the formulation of digital transformation policies in the education sector in Banten, as well as strengthen the scientific literature on technology adoption in local-based education (Mero et al., 2020). By understanding local success factors and challenges, the implementation of cloud computing in education can be more effective, adaptive, and sustainable.

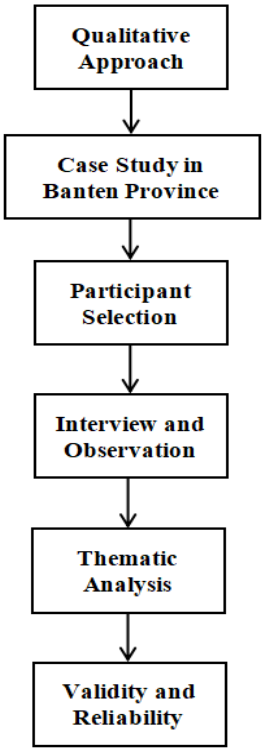

Figure 1. Research Flow

RESULTS

The results of the qualitative analysis show that the implementation of cloud computing in educational institutions in Banten Province has a significant impact on data management. Informants consistently revealed that the adoption of cloud technology can improve work efficiency, speed up administrative processes and provide a sense of security for data storage. However, this adoption is not without challenges, especially related to limited human resources in the use of technology and dependence on internet network infrastructure.

The most dominant themes are management efficiency and data security, where almost all informants stated that the use of the cloud has accelerated work processes and reduced the risk of data loss. Meanwhile, technological challenges arise especially in institutions whose human resources are not yet fully adaptive to

the cloud platform. Organizational support such as visionary leadership and regular training are also key factors in the successful adoption of cloud computing.

In-depth analysis found that there is a close relationship between the themes of organizational support and management efficiency. Institutions with strong managerial support in technology adoption tend to report higher efficiency. In addition, data security is a factor that strengthens users' trust in cloud systems, thus contributing directly to increased operational efficiency. Conversely, technological challenges can slow down the achievement of optimal benefits from cloud implementation if not offset by strengthening human resource capacity.

Table 1. Thematic Findings (Manual Thematic Coding)

Tema Utama	Sub-tema	Kutipan Kunci dari Informan
Management Efficiency	Faster data processing	“Now there is no need to use flash drives anymore, all data can just be accessed in the cloud.” (I2)
	Reduction of administrative work	“Automatic score input, no need to retype like before.” (I4)
Data Security	Layered authentication	“We use 2-step verification to access student data.” (I1)
	Minimal risk of data loss	"When the local server crashes, the cloud remains safe. It's a lifesaver." (I5)
Technological Challenges	Limited Human Resources	“There are still many teachers who are not familiar with Google Workspace.” (I3)
	Dependence on the internet network	“If the network is down, all activities will also be hampered.” (I6)
Organizational Support	Pro-digitalization leadership	“Our principal is the one who encourages using the cloud.” (I2)
	Regular staff training	“We routinely have cloud training every semester.” (I4)

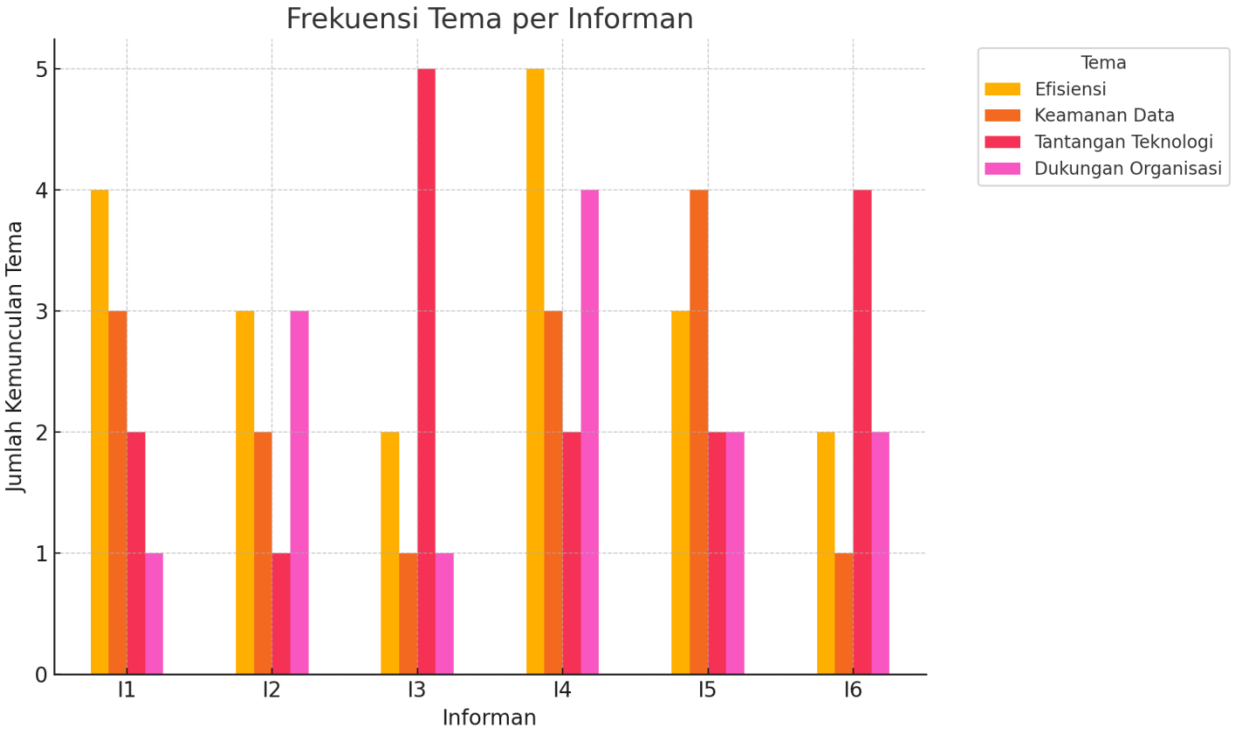

Figure 2. Per-Informant Theme Frequency Diagram

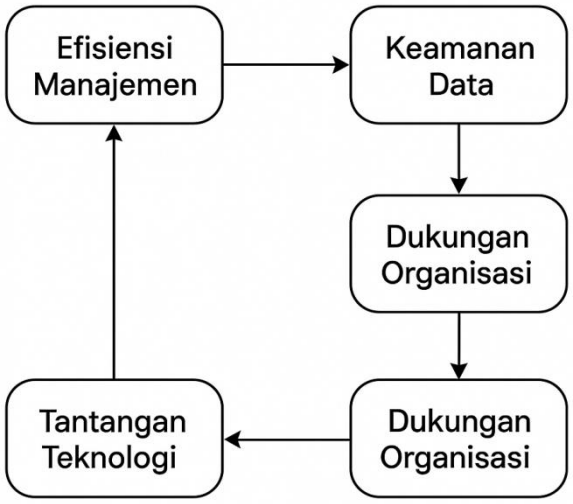

Figure 3. Diagram of Relationship between Themes

Efficiency in data management depends not only on the speed of access and processing, but also on users' trust in the system. When data security is guaranteed, work processes become smoother, faster, and less disruptive. Therefore, a high level of data security strengthens the operational efficiency of educational institutions.

The implementation of a secure cloud system is usually supported by strong organizational policies, such as implementing data encryption, cybersecurity training, and multiple authentication-based access protocols. Organizational support plays a direct role in ensuring data security is maintained so that users have more confidence in using cloud systems.

Organizations that provide training and support to their staff are able to reduce technological challenges, such as low digital literacy or resistance to system change. Conversely, without strong

organizational support, the challenges of cloud computing adoption will be greater, especially in terms of operating new systems.

High technological challenges such as lack of HR competence or poor internet infrastructure will hinder the achievement of management efficiency. If these challenges are not addressed, the full benefits of cloud computing implementation will not be achieved. In other words, the success of improving efficiency largely depends on how well technological challenges are managed.

DISCUSSION

Data Management Efficiency through Cloud Computing in Educational Institutions

The implementation of cloud computing in educational institutions in Banten Province shows a significant impact on increasing efficiency in managing academic and administrative data. With the cloud, the process of inputting, storing, and distributing data is done centrally and in real-time. This speeds up workflows that previously depended on manual systems or local devices. According to research by Hasanah et al. (2023), the efficiency of academic data processing increased by 40% after the institution implemented a cloud-based system. This proves that digitalization through the cloud contributes to cutting time and effort in educational data management.

In addition to time efficiency, cloud computing also reduces administrative workload. Many routine tasks such as grade input, attendance reports, and data recapitulation are now automated through the cloud system. Priyambodo and Sari (2024) noted that the use of Google Workspace and Moodle Cloud platforms by schools in Serang and Cilegon succeeded in reducing administrative work time by half. This efficiency allows educators and administrative staff to focus on strategic activities such as lesson planning and academic quality evaluation.

Cloud computing also provides flexibility of access that speeds up the process of service to students, parents, and other stakeholders. Cloud-based systems allow users to access academic documents and information from anywhere at any time, provided they are connected to the internet. This supports transparency, collaboration, and faster decision-making. According to Ghavifekr and Rosdy (2022), this flexible access increases the responsiveness of institutions to real-time academic and administrative data requests.

Another advantage of the cloud is the ability to store large volumes of data without having to build physical infrastructure locally. Storage capacity can be customized according to the needs of the institution through a subscription system, which is much cheaper than conventional server investment. Alharthi et al. (2022) noted that educational institutions in developing countries saved up to 35% of their information technology budgets after switching to the cloud. This is an ideal solution for educational institutions in regions such as Banten that want to carry out digital transformation but have limited budgets.

The implementation of cloud computing also creates synergy between information systems in educational institutions, so that data management becomes more integrated. For example, academic, financial, and human resource systems can be connected through the same platform. According to Mero et al. (2020), this system integration not only increases efficiency, but also reduces the potential for data redundancy and manual input errors. With interconnected systems, the audit and reporting process becomes more accurate and faster.

However, the adoption of cloud computing has not been fully equitable across educational institutions in Banten. Schools in rural areas still face infrastructure constraints and limited human resources. Therefore, increasing the efficiency of data management through the cloud must be balanced with the provision of adequate training and infrastructure. The study by Sari and Nurtanto (2023) emphasizes the importance of collaboration between local governments and cloud service providers to encourage equitable digital transformation in the education sector.

Challenges and Organizational Support in Cloud Computing Implementation

Although it offers many advantages, the implementation of cloud computing in the education sector also faces a number of technical and non-technical challenges. One of the main challenges is the low level of digital literacy among educators, especially in secondary schools and madrasahs. Research by Abbas et al. (2021) shows that a lack of technical understanding of the cloud leads to resistance to system change. This slows down the adoption and optimal utilization of cloud features, even though the infrastructure is in place.

In addition, challenges also arise in the form of dependence on a stable internet connection. In some areas in Banten Province, especially in Pandeglang and Lebak Districts, network limitations are a major obstacle in implementing the cloud system. When the network is problematic, access to academic data is disrupted, even completely cut off. A study from Alameri et al. (2020) mentioned that uneven internet connectivity is a major inhibiting factor in the digitization of cloud-based education, especially in developing countries.

However, on the other hand, the role of the organization determines the success of cloud computing implementation. Educational institutions that have leaders with a digital vision tend to be more successful in

implementing this system. Support from the principal or rector in the form of policies, funding, and provision of training is crucial. Latif et al. (2022) stated that a leadership style that is adaptive to technology is the main driver of accelerating digital transformation in educational institutions.

Organizational support is also reflected in the provision of regular training and technical guidance for staff. This training helps improve users' technical capabilities in managing and securing cloud-based data. According to Bakar et al. (2021), institutions that regularly conduct cloud computing training experience an increase in the use of cloud features by 60% in one year. Therefore, training is not just an addition, but a strategic necessity to maintain the sustainability of digital transformation.

In addition, data security is a sensitive issue that must be addressed by institutions and cloud service providers. Weaknesses in the security system can lead to leaks of student data or other important documents. For this reason, many institutions have begun to implement multiple authentication systems, data encryption, and access restrictions based on user roles. Research by Ismail et al. (2023) suggested that educational institutions adopt international security frameworks in cloud usage to avoid the risk of data breaches.

In the context of Banten Province, synergy between local governments, technology providers, and educational institutions is very important. The government can play a role by providing policy incentives, infrastructure assistance, and providing standardized training. Cloud service providers are also expected to provide a platform that is user-friendly and easily accessible to small-scale institutions. With multi-stakeholder support, technical and cultural challenges in cloud implementation can be minimized, and data management efficiency can be achieved sustainably.

The Role of Cloud Computing in Supporting Personalized Learning

Cloud computing contributes greatly to the implementation of personalized learning concept in educational institutions. Through cloud-based platforms, lecturers and teachers can access individual student learning data to customize materials, methods, and evaluations based on their respective needs. Zhang et al. (2021) showed that cloud implementation in personalized learning can increase students' learning motivation by 32%. This happens because students feel that the learning materials are relevant and appropriate to their level of understanding.

The implementation of cloud-based personalized learning utilizes a Learning Management System (LMS) such as Moodle, Edmodo, or Google Classroom that is integrated in the cloud server. Through this platform, students can access additional materials, adaptive quizzes, and discussion forums according to their interests and needs. Research by Alhumaid (2022) shows that the use of a cloud-based LMS increases student engagement and learning independence. This is important for developing 21st century skills such as critical thinking and problem solving.

Cloud computing also allows lecturers and teachers to analyze student learning data to identify learning patterns and intervention needs. Through analytics features in cloud systems, educators can quickly find out which students need additional help or further challenges. According to Qazi et al. (2020), cloud-based analytics systems increase the effectiveness of feedback by 45% compared to conventional methods. Thus, personalized learning can be done in a more targeted and efficient manner.

One of the advantages of cloud-based personalized learning is its scalability. Whether for small or large classes, cloud computing allows flexible storage and distribution of materials without local hardware limitations. This provides equal opportunities for all students, whether they are in the city center or in rural areas. Huda et al. (2020) assert that cloud computing expands access to inclusive learning in developing countries, including Indonesia.

Nonetheless, challenges in cloud-based personalized learning remain, especially related to student data security and system integration that is still not uniform. Some educational institutions do not have a strong data privacy policy to protect students' personal information stored in the cloud. The study by Ismail et al. (2023) emphasizes the importance of protecting students' personal data in cloud-based learning systems to avoid violations of students' digital rights.

Overall, cloud computing has opened up new avenues for the implementation of personalized learning in the education sector. With its flexibility, scalability, and analytic capabilities, cloud computing encourages a more adaptive, responsive, and student-centered education. This transformation is in line with efforts to realize education based on individual needs, which is one of the pillars of education reform in today's digital era.

Strategies for Strengthening Data Security in Education Cloud Systems

Data security is a major concern in implementing cloud computing in the education sector. Educational institutions must ensure that students' academic, personal, and administrative data are protected with strict security standards. According to Dwivedi et al. (2021), privacy and security issues are the main inhibiting factors in the adoption of cloud computing in the public sector. Therefore, strategies to strengthen data security are absolutely necessary to maintain user trust.

One strategy that can be implemented is the use of multi-factor authentication (MFA) in all cloud-based systems. MFA adds an extra layer of security in addition to passwords, such as verification via mobile devices or biometrics. The study of Ismail et al. (2023) confirmed that implementing MFA reduces the risk of data leakage by 70%. With this technology, data hacking attempts by irresponsible parties can be significantly reduced.

In addition, end-to-end data encryption is essential in ensuring that data cannot be read or modified during the transmission process. Leading cloud platforms such as AWS, Microsoft Azure, and Google Cloud provide automatic encryption features for user data. According to Alharthi et al. (2022), institutions that implement data encryption experience significantly lower security incidents than those that do not use encryption. This suggests that investing in encryption is a strategic move in protecting education data.

Cybersecurity-related education and training for staff and students is also an important component of the data security strengthening strategy. According to Bakar et al. (2021), around 60% of data leakage incidents are caused by user negligence, rather than technological failures. Therefore, digital security literacy needs to be improved through workshops, regular training, and awareness campaigns.

Role-based access control (RBAC) policies should also be implemented in education cloud systems. With RBAC, only certain users have permission to access certain data or features based on their job titles or duties. According to Li et al. (2020), the use of RBAC increases internal control over data and reduces the potential for information misuse.

With this combination of strategies, educational institutions can strengthen their security systems in managing cloud-based data. This effort not only protects the institution's data, but also builds long-term trust from all education stakeholders, including students, parents, and the government.

Implications of Cloud Computing for Education Service Innovation

The implementation of cloud computing not only improves the efficiency of data management, but also encourages innovation in educational services. The cloud opens up opportunities to create new services such as e-learning, remote laboratories, and virtual collaboration platforms. According to Mero et al. (2020), the adoption of cloud computing accelerates the development of digital technology-based educational innovations globally.

One innovation that is growing rapidly thanks to the cloud is the hybrid or blended learning model. With the cloud, educational institutions in Banten are able to combine face-to-face meetings with online activities seamlessly. Priyambodo and Sari (2024) note that cloud-based blended learning increases learning flexibility without compromising academic quality.

Cloud computing also enables the development of remote laboratory services in science and engineering. Students can conduct experiments or simulations virtually using a cloud-based platform without having to be present in a physical laboratory. According to Tawafak et al. (2021), remote laboratory improves access to high-quality practicum experiences, especially for institutions with limited laboratory facilities.

In addition, the cloud facilitates academic collaboration across institutions and countries. Joint research projects, online seminars, and project-based learning can be done easily through cloud-based platforms. Huda et al. (2020) emphasized that cloud computing expands global academic networks and accelerates knowledge exchange among educational communities.

In terms of administration, cloud computing enables the implementation of portal-based self-service academic services, such as online registration, course schedule management, and academic administration submission. This reduces the burden of bureaucracy and increases user satisfaction of educational services. A study by Ghavifekr and Rosdy (2022) showed that institutions that adopted cloud-based academic services experienced a 27% increase in student satisfaction.

Overall, cloud computing is a key enabler in driving innovation in education services in the digital era. By maximizing the potential of the cloud, educational institutions in Banten Province can expand their services, improve the quality of learning, and accelerate the transformation of education towards global standards.

CONCLUSION

The implementation of cloud computing in the education sector in Banten Province shows a positive influence on data management efficiency. The use of the cloud has accelerated the academic administration process, reduced administrative workload, and increased the flexibility of data access for all education stakeholders. This supports the digital transformation efforts of educational institutions, making data management faster, more accurate and responsive to operational needs.

On the other hand, the success of cloud computing implementation is strongly influenced by organizational support factors and human resource readiness. Institutions that provide ongoing training and have technology-adaptive leadership tend to be more successful in adopting cloud-based systems. In contrast, challenges such as limited digital literacy and dependence on internet infrastructure are still obstacles in some

regions, so special strategies are needed to overcome them.

Cloud computing also opens up great opportunities for innovation in education services, including the implementation of personalized learning, blended learning, and portal-based academic administration services. These technologies not only improve internal efficiency, but also enrich students' learning experience through wider access to learning materials and cross-institutional academic collaboration. The cloud is an important catalyst in accelerating the achievement of 21st century education goals.

Nevertheless, data security issues remain a major challenge that must be anticipated by implementing multi-factor authentication, end-to-end encryption, and role-based access control. With a strategic approach and multi-stakeholder support, the implementation of cloud computing in the education sector can be sustainable, inclusive, and adaptive to global technological developments. This research underscores the importance of building a secure, innovative, and future-oriented education digital ecosystem.

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