

Implementation of OpenStack as a Private Cloud Infrastructure Solution to Support Information Technology-Based Learning

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Abstract

The rapid development of information technology has transformed the educational landscape, particularly through the integration of cloud computing. OpenStack, an open-source platform for private cloud infrastructure, offers high flexibility and full control over IT resources, making it a promising solution for educational institutions. This study explores the implementation of OpenStack to support technology-based learning by conducting a literature review of recent academic publications. The findings highlight several benefits of using OpenStack in education, including improved efficiency in managing digital resources, enhanced students' practical skills through hands-on experiences, and reduced operational costs. These advantages position OpenStack as a valuable tool in promoting digital innovation in schools and universities. However, the study also identifies key challenges, such as infrastructure limitations and the complexity of system management, which may hinder broader adoption. Despite these obstacles, OpenStack's scalability and open-source nature provide educational institutions with opportunities for customization and long-term development. In conclusion, OpenStack presents considerable potential as a foundational platform for digital transformation in education, aligning with the growing demand for flexible, cost-effective, and sustainable technological solutions. Future research is recommended to explore best practices, implementation models, and collaborative strategies that can enhance the adoption and effectiveness of OpenStack in diverse educational settings.

Keywords: Cloud Computing; Education; Openstack; Private Cloud; Resource Management

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Introduction

The development of information and communication technology (ICT) has had a significant impact on various sectors of life, including education. In the current digital era, educational institutions are challenged to adopt technologies that support flexible, efficient, and accessible learning systems. One rapidly developing technology that has become the backbone of digital transformation is cloud computing. This technology allows data storage, processing, and management to be centralized and accessible from various locations via the internet.

Many educational institutions have utilized public cloud services such as Google Cloud, Amazon Web Services (AWS), and Microsoft Azure to meet their computing and storage needs. While these services offer scalability and ease of use, public cloud use also brings its own challenges, such as high subscription fees, limited control over data and infrastructure, and potential risks to the security



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and privacy of academic data. Therefore, there is a need for alternative solutions that provide greater control, cost efficiency, and can be tailored to specific educational needs.

One solution that is gaining increasing attention is the private cloud, a cloud computing infrastructure built and managed independently by institutions. In this context, OpenStack is one of the most widely used open-source platforms for building private cloud infrastructure. With its modular architecture and active global developer community, OpenStack provides flexibility in managing computing, networking, and storage resources according to the needs of educational institutions. Not only does it provide benefits in terms of efficiency and cost savings, but the use of OpenStack also supports technology-based learning, where students can gain hands-on experience in managing cloud computing systems in practice.

However, OpenStack adoption in educational settings is uneven and still faces various challenges, such as limited infrastructure, the need for competent human resources, and the complexity of installation and management. Based on these challenges, this study is designed to answer several key questions: what are the advantages of OpenStack as a cloud computing platform for building private clouds? How can it be implemented in educational settings? And, what challenges and opportunities can be identified in its implementation to support information technology-based learning?

In response to the problem formulation, the purpose of this study is to identify and explain the technical and strategic advantages of OpenStack as a private cloud solution, explore its implementation practices in various educational institutions, and analyze the obstacles and potential for its development in order to support digital transformation in the education sector. Thus, this article is expected to provide theoretical and practical contributions to the development of ICT infrastructure in the increasingly digitalized world of education.

Methodology

This research was conducted using a qualitative approach through a literature review. The aim is to explore and analyze in depth the use of OpenStack as a private cloud infrastructure solution to support information technology-based learning in educational institutions. This approach was chosen because it provides space to examine various empirical and conceptual findings from relevant scientific sources, thus building a comprehensive understanding of the phenomenon under study without conducting direct experiments in the field.

The data collection process was conducted by searching scientific articles, conference proceedings, and research reports published within the last ten years (2015–2024). The articles used were selected purposively based on three main criteria, namely: (1) relevance to the research topic, namely the application of OpenStack and cloud computing technology in the educational context; (2) source credibility, as measured by journal indexing in databases such as Scopus, SINTA, or Google Scholar; and (3) the recency of the information, to ensure compliance with the latest technological developments. The literature search was conducted through various online platforms such as Google Scholar, Scopus, DOAJ, and SINTA, using keywords such as “OpenStack,” “private cloud,” “cloud computing education,” “Infrastructure as a Service (IaaS),” and “digital learning infrastructure.”

Following the selection process, all articles meeting the criteria were analyzed using content analysis techniques to identify key themes related to the advantages, applications, challenges, and opportunities of OpenStack in education. The results were then synthesized to form a conceptual framework that comprehensively answered the research questions. Limitations of this study lie in its reliance on available literature and the diverse geographic context of the research. Therefore, interpretation of the results requires consideration of their relevance to the conditions of educational institutions in Indonesia.

Results and Discussion

The literature review shows that utilizing OpenStack as a private cloud solution in education offers various strategic and technical advantages, while also presenting challenges that must be addressed. Among its advantages, OpenStack is considered highly flexible due to its open-source nature and support for an Infrastructure as Code (IaC) approach, facilitating the automation and efficient management of digital infrastructure (Pericherla, 2020; Putra, Nurwa, Priambodo, & Hasbi, 2022). This is highly relevant to the needs of educational institutions to develop independent and sustainable information technology-based learning systems.

OpenStack's support for virtualization and service orchestration has also proven capable of optimally handling high workloads. Research by Sivalingam and Prathapagiri (2025) shows that virtual machine migration-based load balancing techniques on the OpenStack platform can improve resource utilization efficiency and maintain stable system performance. Furthermore, studies by Saputra, Priyanto, and Safriadi (2020) and Sodinapalli, Kulakrni, Sharief, and Venkatareddy (2022) reveal that load balancing and scientific work scheduling methods integrated with OpenStack can significantly improve the quality of online learning services.

Furthermore, the application of OpenStack in an educational context also opens up opportunities for the development of more adaptive learning media and academic information system architectures. Handriansa, Prayogi, and Harianto (2020) demonstrated that the development of OwnCloud-based cloud storage on top of OpenStack is an effective solution for secure and centralized academic document management. This finding is reinforced by Nugroho and Bethania (2023), who asserted that cloud technology has improved the performance of academic information systems in higher education through more controlled data distribution schemes.

However, technical complexity and infrastructure requirements remain major challenges in implementing OpenStack in educational settings. According to Ernawati and Febiansyah (2022), network and hardware capacity limitations can hamper cloud system performance, particularly in peer-to-peer and massive online learning contexts. Bystrov, Pacevic, and Kaceniauskas (2021) also emphasize the importance of optimizing communication and computational intensiveness within cloud architectures to ensure overall system efficiency. This suggests that without careful planning and investment, OpenStack adoption risks operational bottlenecks.

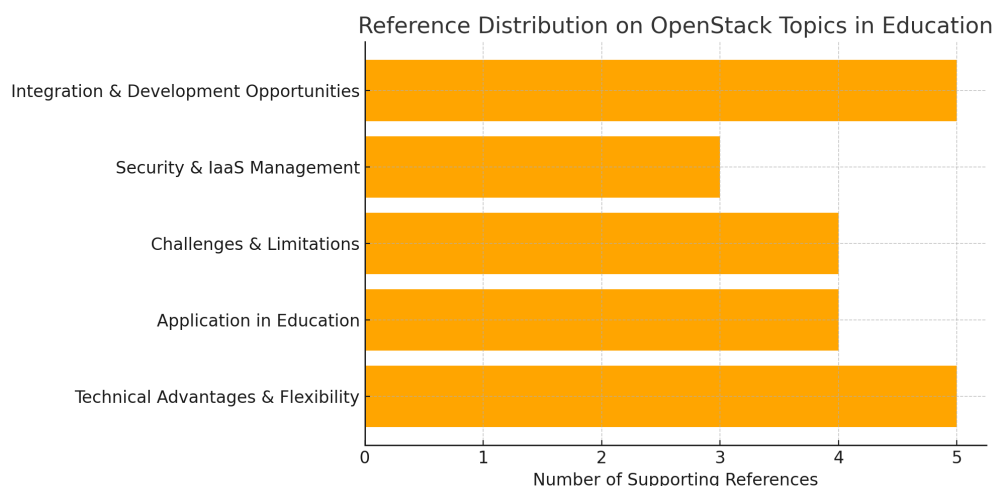
Furthermore, security and service governance are also important concerns. Tissir, Aboutabit, and Kafhali (2025) highlighted the potential threat of man-in-the-middle attacks in OpenStack environments and emphasized the importance of strengthening security management based on monitoring and mitigation systems. In this context, Mycek and Andrzej (2023) suggested implementing an IaaS-based security monitoring and analysis approach to maintain system integrity continuously.

On the other hand, the opportunities for OpenStack development in education are increasingly wide open. Research by Furnadzhiev and Shopov (2024) shows that OpenStack can be used to manage containerized workloads, opening up the possibility of integration with the latest technologies such as Kubernetes and microservices in the development of modern learning systems. At a strategic level, Desfiandia, Singagerda, and Herwanto (2024) emphasize the importance of designing a holistic enterprise architecture in private educational institutions as a sustainable cloud-based governance approach aligned with educational quality goals.

Furthermore, OpenStack-based cloud technology also supports the development of a more structured virtual learning environment (VLE). Malkawi, Bakar, and Dahlin (2023), as well as Hendradi et al. (2020), emphasize the crucial role of cloud computing and artificial intelligence in developing a cloud-based e-learning system that adapts to the needs of the Education 4.0 era. Beyond technological aspects, economic challenges are also a concern. Jawad and Jawad (2021) point out that educational institutions in developing countries face cost challenges in implementing cloud computing, but solutions like OpenStack can be an economical alternative due to their license-free nature and adaptability to local capacity.

From a resource governance perspective, Nzanzu et al. (2022) emphasize the importance of a taxonomic monitoring and resource management system in interconnected clouds. This provides the foundation for developing a more transparent, integrated, and easily controlled OpenStack system for system administrators in educational institutions. To support the learning process itself, Putra, Fadhilah, and Ta'ali (2024) emphasize that network- and cloud-based learning media must be designed in alignment with the principles of infrastructure integration and service accessibility for students.

Finally, Potluri and Rao (2020) added that the quality of services in the cloud is greatly influenced by an efficient service ranking and recommendation system, so the integration of quality management in the OpenStack system is also important to ensure the sustainability of its use in education.



Conclusion

Based on the results of the literature review, it can be concluded that OpenStack is an effective and flexible private cloud infrastructure solution to support information technology-based learning in educational institutions. Its advantages lie in its automation capabilities through Infrastructure as Code, cost efficiency, and support for the integration of digital learning systems such as academic data storage, virtual learning environments, and academic information systems. Furthermore, OpenStack is capable of handling high workloads with the support of adaptive load balancing technology. However, challenges such as infrastructure limitations, technical complexity, and the need for competent human resources remain obstacles that need to be addressed strategically. With collaboration between educational institutions and technology stakeholders, OpenStack has great potential to become a key foundation for sustainable and inclusive digital transformation in education.

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